International Journal of EXERCISE SCIENCE

*Original Research*

# Low Energy Availability, Disordered Eating, Exercise Dependence, and Fueling Strategies in Trail Runners

KEELY HENNINGER‡1, KELLY PRITCHETT‡2, NAMRITA KUMAR BROOKE‡3, and LEAH DAMBACHER†2

[1]Professional Trail Runner and Independent Scientist, Portland, OR, USA; [2]Department of Health Sciences, Central Washington University, Ellensburg, WA, USA; [3]Department of Health and Movement Sciences, University of West Florida, Pensacola, FL, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

***International Journal of Exercise Science 16(2): 1471-1486, 2023.*** Under fueling, disordered eating (DE), exercise dependence (EXD), and high training demands relative to energy intake may increase the risk of low energy availability (LEA) in endurance and ultra-endurance athletes. The purpose of this study was to evaluate the prevalence of LEA risk and relationship with risk of DE, EXD, and fueling habits during training and competition in endurance runners. Trail runners between the age of 18-40 ($n$ = 1,899; males: $n$ = 510, females: $n$ = 1,445) completed a 45-question survey using Qualtrics that included training and racing characteristics, questions regarding carbohydrate intake during training and competition, the Low Energy Availability in Females Questionnaire (LEAF-Q), the Disordered Eating Screen for Athletes (DESA-6), and the Exercise Dependence Scale-21 (EDS-21). Among all runners, 43% of runners were at risk for LEA, 43% were at risk for DE, and 87.3% reported symptoms related to EXD. LEAF-Q scores were positively correlated with EDS-21 ($r$ = 0.33, $p < 0.001$) and DESA-6 scores ($r$ = 0.29, $p < 0.001$). From the population, 47.6% of athletes reported taking in less than the recommended carbohydrate guidelines during endurance events lasting > 2.5 hours. In females, athletes at risk for LEA appear less likely to fuel sufficiently than athletes not at risk for LEA ($p$ < 0.001). Risk of LEA, DE, and EXD appears to be high in endurance runners. Furthermore, meeting carbohydrate recommendations during training and competition should be emphasized to avoid negative health outcomes associated with LEA in endurance runners.

KEY WORDS: Energy balance, carbohydrate intake, running, body satisfaction, ultramarathon

## INTRODUCTION

Low energy availability (LEA) occurs when there is inadequate energy intake to support basic physiological processes after energy expenditure from exercise has been accounted for and normalized according to fat free mass (21, 25). LEA has been shown to impact normal metabolic, endocrine, and physiological processes that can result in negative health outcomes. In young, sedentary women an EA < 30 kcal·kg FFM−1·day−1 has been shown to disrupt normal hormonal function. However, this cut-off has been debated in both female and male athlete populations (8, 21). Furthermore, it is estimated 22-58% of endurance athletes have LEA, with a greater prevalence in females and specifically those in sports with an emphasis on leanness and/or high training demands (25). Furthermore, there is a growing body of literature suggesting that male athletes are also at high risk for LEA and associated long-term complications, even though the "threshold" for LEA symptoms in males may be lower and males may be more tolerant to intermittent LEA, compared to females (1, 8, 11, 18, 25, 29, 37, 40). Chronic or sustained LEA is the primary risk factor in the development of Relative Energy Deficiency in Sport (RED-S). RED-S refers to impaired function of key physiological processes around metabolism, bone health, immunity, and hormonal health, which can negatively impact health and athletic performance (29).

Disordered eating (DE) behaviors may also be prevalent in endurance athletes. DE can range from unhealthy dietary habits such as skipping meals, calorie restriction and excessive exercise with the goal of weight loss to similar but less severe characteristics observed with an eating disorder (5, 44). Furthermore, DE habits can vary throughout a season and athletic career. While not always meeting the criteria for an eating disorder (ED) diagnosis, DE habits can negatively impact the health, well-being, and performance of the athlete. Runners and other endurance athletes can experience DE alongside LEA, particularly accompanying the belief that "lighter is faster" or that extra weight may negatively affect performance (5, 14, 39). In one study of ultramarathon runners, 44% of females competing in the 2014 89-km Comrades Marathon were at risk for the Female Athlete Triad, while one-third of participants demonstrated DE behaviors (14).

Exercise dependence (EXD), which describes an unhealthy preoccupation with or addiction to exercise (15), has also been shown to be related to body dissatisfaction and ED (4). High training volumes, which are common in the ultra-running community, can contribute to excess exercise energy expenditure, but cannot be used as the primary method to assess risk of EXD (9). However, this increase in exercise energy expenditure with or without DE, can further contribute to LEA and related health and performance outcomes associated with RED-S. Higher scores on the Exercise Dependence Scale (EDS-21) have been associated with having larger energy deficits, and ED symptoms in both male and female endurance athletes (3, 13, 42). Therefore, under-fueling and other behaviors related to DE, high training loads, EXD, and related excess exercise energy expenditure relative to energy intake, create a unique situation in which LEA could be of greater risk in a sport like ultra-endurance running.

Interestingly, low carbohydrate availability, independent of or in addition to LEA, is another risk factor in development of RED-S and related health and performance outcomes (37). It has been suggested that ultra-runners may fail to meet hourly carbohydrate intake guidelines during training and competition due to improper knowledge around fueling, higher reliance on fats as fuel, and gastrointestinal (GI) distress (7, 36). Furthermore, a recent systematic review suggested that most runners did not meet the standard carbohydrate recommendations of 90 grams per hour for events lasting > 2.5 hours during single stage ultra-trail events (2, 41). Ultra-runners failing to consume adequate carbohydrates during long race distances coupled with very high training and racing volumes can put an athlete in a larger energy deficit, possibly leading to LEA (43). In addition, high levels of body dissatisfaction and ED tendencies also influence overall energy intake in female endurance athletes and could impact fueling strategies and dietary practices of athletes participating in endurance running (5).

Studies examining risk of LEA and DE and EXD as contributing factors are still lacking in trail and ultra-runners, particularly in the male participants who comprise a large percentage of athletes in the sport. Finally, the relationship between risk for DE and LEA and how they may relate to dietary habits and fueling strategies of endurance runners warrant further investigation. Therefore, the purpose of this study was: [1] to examine the risk of LEA, DE, and EXD in trail runners, and [2] compare risk of DE, EXD, and fueling habits during competition and training between athletes at risk vs. athletes not at risk for LEA.

