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Validity of REDS Screening Tools: A Review of Recent Literature

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ABSTRACT

Relative energy deficiency in sport (REDS) was introduced by the International Olympic Committee in 2014 with the intention of establishing a diagnosis that would build on the conceptual framework of the female athlete triad but would also recognize that both male and female athletes from various sport backgrounds could be affected by low energy availability. However, there is no gold standard screening method for this condition. This literature review was conducted to identify recent studies that have validated the various screening tools for REDS. A literature search was conducted using the National Library of Medicine MEDLINE database via PubMed, articles were manually sorted by title and abstract review, then thorough review of the selected articles was conducted and reported in this paper. We found that in the last 15 years there have been many studies related to REDS. A small proportion of these studies attempted to validate REDS screening tools (Low Energy Availability in Females Questionnaire, Relative Energy Deficiency in Sport Clinical Assessment Tool, etc.) and did so with reasonable success. Given that the volume of research on this specific topic is relatively limited, especially in diverse populations, it seems that no single tool could be considered a gold standard. However, given that most of these tools (particularly the newer Female Energy Deficiency Questionnaire) were validated with statistical significance, we think they could play a strong role in the initial clinical assessment of an athlete or patient.
Keywords: Relative energy deficiency, screening, validity

INTRODUCTION

Relative Energy Deficiency in Sport (REDS) is "a syndrome of impaired physiological and/or psychological functioning experienced by female and male athletes that is caused by exposure to problematic (prolonged and/or severe) low energy availability" (Mountjoy et al., 2023). While low energy availability (LEA) is widely accepted as a risk factor for endurance athletes (Mountjoy et al., 2023), research has been done recently to show other populations are also at risk, including active individuals with no athletic competition engagement (Schofield et al., 2019; Strock et al., 2020b; Rogers et al., 2021; Ferraris et al., 2025; Salamunes et al., 2025). However, knowledge of REDS still appears to be low across various populations from athletes to coaches and even some healthcare professionals (Miller et al., 2012; Kroshus et al., 2015; Kroshus et al., 2018; Lodge et al., 2022; Hou et al., 2025).

While recognition of this serious condition is growing, REDS can be difficult to recognize and, furthermore, difficult to diagnose in its early stages, before the poor health outcomes manifest in the patient (Mountjoy et al., 2023). There remains inconclusive validation across sexes, ages, and types of sport, leaving males, adolescents, recreational, and still some female exercisers at risk of missed diagnoses and, for clinicians, missed opportunities to prevent problematic orthopedic, hormonal, and mental health outcomes.

The goal of this literature review, then, was to (i) review the recent literature regarding validation of REDS/LEA screening tools, (ii) propose a consensus regarding the ability of these tools to "catch" an individual with an energy-availability associated condition, and (iii) identify opportunities for further research in the field.

METHODS

Database search and literature collection

Although not a systematic review, we attempted to follow transparent search reporting principles as outlined by the PRISMA 2020 guidelines (Figure 1; Page et al., 2021). We began with identification of encompassing, but specific, search criteria. Using the National Library of Medicine MEDLINE database via PubMed, the following search terms were used in September of 2025:

(("relative energy deficiency in sport" OR “RED-S” OR "low energy availability" OR "energy deficiency") [A]
AND
(athlete OR sport OR "endurance runner" OR cyclist OR dancer OR "recreational exercise" OR "physically active") [B]
AND
("bone health" OR "stress fracture" OR osteoporosis OR "menstrual dysfunction" OR amenorrhea OR "endocrine" OR "hormone" OR "metabolic adaptation" OR "performance" OR fatigue OR recovery) [C]
AND
(assessment OR diagnostic OR screening OR questionnaire OR LEAF-Q OR “RED-S CAT”)) [D]

The rationale for this approach was to include [A] the primary condition, [B] population modifiers, [C] health outcome modifiers, and [D] screening tool modifiers. This initial search criteria provided 376 results.

Filters applied

The following filters from the database website were then applied: (i) studies in English, (ii) studies with participants nineteen years old or older to focus on the adult population, (iii) studies on humans to exclude any animal research, and (iv) studies within the last fifteen years in order to provide an update that leans primarily on recent literature. These filters narrowed the results to 138.

