International Journal of EXERCISE SCIENCE

Original Research

The Prevalence of Stress Fractures and the Associated LEAF-Q Responses, Self-Reported Exercise Volume and Dietary Behaviors in Female Recreational Runners

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ABSTRACT

International Journal of Exercise Science 17(2): 1092-1104, 2024. Previous research suggests a high prevalence of low energy availability (LEA) and stress fractures (SF) among competitive female endurance athletes. However, much less is known about these issues among recreational female runners. This study aimed to assess the prevalence and number of self-reported SF and risk of LEA among noncompetitive, recreationally active female runners, aged 18 – 25 years. Additionally, it compared characteristics between females with a history of multiple SF vs. one or no SF, and between those 'at risk' vs. 'not at risk' of LEA. Female recreational runners (n=485) completed an online survey that included the Low Energy Availability in Females Questionnaire (LEAF-Q) and the Disordered Eating Screening Assessment (DESA-6). Thirty-three percent of participants reported ≥ 2 SF. Eighty-two percent of the ≥ 2 SF group were classified as 'at risk' of LEA (LEAF-Q score ≥ 8). In addition, ≥ 2 SF was associated with higher total LEAF-Q score, self-reported intentional food restriction for weight loss, and self-reported current eating disorder while weekly exercise duration was inversely associated with ≥ 2 SF. In conclusion, one-third of participants had multiple SF with a majority (82%) of this group classified as 'at risk' of LEA. Screening tools such as the LEAF-Q and DESA-6 are useful tools to identify characteristics associated with multiple SF in this demographic, especially questions regarding food restriction and the presence of a current or previous eating disorder.

KEY WORDS: Low energy availability, recreationally active, young adult females, distance runners, Female Athlete Triad, bone stress injuries, bone fractures, eating disorders, amenorrhea, RED-S

INTRODUCTION

Bone stress injuries (BSI) exist on a continuum of severity, with early signs including bone marrow edema or stress reactions while more advanced cases result in stress fractures (SF) (36). SF show a fracture line with radiographic imaging (36). For consistency, this paper will use the term BSI or SF as per the source's terminology. Specifically, SF will be employed when referencing our own research, aligning with the term used during participant surveys. SF are common injuries among competitive and recreational runners. Over one-third of female long-distance runners report a history of SF with a high risk of reoccurrence (16). Risk factors for BSI and SF include increased volume or intensity of weight-bearing activity, restrictive eating tendencies, low bone mineral density, previous SF, later age of menarche (>14 years old), and fewer menses per year (9, 39).

Low energy availability (LEA) occurs when energy expenditure exceeds energy intake and the body does not have enough energy to support physiological functions associated with optimal health (25). LEA has been identified as the underlying factor for the Female Athlete Triad and Relative Energy Deficiency in Sport (REDs) (25). REDS includes a range of potential physiological consequences thought to be associated with LEA, including effects on growth and development, bone health and reproductive, metabolic, endocrine, cardiovascular, gastrointestinal, immunological, hematological, and psychological functions (25). Poor bone health is incorporated into the REDS model and is a known consequence of LEA.

In general, weight-bearing activity, such as running, increases bone mineral density (20, 30). However, in females with menstrual dysfunction (MD), running may increase SF risk. MD and SF risk are associated with LEA. LEA promotes increased bone reabsorption and reduced bone formation, and in combination with repeated mechanical loading, SF risk is increased (29). Furthermore, LEA-related MD is thought to exacerbate these negative bone effects (5, 33). Females who have a history of multiple BSI are more likely to have greater previous and current estimates of LEA (9). In addition to SF, young females (<26 years of age) with LEA-related MD are at risk of suboptimal peak bone mass acquisition and future osteoporosis (28). As such, easily administered tools to promptly identify young females at risk of repeated SF are needed to provide timely interventions and mitigate potential injury and poor bone health. Identifying factors associated with multiple SF may help practitioners identify at-risk individuals before injury occurs.