## METHODS

*Participants*

1,955 athletes (males: $n$ = 510; female: $n$ = 1,445) who self-identified as a "trail or ultra-runner" completed the survey (Table 1). Most athletes (84.5 %) reported primarily participating in either ultra-trail races (> 50km in length) or trail races (< 50km in length). The remaining athletes reported primarily competing in races on the road or track or a combination of the two or do not race at all. 90.1% of runners reported running either low mileage (< 30 miles) or moderate mileage (31 - 60 miles) each week.

**Table 1.** Participant descriptive, racing, and training characteristics based on sex.

| | | All athletes ($n$ = 1,955) | Females ($n$ = 1,445) | Males ($n$ = 510) |
|---|---|---|---|---|
| Age Range (years) | 18-24 | 205 (10.5%) | 153 (10.6%) | 52 (10.2%) |
| | 25-40 | 1,750 (89.5%) | 1,292 (89.4%) | 458 (89.8%) |
| Runner Classification | Recreational | 1,072 (54.8%) | 840 (58.1%) | 232 (45.5%) |
| | Competitive | 883 (45.2%) | 605 (41.9%) | 278 (54.5%) |
| Primary Race Category | Ultra-Trail | 875 (44.7%) | 592 (41.0%) | 283 (55.5%) |
| | Trail | 778 (39.8%) | 620 (42.9%) | 158 (31.0%) |
| | Road/Track | 242 (12.4%) | 190 (13.1%) | 52 (10.2%) |
| | Do not race/other | 60 (3.1%) | 43 (3.0%) | 17 (3.3%) |
| Weekly Mileage Classification | Low (< 30 miles) | 715 (36.6%) | 567 (39.2%) | 148 (29.0%) |
| | Moderate (31-60 miles) | 1,047 (53.5%) | 757 (52.4%) | 290 (56.9%) |
| | High (> 60 miles) | 193 (9.9%) | 121 (8.4%) | 72 (14.1%) |

Data are displayed as $n$ (%).

*Protocol*
In this cross-sectional study, participants completed a 45-question survey using the Qualtrics system. The study was advertised through social media platforms and through trail- and ultra-running media outlets such as magazines, e-mail subscriptions, and training groups. A link to both the informed consent and questionnaire on the Qualtrics website were provided in emails and social media advertisements for those choosing to participate. All data collected were anonymous and used in aggregate. Participants were informed that they could stop taking the survey at any time without consequence. Participants who completed the questionnaire had the option to enter a raffle using a separate anonymous link for personalized sports nutrition products. This study was granted approval by the Human Subjects Review Committee at Central Washington University (CWU) (study # 2022-047) and the research was conducted fully in accordance with the ethical standards of the International Journal of Exercise Science (29).

Three previously validated and reliable instruments used to assess risk for LEA, DE, and EXD (Low Energy Availability in Females Questionnaire (LEAF-Q), Disordered Eating Screen for Athletes (DESA-6), Exercise Dependence Scale-21 (EDS-21)) were included within the questionnaire and are described below (28). Additional question topics included: age category [18-24, 25-40], type of runner (self-classified as competitive or recreational), running mileage per week (low < 30 miles, moderate 31 - 60 miles, and high > 60 miles), primary race focus (road/track, ultra-trail, trail), and carbohydrate intake practices during racing and training.

The LEAF-Q is used to identify athletes at risk for LEA by gathering information regarding injury frequency, menstrual dysfunction (MD), and GI symptoms (14). The LEAF-Q has acceptable sensitivity (78%) and specificity (90%) in its ability to classify current reproduction function and to screen at risk populations for components of the Female Athlete Triad such as amenorrhea (28). Lower bone mineral density ($p = 0.021$) and menstrual dysfunction ($p < 0.001$) were more prevalent in subjects with higher scores on the LEAF-Q (28). Test-retest reliability was 0.79 after a two-week interval (28). Participants who score $\geq$ 8 on the LEAF-Q are considered "at risk for LEA" while participants scoring < 8 are considered "low risk". A section score of $\geq$ 2 for injuries, $\geq$ 2 for GI function, and $\geq$ 4 for MD is considered "at risk" for each subcategory (19, 28). Participants were asked about previous menstrual history and whether they had ever missed three or more consecutive menstrual cycles. Participants currently not menstruating for three or more consecutive cycles not caused by any of the "other" factors, or who reported between four to nine periods within the previous 12 months but did not miss three consecutive cycles were classified as having MD unless on hormone therapy. "Other" factors included: Pregnancy, breastfeeding, use of hormonal IUD, use of contraceptive implants or other hormonal treatment that could alter menstruation, or history of hysterectomy and/or removal of ovaries. Participants on hormone therapy were questioned about previous menstrual history to determine if MD was a precipitating factor for choosing to use hormone therapy. Females also had the option to indicate peri- or post- menopause as a cause of menstrual cycle disruption. Two females indicated perimenopause and one female indicated post-menopause and were removed from the findings of this analysis.

Males completed only the LEAF-Q questions pertaining to injury and GI function (frequency of bowel movement, consistency of bowel movement (Table 2), injury prevalence, and missed training days from injury). For our scoring purposes, males scoring a combined score of $\geq 3$ on the GI and injury sections of the LEAF-Q questionnaire were deemed as "at-risk" for LEA. A score of $\geq 1$ on the GI section or $\geq 2$ on the injury section of the LEAF-Q were deemed "at risk" for those subsections. Previous studies have used a cut-off score of 3.2 to ensure athletes scored at least 1 point in each section (GI and Injury) and classify male athletes at risk for LEA (35). However, it should be noted that a tool to identify risk of LEA in male athletes has yet to be validated (19).