Title and abstract manual review

Then, to narrow the search to articles related to the question at hand, manual title and abstract review and selection was performed based on the following inclusion and exclusion criteria. Studies had to discuss the screening, diagnosis, or identification of REDS and its related conditions, with or without a formal screening tool. Studies could not: be carried out on a sedentary population, be a case study or case series, use or mention a screening method without discussing its validity, or focus only on disordered eating without the context of physical activity. During this process, 125 papers were identified that did not fit the inclusion criteria, or did meet one or more of the exclusion criteria, leaving thirteen articles that appeared to discuss screening and assessment techniques for REDS and related conditions.

While reviewing these thirteen articles, when a reference was made to a study that supported validity of a screening technique, this study was included, if not already. This led to the discovery of three more articles that fit the inclusion and exclusion criteria but did not appear in the original search. While reviewing the articles, one article was discovered that did not actually assess the validity of a particular screening tool or method. It was marked as such and removed from consideration for this review. These were combined to reach the final result of fifteen papers within the last fifteen years that discussed both (i) methods for screening REDS and related conditions, and (ii) the validity of these methods, determined either by their ability to group individuals based on energy status or proxies of energy status such as oligo-/amenorrhea, bone stress injuries, changes in hormone levels, and poor performance outcomes.

In-depth review was conducted on these articles to identify trends and propose a current consensus regarding the validity of various tools used to screen for REDS. For this review, REDS, LEA, The Female Athlete Triad, and other similar conditions will be collectively referred to as “REDS” unless otherwise indicated.