**Table 2.** Questions from the LEAF-Q used to evaluate GI function in male and female runners.

| LEAF-Q: GI Function | Females | Males |
|---|---|---|
| Do you feel gaseous or bloated in the abdomen even when you do not have your period? | Yes, several times a day ($n$ = 109)<br>Yes, several times a week ($n$ = 360)<br>Yes, once or twice a week ($n$ = 531)<br>Rarely or never ($n$ = 445) | N/A |
| Do you get cramps or stomachaches unrelated to your menstruation? | Yes, several times a day ($n$ = 39)<br>Yes, several times a week ($n$ = 182)<br>Yes, once or twice a week ($n$ = 428)<br>Rarely or never ($n$ = 796) | N/A |
| How often do you have bowel movements on average? | Several times a day ($n$ = 496)<br>Once a day ($n$ = 790)<br>Every second day ($n$ = 113)<br>Twice a week ($n$ = 34)<br>Once a week or more rarely ($n$ = 12) | Several times a day ($n$ = 245)<br>Once a day ($n$ = 245)<br>Every second day ($n$ = 8)<br>Twice a week ($n$ = 6)<br>Once a week or more rarely ($n$ = 4) |
| How would you describe your normal stool? | Normal ($n$ = 1209)<br>Diarrhea-like (watery) ($n$ = 186)<br>Hard and dry ($n$ = 50) | Normal ($n$ = 475)<br>Diarrhea-like (watery) ($n$ = 31)<br>Hard and dry ($n$ = 4) |

Disordered eating behaviors were assessed using the Disordered Eating Screen for Athletes (DESA-6). Participants scoring $\geq 3$ were considered at risk for disordered eating (DE). Higher DESA-6 scores are correlated with risk for eating disorders as identified by the Eating Disorder Examination (EDE-Q) ($r$ = 0.89, $p$ < 0.001) (22). Test-retest reliability of the DESA-6 showed strong and significant positive correlations in both males ($r$ = 0.83, $p$ < 0.001) and females ($r$ = 0.76, $p$ < 0.001).

Exercise dependence (EXD) was scored using the Exercise Dependence Scale-21 (EDS-21) (10). The EDS-21 is a 21-item assessment of EXD symptoms based on the DSM-IV criteria for substance dependence (16). The scale has shown adequate internal consistency and test-retest reliability with subjects scoring at risk for EXD demonstrating more exercise behavior and traits of perfectionism (10). The scale also showed convergent validity as participants who were at-risk for EXD displayed the most perfectionism components, and participants who were non-dependent symptomatic showed more perfectionism components than participants who were non-dependent asymptomatic (10). Athletes were asked 21 questions about exercise and had to rank the statement between 1 (Never) and 5 (Always). The questions were then grouped into one of seven criteria. The seven components used to assess symptoms include: 1) Tolerance 2) Withdrawal 3) Continuance, 4) Lack of control, 5) Reduction in other activities, 6) Time, and 7) Intention. The scores for each component were calculated by adding together the individual responses to the questions in that category. Total EDS-21 Score was calculated by adding together the scores of all 21 questions. A higher score reveals more EXD symptoms (15,16). Athletes were grouped into the following categories: non-dependent asymptomatic, non-dependent symptomatic, and dependent symptomatic based off the grading criteria (16). To score as "at-risk dependent", respondents need to score a 5 in all questions of 3 of the 7 components. If they did not score 5 in 3 of the 7 components but scored between 3-4 on most components, they were classified as "symptomatic non-dependent". Athletes who did not score greater than 1-2 on the questions in at least 3 of the 7 categories were rated as "asymptomatic non-dependent". For the context of this study, athletes rated as non-dependent symptomatic and dependent symptomatic were classified as "symptomatic for EXD" (16, 32).

All participants were asked about carbohydrate intake during training and competition (durations of 1 to 2.5 hours, and longer than 2.5 hours). The responses were compared to the evidence-based guidelines for carbohydrate consumption during exercise that suggest consuming 30 to 60 grams of carbohydrate during exercise lasting > 1 hour up to 2.5 hours, and 60 to 90 grams of carbohydrate for events lasting > 2.5 hours in duration (41). Fueling responses were ranked as either "insufficient" or "sufficient" based off the distance of the event and recommended carbohydrate consumption (e.g., consuming less than 60g CHO/hour for endurance events lasting longer than 2.5 hours and less than 30g/hour for endurance activities lasting less than 2.5 hours were considered "insufficient"). A cumulative fueling score was then calculated for all athletes based off all 4 racing and training scenarios by giving "insufficient" 1 point and "sufficient" 0 points. Fueling scores were then calculated by adding up the scores for all 4 racing and training categories. Fueling insufficiently for all 4 scenarios would equal a score of 4, whereas fueling sufficiently for all four scenarios would be a score of 0.

*Statistical Analysis*

Results from the Qualtrics Survey were analyzed using Python, Jupyter Notebooks 6.4.8 running pandas and sci.py stats to compute means and standard deviations (SD) (22). Independent t-tests were used to compare differences between scores on the LEAFQ, DESA-6, and EDS-21 between groups (sex, age). A chi-square analysis of independence was used to examine differences in risk of LEA between groups (mileage group, race category, runner classification). Pearson correlations were used to examine the relationship between variables of interest such as risk of LEA and EXD, DE, and fueling scores. A Chi-square analysis was used to determine if there was a significant association between risk for LEA, DE, EXD and sufficiency of carbohydrate intake during training and competition. Independent t-tests were used to compare differences between calculated fueling score and LEAF-Q and DESA-6 scores. Statistical significance was established at $p < 0.05$. Effect size was calculated using Cohen's d (d) calculation for t-tests, Cramer's phi ($\varphi_c$) for chi-square.

## RESULTS

Of all runners, 43% were classified at-risk for LEA. The percentage of runners at risk for LEA by sex are displayed in Figure 1. Because they answered questions related to menstruation, female runners scored higher than male runners on LEAF-Q ($p < 0.001$). Therefore, no between-sex analysis of total LEAF-Q score was made. LEAF-Q and subsection scores are displayed in Table 3 for all participants by sex.

**Table 3.** LEAF-Q, and all sub section (GI function, injury risk, and menstrual function) scores by sex.

| Sex | LEAF-Q Total Score | LEAF-Q Sub Sections | | |
|---|---|---|---|---|
| | | GI | Injury | Menstrual |
| Females (*n*=1,445) | 8.5(5.9) | 2.5(2.0) | 1.4(2.4) | 4.6(4.3) |
| Males (*n*=510) | 1.8(2.4) | 0.7(0.8) | 1.2(2.3) | N/A |

Data are mean (± SD).

Almost half (49.7%) of female runners were identified as "at risk for LEA" based on an overall score > 8 on the LEAF-Q whereas 22.3% of males were identified "at risk for LEA" based on an overall score > 3 on the GI and injury section of the LEAF-Q (Table 3). Table 4 displays the prevalence of risk for LEA based on sex and age. Younger females (66.7%) were more likely to be at risk for LEA than older females (47.7%) ($\chi^2_1 = 18.9$, $p < 0.001$; $\varphi_c = 0.18$).

**Table 4.** Prevalence of at risk and not a risk for LEA based on sex and age.

| | Entire Population (*n* = 1,955) | | Females (*n* = 1,445) | | Males (*n* = 510) | |
|---|---|---|---|---|---|---|
| Age Category | At-Risk | Not at Risk | At-Risk | Not at Risk | At-Risk | Not at Risk |
| Younger (18-25) | 115 (56.1%) | 90 (43.9%) | 102 (66.7%) | 51 (33.3%) | 13 (25.0%) | 39 (75.0%) |
| Older (26-45) | 717 (41.0%) | 1033 (59.0%) | 616 (47.7%) | 676 (52.3%) | 101 (22.0%) | 357 (78.0%) |

Data are displayed as *n* (%).

Out of the female respondents, 44.8% ($n = 648$) scored $\geq 4$ indicating MD. Younger females (64%; $n = 98$) were more likely to score higher for MD compared to older females (42.6%; $n = 550$) ($\chi^2_1 = 24.7$, $p < 0.001$; $\varphi_c = 0.31$). Female athletes with MD were more likely to experience inconsistent menstruation compared to female athletes not at risk for MD (Figure 1). MD scores were also correlated with higher LEAF-Q scores ($r = 0.83$, $p < 0.001$).

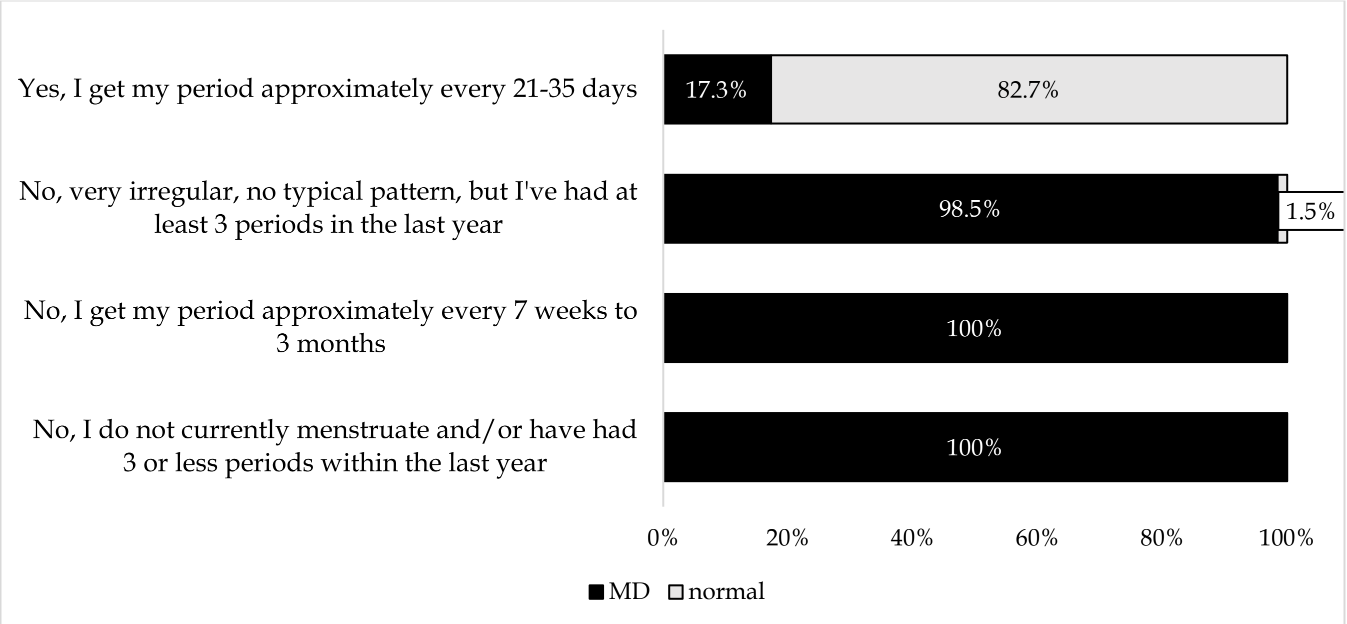


**Figure 1.** Responses to LEAF-Q menstrual function subsection questions between females with MD compared to normal menstrual function.

Of all respondents, 87.3% were identified as symptomatic for EXD (7.1% "at-risk" and 80.2% "non-dependent symptomatic" on the EDS-21 scale). Females exhibited significantly higher mean EXD scores in the withdrawal ($p < 0.001$), continuance ($p < 0.001$) and lack of control ($p < 0.05$) subcategories than males, while males scored significantly higher in the tolerance section ($p < 0.05$) (Table 5). There were no sex differences in scores in time, intention, or reduction in activity. Younger runners were more likely to be symptomatic for EXD than older athletes ($\chi^2_1 = 5.3$, $p < 0.05$; $\varphi_c = 0.13$).

**Table 5.** Total EDS-21 score and subsection scores for the entire population and by sex.

| | Exercise Dependence Total Score | Exercise Dependence Subsections | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Withdrawal | Continuance | Tolerance | Lack of Control | Reduce activities | Time | Intention |
| Total population (*n* = 1,955) | 62.6(17.1) | 12.1(3.8) | 7.5(3.5) | 10.4(3.5) | 6.7(3.4) | 8.0 (2.9) | 10.7 (3.4) | 7.1 (3.1) |
| Females (*n* = 1,445) | 63.1(17.4)* | 12.5(3.6)** | 7.62(3.6)** | 10.2(3.5) | 6.8(3.4)* | 7.9(2.9) | 10.7(3.4) | 7.1(3.1) |
| Males (*n* = 510) | 61.1(16.2) | 10.8(3.9) | 7.1(3.3) | 10.7 (3.6)* | 6.5(3.2) | 8.1(2.9) | 10.7(3.4) | 7.1(3.1) |

Data are reported as Mean (± SD). Significant differences between sexes: *indicates $p < 0.05$, **indicates $p < 0.001$

Of all runners, 43% were identified at risk for DE. Risk for DE was significantly higher in females compared to males (48% vs. 27% respectively, $\chi^2_1 = 70.8$, $p < 0.001$; $\varphi_c = 0.32$). Younger female runners were more likely to be risk for DE than older female runners ($\chi^2_2 = 4.0$, $p < 0.05$; $\varphi_c = 0.10$). There was no association between age and risk for DE in males ($\chi^2_1 = 0.20$, $p = 0.65$).