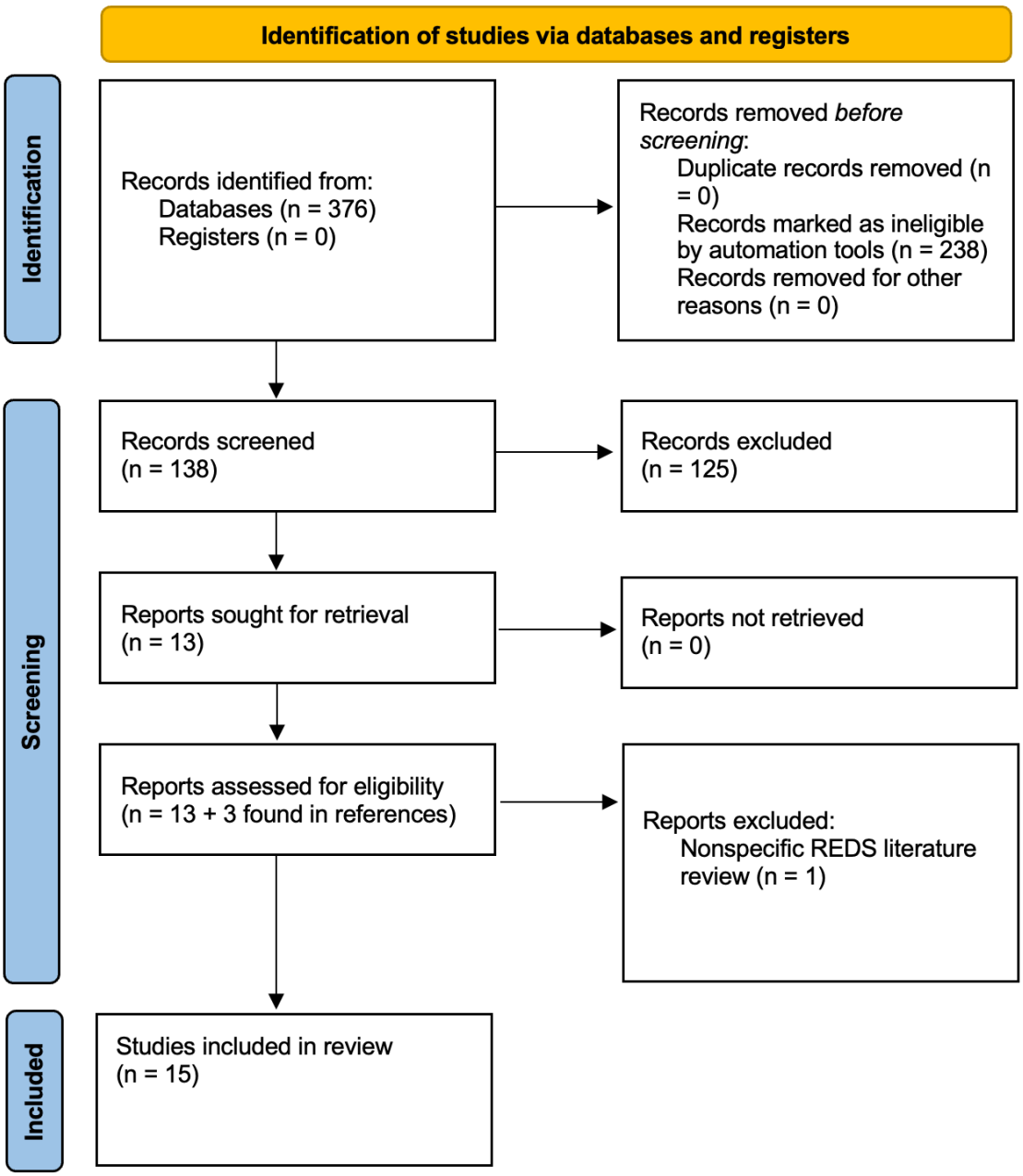

Figure 1. PRISMA 2020 Flow Diagram (Page et al. 2021)

FINDINGS

Physiological measurements and markers

Three studies attempted to validate physiologic metrics as indicators of REDS. A 2019 literature review sought to explore the validity of *p*RMR equations when used in athletic populations as compared to general population, and concluded that since most of the equations were created based on the general population, the data to support use of *p*RMR equations in athletic populations is equivocal, suggesting that future research be done to validate these equations in athletic populations, and proposing the use of Energy Availability (EA; Where EA = (Energy Intake - Exercise Energy Expenditure)/RMR) in the meantime (Schofield et al., 2019). They also recommended that users be aware if their *p*RMR equation takes fat free mass or lean mass into account, as this could present a substantial confounding variable when studying the athletic population.

A 2020 study of 217 exercising women found that when a Resting Metabolic Rate Ratio was calculated by dividing Cunningham's 1980 RMR equation (Cunningham, 1980) by RMR measured via indirect calorimetry, a RMR ratio cutoff value of 0.92 could identify individuals with low energy availability, which was defined as TT3<1.12nmol/L, BMI<18.5, or high drive for thinness. The regression models created by this team correctly predicted low TT3 with 73% accuracy and amenorrhea with 65% accuracy (Strock et al., 2020b).

Another 2020 study evaluated lipidomic profiles in 38 elite female endurance athletes with known energy status to see if the profiles had any meaningful associations with energy availability status, among other attributes known to be associated with RED-S, such as various hormones, BMI, BMD, and fat mass percentage. They found that when taking five blood samples throughout a day of multiple exercise tests, lipid trajectories of SM(d41:1), a sphingomyelin, differed in magnitude between individuals with LEA and sufficient EA status (Varga et al., 2020).

Female athlete triad cumulative risk assessment (Triad CRA)

Two studies assessed the validity of the Triad CRA. A 2018 cross sectional analysis of 59 world class athletes (35 female, 24 male) found that Triad CRA score correlated positively with all-time fracture history ($r = .566$, $p < .001$), and negatively with T3 ($r = -.338$, $p = .009$) and spine z score ($r = -.263$, $p = .044$) (Heikura et al., 2018).

A 2019 retrospective chart review (2010-2013) and prospective cohort (2013-2017) study assessed 156 male distance runners with a modified Triad CRA tool (menstrual categories removed, leaving four scoring categories instead of the original six) where a baseline model demonstrated each risk assessment point was associated with 37% increased risk for BSI ($p=0.0079$), and a longitudinal model demonstrated an elevated future-event risk of 27% for each point ($p=0.05$) (Kraus et al., 2019).

International olympic committee REDS clinical assessment tool (IOC REDS CAT or REDS CAT)

Three studies assessed the validity of the IOC REDS CAT. The previously mentioned 2018 cross sectional analysis of 59 elite endurance athletes found RED-S criteria correlated positively with all-time fracture history ($r = .328$, $p = .011$), and negatively with T3 ($r = -.396$, $p=.002$) and spine z score ($r = -.323$, $p = .013$) (Heikura et al., 2018).

A 2023 experiment classified forty case studies into the four REDS traffic light groups and found positive correlation ($r=0.885$, $p<0.01$) and a 62±19% complete agreement rate when the same forty case studies were grouped by an expert panel. A positive correlation ($r=0.963$, $p<0.01$) and a 90±10% complete agreement were also found when the expert groupings were compared to groups made when intended end users (coaches, therapists, physicians, and physiologists) used the REDS CAT tool to stratify the case studies (Stellingwerff et al., 2023).