Out of the 1,955 participants, 56 did not participate in races, therefore only the remaining 1,899 responded to the questions around amount of carbohydrate consumed during training and race durations of 1 to 2.5 hours, and training and competition durations > 2.5 hours. Figure 2 displays the percentage of athletes who self-reported fueling sufficiently or insufficiently for training runs and races based on duration. Out of the sample, 37.6% (*n* = 715) of participants reported fueling sufficiently across all 4 categories, while 62.4% (*n* = 1,184) reported fueling insufficiently in at least one of the categories, and 47.2% (*n* = 896) of the athletes reported fueling insufficiently for 2 - 4 out of 4 categories. Females were more likely to insufficiently fuel for long training runs ($\chi^2_1 = 4.85$, $p < 0.05$; $\varphi_c = 0.13$) and long competitions ($\chi^2_1 = 12.17$, $p < 0.001$; $\varphi_c = 0.20$) than males. However, there was no association between sex and fueling for competition or training runs between 1 to 2.5 hours in duration ($\chi^2_1 = 1.12$, $p = 0.05$). Younger athletes had significantly higher fueling scores (1.7 ± 1.4) indicating they were less likely to fuel sufficiently during training and competition than older athletes (1.3 ± 1.3) in all categories ($p < 0.001$; d = 0.31).

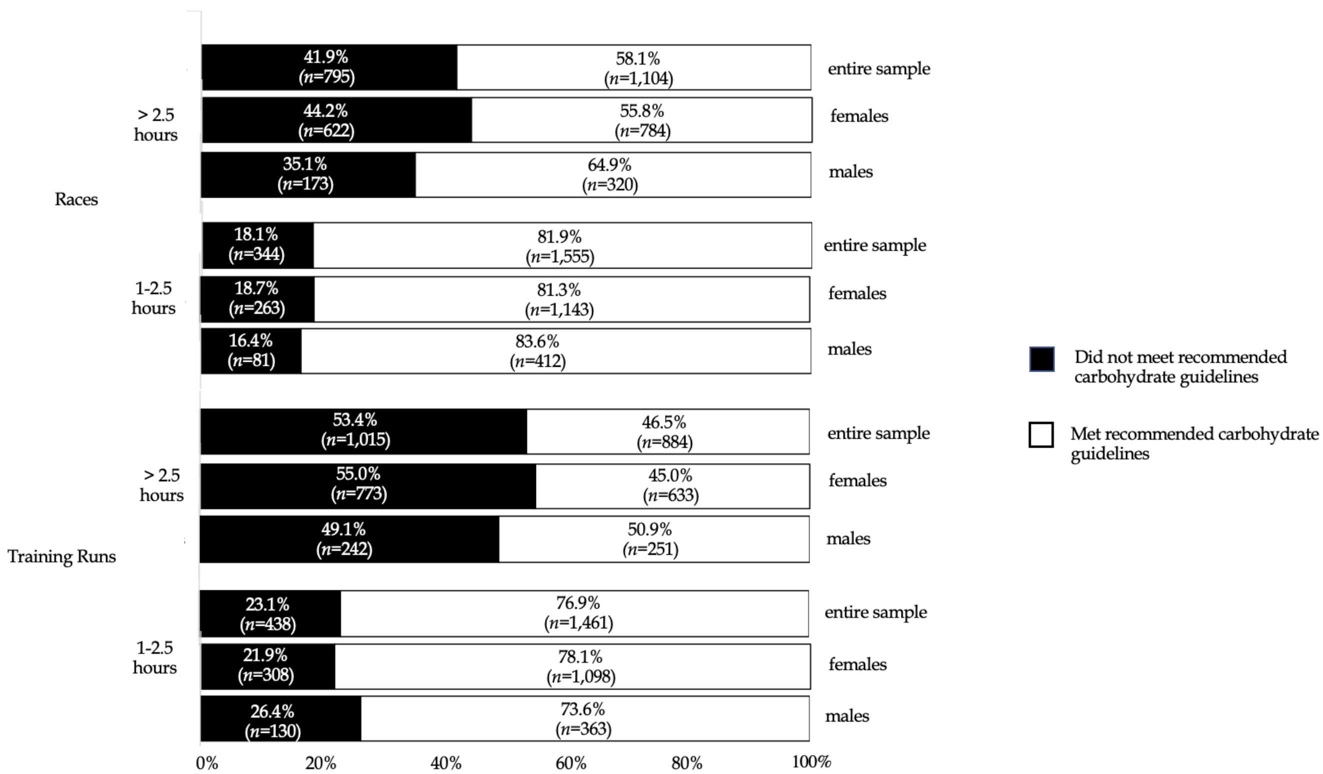


**Figure 2.** Percentage of athletes who reported meeting or not meeting recommended carbohydrate guidelines during training and race durations of 1 to 2.5 hours, and > 2.5 hours.

Risk for LEA was positively correlated with risk for DE ($r = 0.43$, $p < 0.001$) and with risk for EXD ($r = 0.29$, $p < 0.001$) in this population of trail runners. Fueling score was positively correlated with LEA in females ($r = 0.15$, $p < 0.001$), however, but not correlated with LEA in males ($r = -0.002$, $p = 0.95$). Differences for DESA-6, EDS-21, and fueling scores between athletes at risk versus not at risk for LEA are displayed in Table 7. Using the calculated fueling scores, female athletes at risk for LEA (1.55 ± 1.4) fueled less sufficiently than females not at risk for LEA (1.24 ± 1.2) ($p < 0.001$; d = 0.25). Male athletes at risk for LEA did not report fueling differently than males not at risk for LEA ($p = 0.89$). Fueling scores were also correlated with DE in females ($r = 0.18$, $p < 0.001$), but not in males ($r = 0.02$, $p = 0.54$).

**Table 7**. DESA-6, EDS-21, and fueling scores between athletes at risk versus not at risk for LEA.

| | Entire Population | | Females | | Males | |
|---|---|---|---|---|---|---|
| | At-Risk for LEA | Not at Risk for LEA | At- Risk for LEA | Not at Risk for LEA | At- Risk for LEA | Not at Risk for LEA |
| DESA-6 scores | 2.8(1.4) | 1.8(1.3)** | 2.9(1.4) | 1.9(1.3)** | 2.6(1.4) | 1.4(1.3)** |
| EDS-21 scores | 66.9 (18.2) | 59.4(15.5)** | 67.0 (18.3) | 59.3(15.6)** | 66.5(18.1) | 59.5(15.3)** |
| Fueling Scores | 1.5 (1.4) | 1.2(1.2)** | 1.5 (1.4) | 1.2 (1.2)** | 1.3(1.3) | 1.3(1.2) |

Data are mean (±SD). At risk for LEA based on a LEAF-Q score of > 8.
*$p < 0.05$, ** $p < 0.001$, significant difference between "at risk" and "not at risk" for LEA.
Fueling scores - a higher fueling score indicated fueling insufficiently, total population was only 1,899 for this analysis.

## DISCUSSION

This is one of the first studies to examine the interplay of risk of LEA, DE, EXD, and fueling habits during training and competition in the trail and ultra-running population. Given the difficulty with accurately assessing and identifying LEA, we aimed to examine contributing factors that may be associated with an increased risk of LEA. This research compared the relationship between descriptive characteristics (sex, age), risk for DE, EXD, and fueling strategies in runners identified as "at risk" and "not at risk" for LEA. Findings from the current study suggest that risk for LEA, DE, and EXD appear to be high in trail runners, particularly in female runners. Athletes at risk for LEA had significantly higher risk for EXD and DE. Furthermore, female athletes at risk for LEA and DE appear to be less likely to meet fueling recommendations during training and racing.

Although EA was not directly assessed in the current study, research has suggested that questionnaires such as the LEAF-Q can be a convenient screening tool for risk of LEA. In the current study, approximately half of female trail runners were at risk for LEA, which is comparable to the prevalence (44.1%) found by Folscher, et al. (2015) in ultramarathon athletes. In contrast, other studies using the LEAF-Q have reported a higher prevalence (65-79.5%) of LEA in elite cross-country runners and in female endurance athletes (13, 19). Furthermore, younger female runners in the current study were more likely to be at risk for LEA than older female runners. However, these discrepancies in the reported prevalence may be due to the

smaller sample sizes used in the studies, and/or false positives or negatives due to the nature of survey research (13).
The LEAF-Q has also been used to assess MD in previous literature as MD is a common symptom known to be correlated with risk for LEA in female athletes (6, 14, 18, 28). In the current study, approximately half of female runners reported MD, with younger females more likely to report MD than older females, consistent with previous literature (33). Female athletes with MD were more likely to experience inconsistent menstruation, lose their period during phases of high training, experience less periods over the past year, and to have lost their menstrual cycle for more than 3 months not due to pregnancy than female athletes not at risk for MD. However, participants who reported using oral or hormonal contraceptives could potentially result in a false negative for MD. As noted in previous research, female athletes may lack knowledge and awareness around the negative consequences of LEA female reproductive health which warrants the need for educational interventions (12).

Currently, there is no validated questionnaire for assessing risk of LEA in male athletes, therefore these results should be interpreted with caution. Like Jesus et al. (2021), the LEAF-Q was analyzed across 2 sub-categories (GI, and injury risk) to include males. The current study suggested that approximately one quarter of males were at risk for LEA, which was lower than the 54% reported by Jesus et al. (2021), potentially the result of additional questions used in their survey (19). Also consistent with findings by Jesus et al. (2021), male runners were less likely to be at risk for LEA compared to female athletes. Similar to Kuikman et al. (2021), LEAF-Q scores were correlated with DE scores, and slightly correlated with EDS-21 scores in males (24).

Disordered eating has been suggested to be a contributing factor that may lead to LEA in athletes (20, 31, 44). Consistent with other studies on endurance athletes participating in leanness-focused sports, the current study suggested that just under half the sample population of runners, mainly females, were at risk for DE (41). Furthermore, DE was correlated with LEA. This is similar to the findings by Kuikman et al. (2021) who suggested that athletes at risk for DE were more likely to be classified as at risk for LEA (24). These findings further suggest that DE may be a contributory issue and help identify athletes who may be at risk for LEA. Some examples of DE include skipping meals, restricting calories, and excessive exercise, which can impact energy intake and energy balance and may contribute to LEA in athletes (44). However, while some athletes may not score on the spectrum of DE, they may still fail to meet energy requirements for sport. Therefore, DE should not be used as the only qualifier for investigation into the presence of LEA in athletes (44).

In agreement with previous findings (13, 26, 45) this study suggested that most of the trail runners were "non-dependent symptomatic" for EXD, which is defined as having the symptoms of exercise dependency but not being classified as "at-risk" while a much smaller percentage of athletes scored "at risk" for EXD in the current study (17, 32). Female runners scored significantly higher on the Withdrawal, Continuance, and Lack of Control sub-categories on the EDS-21 than males, whereas male runners scored significantly higher on the Tolerance subsection. Additionally, athletes identified as "at risk" for LEA reported higher EDS-21 scores, suggesting that EXD may be a contributing factor for risk for LEA. Similarly, Fahrenholtz (2022) reported higher risk of exercise addiction in female endurance athletes at risk for LEA (13). Consistent with Remilly et al. (2023) and Torsveit et al. (2018) (examining long distance runners, triathletes, and cyclists), EDS-21 scores were correlated with DE behaviors, suggesting that symptoms of EXD may be more prevalent in athletes at risk for DE (34, 42).

Most runners reported meeting carbohydrate recommendations of 30 to 60 grams of carbohydrate per hour during competition and training lasting 1 to 2.5 hours in duration. However, a large percentage of trail runners reported not meeting current fueling recommendations of 60 to 90 grams of carbohydrate per hour during training runs and competitions lasting longer than 2.5 hours (40). Similarly, other studies have suggested that most athletes racing ultramarathons in different environments failed to meet recommended levels of carbohydrate consumption during exercise (2, 7). Stellingwerf (2016) followed ($n$ = 3) runners over the course of year and several 100-mile races including the Western States 100-mile race, and found that these three veteran male runners implemented fueling strategies that met evidenced based guidelines for carbohydrate intake during exercise (36). These difference in findings between the studies may be attributed to the smaller sample size of the Western States study, and the self-reported nature of our study. In the current study, female runners who did not meet fueling recommendations during workouts or races were more likely to be at risk for LEA and DE. Furthermore, younger runners were less likely to meet fueling recommendations and are at a greater risk for LEA in comparison to older athletes.