A 2024 retrospective, cross sectional, and prospective study applied the REDS CAT to 213 elite athletes (143 female, 70 male) and found that as individuals had increasing REDS traffic-light risk classification, they also had higher prevalence and worse absolute values of all REDS primary indicators (free T3, testosterone, any amenorrhea, low BMD, EDE-Q score, BSI). For example, "green versus orange risk differences were associated with an 18--fold higher frequency of past (previous 2 years) and new (OR 7.71) BSI's" (Heikura et al., 2024).

Low energy availability in female's questionnaire (LEAFQ) & LEAFQ adaptations

Seven studies assessed the validity of the LEAFQ or adaptations of the LEAFQ. A 2014 cross sectional analysis and validation with 84 female athletes (cross sectional n=37 for internal consistency; external validation n=47) created the LEAFQ and administered it to a group of 47 female athletes, finding that a LEAF-Q score ≥8.0 produced a sensitivity of 78% and a specificity of 90% for correctly classifying current energy availability and/or reproductive function and/or bone health. When excluding athletes with PCOS, oligomenorrhea and functional hypothalamic amenorrhea, the total LEAF-Q score produced a sensitivity of 83% and a specificity of 90% (Melin et al., 2014a).

The previously mentioned 2018 cross sectional analysis of 59 elite endurance athletes found that amenorrheic females had higher LEAFQ scores than eumenorrheic females (effect size 1.08, $p<0.01$) (Heikura et al., 2018).

A 2021 cohort study of 18 paralympic athletes administered the LEAFQ to its 9 female participants, calculated EA based on dietary intake and Exercise Energy Expenditure (EEE), and found

no athletes within the sample population had LEA and that while 78% of the women scored "at risk," the menstrual cycle sub-scores were skewed by birth control use, and the overall risk for REDS was actually low (Pritchett et al., 2021).

A 2021 study found that when the LEAFQ was administered to a cohort of 75 female, mixed sport athletes, "the injury and menstrual function subscale scores identified low bone mineral density (100% sensitivity, 95% confidence interval [15.8%,100%]) and menstrual dysfunction (80.0% sensitivity, 95% confidence interval [28.4%, 99.5%]), respectively" however the specificity values were generally low and the authors propose that LEAFQ be used to "rule out" rather than "rule in" REDS (Rogers et al., 2021).

A 2024 non-randomized cohort study surveyed 1030 athletes (586 women, 484 men) before and after the 2022 Boston Marathon and found that before the event, athletes with low energy availability indicators (LEA-I) had increased odds of (i) pre-race overload injury involving bone or soft tissue (female: OR: 14.22, 95% CI: 8.59 to 23.54, p<0.001; male: OR: 1.99, 95% CI: 1.24 to 3.19, p=0.004), (ii) illness causing lost/modified training days within the past 6 months (female: OR: 2.56, 95% CI: 1.71 to 3.85, p<0.001; male: OR: 8.57, 95% CI: 5.12 to 14.30, p<0.001), and (iii) a bone stress injury within the past 12 months (female: OR: 2.67, 95% CI: 1.33 to 5.37, p=0.006; male: OR: 3.47, 95% CI: 1.76 to 6.83, p<0.001) (Whitney et al., 2025). This study also found that during the event, (i) LEA-Is were a significant predictor for race performance (females: d=0.33, males: d=0.53), (ii) "LEA-I athletes had approximately twice the risk of an intra-event medical encounter of any severity level (relative risk (RR)=1.99, 95% CI: 1.15 to 3.43, p=0.013) and (iii) LEA-Is were found to be the only significant predictor (OR: 2.43, 95% CI: 1.30 to 4.52, p=0.005) of respondents experiencing an intra-event medical encounter" (Whitney et al., 2025). In this study, athletes were determined to have LEA if they met any one of the following LEA-I criteria: Female LEA-Is: self-reported ED, Eating Disorder Examination Questionnaire (EDEQ) score > 2.3, or LEAFQ >/= 8, Male LEA-Is: self-reported ED, EDEQ >1.68, or gonadal dysfunction based on 5 questions from LEAMQ (the male version of LEAFQ), however they report the majority of athletes met LEA-I criteria solely with LEAFQ and LEAMQ scores and without signs of eating disorders (Whitney et al., 2025).

A 2025 study set out to create an Italian version of the LEAFQ (LEAFQ-ITA) and test it on 215 female athletes and exercisers, where they found the new format to be internally consistent (ICC = 0.832) and propose that more research be done to externally validate the LEAFQ and newer versions like LEAFQ-ITA (Ferraris et al., 2025).

A different 2025 cross sectional study analyzed the LEAFQ scores (completed by participant) and REDS CAT groupings (completed by researchers) of 50 female athletes, and found that fourteen athletes were considered REDS cases and also found that LEAFQ identified these athletes with a sensitivity of 79%, a specificity of 50%, with a positive predictive value (PPV) of 38% and a negative predictive value (NPV) of 86% (Wasserfurth et al., 2025).

Original questionnaire

A 2024 cross sectional, observational study of 288 female athletes administered a novel questionnaire based on components from the LEAFQ, EDEQ, and Brief Eating Disorder in Athletes Questionnaire (BEDAQ), and found that training for lean sports such as ballet and gymnastics increased risk of menstrual irregularity when compared to athletes not in lean sports (AOR 2.02, p-value 0.018), that among athletes with menstrual irregularity, 27.4% were found to overestimate their body image (p=0.001). They also stated that menstrual irregularity is linked to low energy availability (Bullen et al., 1985; Beitins et al., 1991; Loucks & Heath, 1994; Williams et al., 2001; Loucks & Thuma, 2003; Williams et al., 2015; Lieberman et al., 2018; Amaruso et al., 2024).

A 2025 retrospective and cross-sectional study used data from 152 female athletes to develop a novel screening tool, the Female Energy Deficiency Questionnaire (FEDQ) and tested this new tool on a separate group of 50 female athletes for external validation. The FEDQ was made of components from a dietary cognitive restraint (DCR) adapted score, body dissatisfaction 3 index (BD3-I) as well as BMI and number of menstrual cycles within the last six months. Athletes were categorized as having LEA if they had TT3 < 80ng/dL, however serum leptin and *p*RMR/*m*RMR ratios were also measured to corroborate the TT3 based LEA classifications, with each of these serving as previously verified indicators of energy status (Hilton & Loucks, 2000; Strock et al., 2020a, 2020c). The FEDQ had 85% sensitivity, 83.3% specificity, 77.3% positive predictive value, and 89.3% negative predictive value,

with an overall accuracy of 84% in the external validation group, correctly classifying the energy status of 42/50 women (Salamunes et al., 2025).

DISCUSSION AND CONCLUSION

Physiological measurements and markers

While pRMR equations have not been extensively validated for use in athletic populations, with specific concerns around those equations which do not account for fat free mass (Schofield et al., 2019), recent studies have shown that the *p*RMR/*m*RMR ratio can serve as a strong predictor of low TT3 (Strock et al., 2020b) which we understand to be an adequate marker for energy availability (Strock et al., 2020c). The use of the RMR ratio has also shown to adequately screen for amenorrhea with similar accuracy (Strock et al., 2020b).

However, these methods of screening may not be feasible for some parties, such as coaches or clinicians with limited resources, which ultimately highlights the need for further development and validation of simple screening tools that can be relied on without complex measurements or advanced lab tests. Aside from TT3 and the RMR ratio, we did not find recent studies to suggest other biomarkers as candidates for LEA screening.

Weakness of the studies in this section of the review include the use of exclusively female populations (Strock, 2020b), or the use of metabolic equations that may or may not include fat free mass (Schofield et al., 2019; Strock et al., 2020b), while strengths include the use of objective measurements (Schofield et al., 2019; Strock et al., 2020b, Varga et al., 2020) understood to have strong connection to LEA and its poor health outcomes (Hilton & Loucks, 2000; Strock et al., 2020a, 2020c).

Future opportunities for research in this area were explored in one study that collected lipidomic profiles of athletes with and without LEA, showing that there may be some differences in lipid profiles between these two groups, but no further conclusions were drawn (Varga et al., 2020).

Female athlete triad cumulative risk assessment (Triad CRA)

While recent studies have shown the Triad CRA scores can correlate with TT3, testosterone, estrogen and even risk of bone stress injury (Heikura et al., 2018; Kraus et al., 2019), this review found no recent papers that directly validate the ability of Triad CRA scores to predict low energy availability. Furthermore, a previous bone stress injury is one of the primary components of this risk assessment tool, which raises the question of whether the tool truly screens for LEA, or if its apparent predictive ability is driven by previous BSIs alone serving as strong predictors of future BSIs.

These studies were primarily conducted on elite athletes (Heikura et al., 2018, Kraus et al., 2019). One only used disordered eating as a proxy for low energy availability and did not actually find a statistically significant relationship between LEA and their end outcome (BSIs) (Kraus et al., 2019).