The cross-sectional design of this study limits any assumptions regarding causality. False negatives/positives on the LEAF-Q associated with questions around MD (13). Due to the lack of a validated LEAF-Q for males, the prevalence of LEA in males may be under-estimated due to the lack of questions targeting other physiological processes known to be impacted by LEA. Athletes willing to take a survey on with a disclaimer around disordered eating may be more likely to be recovered from or without symptoms of a DE, which may also impact the prevalence in this sample of athletes. The results of this study may not be representative of athletes in other endurance sports such as triathlon, cycling, or swimming where leanness may not be as highly emphasized and fueling may be easier or more common. The results should not be extrapolated to athletes who are younger or older than the age range (18-40), especially those around LEA, as the LEAF-Q has not been validated on these age ranges.

This study suggests that a high percentage of trail runners are at risk for LEA and DE. Furthermore, while clinical risk of EXD is low, a high percentage of athletes were symptomatic for EXD. However, this was unrelated to training volume. Trail runners at risk for LEA were more likely to be risk for DE and EXD. Thus, symptoms of EXD and DE may be a red flag for practitioners identifying and assessing risk of LEA. Female athletes were more likely to be at risk for DE and LEA compared to male athletes and MD was correlated with risk of LEA. Thus, understanding and awareness of menstrual health, injury history, and the eating behaviors of female athletes is important for practitioners and coaches to help athletes avoid symptoms of LEA. Trail runners were unlikely to meet fueling recommendations during endurance events lasting > 2.5 hours, which emphasizes the importance of improving trail runners' knowledge of current fueling guidelines.

Furthermore, the relationship between risk of LEA and inadequate fueling habits during training and competition lasting longer than 1 hour indicates the importance of meeting carbohydrate intake recommendations to avoid negative health outcomes, especially in younger female runners. More research is warranted to examine how risk of DE, EXD, and fueling behaviors impact risk for LEA among ultra-runners. Moreover, athletes should be referred to a registered sports dietitian for assessment and treatment of LEA as a reduction in exercise energy expenditure, and an increase in energy intake are necessary for correction of LEA. Athletes should seek guidance from a sports dietitian to help with fueling plans that meet carbohydrate needs during training runs and races. Coaches working with trail and ultra-runners should ask questions regarding menstrual health, injuries, and fueling behaviors during exercise to better understand the athletes' needs prior to prescribing extremely high training loads. Lastly, education regarding the negative physiological and performance consequences of LEA is warranted to increase awareness in trail runners.

## ACKNOWLEDGEMENTS

The author(s) received no financial support for the research, authorship, and/or publication of this article.

## REFERENCES

1. Areta JL, Taylor HL, Koehler K. Low energy availability: History, definition and evidence of its endocrine, metabolic and physiological effects in prospective studies in females and males. Eur J Appl Physiol 121(1): 1-21, 2021.
2. Arribalzaga S, Viribay A, Calleja-González J, Fernández-Lázaro D, Castañeda-Babarro A, Mielgo-Ayuso J. Relationship of carbohydrate intake during a single-stage one-day ultra-trail race with fatigue outcomes and gastrointestinal problems: A systematic review. Int J Environ Res Public Health 18(11): 5737, 2021.
3. Bamber DJ, Cockerill IM, Rodgers S, Carroll D. Diagnostic criteria for exercise dependence in women. Br J Sports Med 37(5): 393-400, 2003.
4. Bamber DJ, Cockerill IM, Carroll D. The pathological status of exercise dependence. Br J Sports Med 34(2): 125-132, 2000.
5. Berg S, Pritchett K, Ogan D, Larson A. Self reported history of eating disorders, training, weight control methods, and body satisfaction in elite female runners competing at the 2020 U.S. Olympic marathon trials. Int J Exerc Sci 15(2): 721-732, 2022.
6. Cobb KL, Bachrach LK, Greendale G, Marcus R, Neer RM, Nieves J, et al. Disordered eating, menstrual irregularity, and bone mineral density in female runners. Med Sci Sports Exerc 35(5): 711-719, 2003.
7. Costa R, Swancott A, Gill S, Hankey J, Scheer V, Murray A, et al. Compromised energy and nutritional intake of ultra-endurance runners during a multi-stage ultra-marathon conducted in a hot ambient environment. Int J Sports Sci 3(2): 51-62, 2013.

8. De Souza MJ, Koltun KJ, Williams NI. The role of energy availability in reproductive function in the female athlete triad and extension of its effects to men: An initial working model of a similar syndrome in male athletes. Sports Med 49(Suppl 2): 125-137, 2019.

9. Di Lodovico L, Poulnais S, Gorwood P. Which sports are more at risk of physical exercise addiction: A systematic review. Addict Behav 93: 257-262, 2019.

10. Downs DS, Hausenblas HA, Nigg CR. Factorial validity and psychometric examination of the exercise dependence scale-revised. Meas Phys Educ Exerc Sci 8(4): 183-201, 2004.

11. Fagerberg P. Negative consequences of low energy availability in natural male bodybuilding: A review. Int J Sport Nutr Exerc Metab 28(4): 385-402, 2018.

12. Fahrenholtz IL, Sjödin A, Benardot D, Tornberg AB, Skouby S, Faber J, et al. Within-day energy deficiency and reproductive function in female endurance athletes. Scand J Med Sci Sports 28(3): 1139-1146, 2018.

13. Fahrenholtz IL, Melin AK, Wasserfurth P, Stenling A, Logue D, Garthe I, et al. Risk of low energy availability, disordered eating, exercise addiction, and food intolerances in female endurance athletes. Front Sports Act Living 4: 869594, 2022.

14. Folscher LL, Grant CC, Fletcher L, Janse van Rensberg DC. Ultra-marathon athletes at risk for the female athlete triad. Sports Med Open 1(1): 29, 2015.

15. Hausenblas HA, Danielle SD. Exercise dependence: A systematic review. Psychol Sport Exerc 3(2): 89–123, 2002.

16. Hausenblas HA, Danielle SD. How much is too much? The development and validation of the exercise dependence scale. Psychol Health 17(4): 387–404, 2002.

17. Hausenblas HA, Danielle SD. Relationship among sex, imagery and exercise dependence symptoms. Psychol Addict Behav 16(2): 169–172, 2002.

18. Heikura IA, Uusitalo ALT, Stellingwerff T, Bergland D, Mero AA, Burke LM. Low energy availability is difficult to assess but outcomes have large impact on bone injury rates in elite distance athletes. Int J Sport Nutr Exerc Metab 28(4): 403-411, 2018.

19. Jesus F, Castela I, Silva AM, Branco PA, Sousa M. Risk of low energy availability among female and male elite runners competing at the 26th European cross-country championships. Nutrients 13(3): 1–11, 2021.

20. Joy E, Kussman A, Nattiv A. 2016 update on eating disorders in athletes: A comprehensive narrative review with a focus on clinical assessment and management. Br J Sports Med 50(3): 154-162, 2016.

21. Loucks AB. Low energy availability in the marathon and other endurance sports. Sports Med. 37: 348–352, 2007.

22. Kennedy SF, Kovan J, Werner E, Mancine R, Gusfa D, Kleiman H. Initial validation of a screening tool for disordered eating in adolescent athletes. J Eat Disord 9(1): 21, 2021.

23. Kluyver T, Ragan-Kelley B, Pérez F, Granger B, Bussonnier M, Frederic J, et al. Jupyter Notebooks – A publishing format for reproducible computational workflows. International Conference on Electronic Publishing, 2016.

24. Kuikman MA, Mountjoy M, Burr JF. Examining the relationship between exercise dependence, disordered eating, and low energy availability. Nutrients 13(8): 2601, 2021.

25. Logue DM, Madigan SM, Melin A, Delahunt E, Heinen M, McDonnell S-J, et al. Low energy availability in athletes 2020: An updated narrative review of prevalence, risk, within-day energy balance, knowledge, and impact on sports performance. Nutrients 12(3): 835, 2020.

26. Łuszczki E, Jagielski P, Bartosiewicz A, Kuchciak M, Deren K, Stolarczyk A, et al. The LEAF questionnaire is a good screening tool for the identification of the female athlete triad/relative energy deficiency in sport among young football players. PeerJ. 9: e12118, 2021.

27. Magee CA, Buchanan I, Barrie L. Profiles of exercise dependence symptoms in Ironman participants. Psychol Sport Exerc 24: 48–55, 2016.

28. Melin A, Tornberg AB, Skouby S, Faber J, Ritz C, Sjödin A, et al. The LEAF questionnaire: A screening tool for the identification of female athletes at risk for the female athlete triad. Br J Sports Med 48(7): 540-545, 2014.

29. Mountjoy M, Sundgot-Borgen J, Burke L, Ackerman KE, Blauwet C, Constantini N, et al. International Olympic Committee (IOC) consensus statement on relative energy deficiency in sport (RED-S): 2018 update. Int J Sport Nutr Exerc Metab 28(4): 316-331, 2018.

30. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1): 1-8, 2019.

31. Nattiv A, De Souza MJ, Koltun KJ, Madhusmita M, Kussman A, Williams NI, et al. The male athlete triad-A consensus statement from the Female and Male Athlete Triad Coalition Part 1: Definition and scientific basis. Clin J Sport Med 31(4): 345-353, 2021.

32. Orhan S, Yücel AS, Sadeq BJ, Orhan E. Investigation of the exercise dependence of athletes doing kickboxing, Taekwondo, and Muay Thai. Sports (Basel) 7(2): 52, 2019.

33. Ravi S, Ihalainen JK, Taipale-Mikkonen RS, Kujala UM, Waller B, Mierlahti L, et al. Self-reported restrictive eating, eating disorders, menstrual dysfunction, and injuries in athletes competing at different levels and sports. Nutrients 13(9): 3275, 2021.

34. Remilly M, Mauvieux B, Drigny J. Personality traits associated with the risk of exercise dependence in ultraendurance athletes: A cross-sectional study. Int J Environ Res Public Health. 20(2): 1042, 2023.

35. Schimek RL, Salafia EB, Stastny S. Relative energy deficiency in sport among a collegiate cross-country team. Open J Intern Med 11: 81-90, 2021.

36. Stellingwerff T. Competition nutrition practices of elite ultramarathon runners. Int J Sport Nutr Exerc Metab 26(1): 93–99, 2016.

37. Stellingwerff T. Overtraining syndrome (OTS) and relative energy deficiency in sport (RED-S): Shared pathways, symptoms, and complexities. Sports Med 51(11): 2251-2280, 2021.

38. Sundgot-Borgen J, Torstveit MK. Aspects of disordered eating continuum in elite high-intensity sports. Scand J Med Sci Sports 20 (Suppl 2): 112-121, 2010.

39. Sundgot-Borgen J, Torstveit MK. Prevalence of eating disorders in elite athletes is higher than in the general population. Clin J Sport Med 14(1): 25-32, 2004.

40. Tenforde AS, Barrack MT, Nattiv A, Fredericson M. Parallels with the female athlete triad in male athletes. Sports Med 46(2): 171-182, 2016.

41. Thomas DT, Erdman KA, Burke LM. Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and athletic performance [published correction appears in J Acad Nutr Diet 117(1): 146, 2017]. J Acad Nutr Diet 116(3): 501-528, 2016.

42. Torstveit MK, Fahrenholtz I, Stenqvist TB, Sylta Ø, Melin A. Within-day energy deficiency and metabolic perturbation in male endurance athletes. Int J Sport Nutr Exerc Metab 28(4): 419-427, 2018.

43. Wardenaar FC, Dijkhuizen R, Ceelen IJM, Jonk E, de Vries JHM, Witkamp RF, et al. Nutrient intake by ultramarathon runners: Can they meet recommendations? Int J Sport Nutr Exerc Metab 25(4): 375-386, 2015.

44. Wells KR, Jeacocke NA, Appaneal R, Smith HD, Vlahovich N, Burke LM, et al. The Australian Institute of Sport (AIS) and National Eating Disorders Collaboration (NEDC) position statement on disordered eating in high performance sport. Br J Sports Med 54(21): 1247-1258, 2020.

45. Zandonai T, Manresa-Rocamora A, Monese L, Moya-Ramón M, Schena F, Chiamulera C. A descriptive study of exercise dependence: A short report among Italian and Japanese runners. J Addict Dis 39(1):133-137, 2021.