However, the Triad CRA is a tool that clinicians or coaches could readily use in a clinical or field setting and may be a better first choice than physiologic measurements, like RMR and TT3, which may not be obtainable for some.

International olympic committee REDS clinical assessment tool (IOC REDS CAT or REDS CAT)

The studies in this review, in similar fashion to those previously mentioned, compared REDS CAT scores to physiologic parameters that are well understood to be associated with low energy availability (Heikura et al., 2018; Hilton & Loucks, 2000; Strock et al., 2020a, 2020c; Heikura et al., 2024) with one study aiming to increase the strength of findings by verifying REDS CAT scores with six primary physiologic indicators (Heikura et al., 2024). However none of these studies compared REDS CAT scores to actual measurements of energy availability. These studies were also carried out primarily on populations of elite athletes (Heikura et al., 2018, 2024).

So, while more work needs to be done to validate the ability of REDS CAT to identify LEA, especially in populations other than elite athletes, these studies show that it is a valid tool for identifying the poor outcomes often associated with LEA, and thus it may be appropriate to use it in the clinical setting in conjunction with other screening modalities.

Low energy availability in females questionnaire (LEAFQ) & LEAFQ adaptations

Of the studies assessing validity of the LEAFQ, all provided validation of LEAFQ scores through physiologic measurements, expert opinions, previous studies, or to health outcomes that are understood to be associated with LEA with statistical significance (Melin et al., 2014a; Heikura et al., 2018; Pritchett et al., 2021; Rogers et al., 2021; Ferraris et al., 2025; Wasserfurth et al., 2025; Whitney et al., 2025). One of these studies compared LEAFQ scores to actual measurements of energy availability, with LEA defined as <125 kJ/kg FFM/day. While this team showed that LEAFQ could predict poor health outcomes associated with LEA, individuals with LEAFQ scores over 8 had an average EA of 156 +/- 55 (not LEA) and the relationship was not statistically significant (p=0.49).

While not much work has been done recently to establish validity of the LEAFQ through direct measurements of energy availability, there has been substantial evidence published showing that LEAFQ can adequately screen for LEA through its associated poor health outcomes (Melin et al., 2014). With this in mind, the LEAFQ should continue to be used in the clinical and field setting, especially in conjunction with other methods of assessment.

Original questionnaire

While this review found two studies creating an original questionnaire that yielded promising results (Amaruso et al., 2024; Salamunes et al., 2025), only one of these studies (Salamunes, 2025) compared questionnaire results to verified metrics for energy availability (TT3, RMR ratio). This was the only study found by this review which compared a screening tool to both biomarker (TT3) and energy availability (RMR ratio) measurements. The tool (FEDQ) was created and validated in a population of young female athletes, with moderate demographic diversity in BMI (16-24.99), age (18-35), and exercise modality (both endurance and resistance training). The authors also discuss that they hope to publish data supporting a new version of the tool for male athletes as well.

Overall, this study highlights a new tool that can be used to screen for REDS in the clinical or field setting and potentially highlights an opportunity for future research to validate the FEDQ in more diverse populations.

Conclusion

There are various tools used to diagnose REDS (and related conditions: Low Energy Availability and Female Athlete Triad), including but not limited to: physiologic metrics, REDS CAT2, LEAFQ, FEDQ, and various adaptations of these forms. To the authors knowledge, a consensus has not been reached on the validity of these tools for screening athletes for LEA specifically (Mountjoy et al., 2023).

In this review, we evaluated studies published in the last fifteen years that discuss the validity of clinical tools used to screen for REDS. It seems that all the tools mentioned have data to support their use in the clinical setting, with the most convincing studies being in support of the LEAFQ and FEDQ. Despite the increasing volume of research conducted around REDS and LEA, only a small proportion of studies are attempting to validate screening tools and increase our diagnostic abilities. Furthermore, the small number of studies that attempt to validate tools have primarily been conducted on female endurance athletes, particularly leaving room for studies to be conducted on mixed sport and gender cohorts.

Due to the potentially serious long-term effects of REDS and variable awareness of the condition, it is important that clinicians, coaches, and athletes have access to easy-to-use LEA screening forms that can reliably identify individuals at risk of REDS early in the disease course. Therefore, more studies should be done that validate these tools against direct measurements of energy availability in diverse populations. However, given the recent work that has been done, screening tools like REDS CAT, LEAFQ and FEDQ should continue to be among our first choices when screening for REDS/LEA, especially in the female population.

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