Estimating energy availability is cumbersome and generally untenable for larger, population-based studies or when working with large groups of physically active individuals, and is best used as a follow-up procedure, implemented by trained medical professionals, when an individual exhibits signs of LEA. For a review of techniques used to estimate energy availability refer to Heikura et al., (2022). Screening tools, such as questionnaires, can be used to identify those at risk of LEA without the burden, logistical challenges, and cost of energy intake and expenditure measures. A frequently used survey tool is the Low Energy Availability in Females Questionnaire (LEAF-Q). The LEAF-Q includes sections covering injuries, gastrointestinal function, and menstrual function and has been shown to properly identify individuals at high risk of LEA (23). It is also relatively easy to administer and requires minimal knowledge on the part of the participant of the underlying constructs it is intended to assess. Unfortunately, the LEAF-Q does not include questions specifically related to SF, as such, less is known about the relationship between risk of LEA and SF incidence. However, a study conducted by Tenforde et al., (2017), classified collegiate athletes from 16 sports into low-, moderate-, and high-risk categories using the Female Athlete Triad Cumulative Risk Assessment score and evaluated the predictive value of the risk categories for subsequent SF; moderate- and high-risk athletes were more likely to subsequently sustain a SF and most SF were sustained by cross-country runners (35). The Female Athlete Triad Cumulative Risk Assessment requires knowledge of an athlete's BMI or expected body weight, bone mineral density z-score, and if the athlete meets DSM 5 criteria for an eating disorder, making this tool less practical for large cross-sectional studies. However, Tenforde's findings justify an examination of the relationship between LEAF-Q score, LEAF-Q subsection scores, and history of SF among young female runners (35).

Previous research suggests that there is a high prevalence of LEA among female endurance athletes, particularly among young, female runners. Melin et al., (2014) found that 62.2% of female endurance athletes were at high risk of LEA, which is comparable to more recent findings by Dervish et al., in competitive and recreational female endurance runners (n = 248, 47.3%) (6, 24). Dervish, also reported 18 to 24-year-old female endurance runners were at greater risk of LEA, disordered eating and eating disorders compared to other age categories (6). In general, LEA is more prevalent among athletes in sports where leanness is emphasized and considered a performance advantage (these sports are broadly referred to as "weight-sensitive sports" and includes distance running) (34, 37). However, most research has been conducted in competitive athletes and less is known about the incidence and risk of LEA and SF among recreational female runners, who may have lower training loads and goals not related to competitive performance outcomes. Therefore, the purpose of this study is to assess the prevalence and number of self-reported SF among noncompetitive, recreationally active female runners, aged 18 – 25 years, and risk of LEA. We hypothesize that there will be a high prevalence of self-reported SF in those 'at risk' of LEA. A secondary purpose is to compare relevant characteristics such as exercise volume, BMI, eating disorder history, body weight dissatisfaction, and restrictive eating behaviors between females with a history of multiple SF and those with a history of ≤1 SF. The LEAF-Q will be evaluated in the context of self-reported SF. We hypothesize that these characteristics will be higher in females with a history of multiple SF. A third purpose is to compare LEAF-Q subsection scores and specific LEAF-Q questions between those 'at risk' vs. 'not at risk' of LEA. Our hypothesis is that the subsection scores and specific questions will be higher in those 'at risk'.

METHODS

Participants

Female non-competitive, recreational runners with a minimum weekly mileage >10, between 18 - 25 years of age, of any ethnicity were included in the present study analysis. Exclusion criteria included inactivity, current or former collegiate runners, or currently training for professional, competitive races. The study was approved by the Institutional Review Board (IRB) of a western regional university. The research was conducted in accordance with the ethical standards of the *International Journal of Exercise Science (27).* The first question of the survey informed participants of the nature of the study and asked for anonymous, informed consent via answering the first question as "yes".

Protocol
Participants completed an online survey (Qualtrics; Provo, Utah, USA, 2019) that was advertised via Instagram. The first 200 participants were offered the opportunity to receive a $20 Amazon gift card for participating and completing the survey. The advertisement used Instagram's algorithm to target runners within our demographic to minimize selection bias. The survey contained 45 questions from the Disordered Eating Screening Assessment (DESA-6) and Low Energy Availability in Females Questionnaire (LEAF-Q). Questions included those related to type of runner (collegiate, competitive, recreational), training regime (mileage per week), weight control methods, weight satisfaction, history or presence of an eating disorder or disordered eating, injury history (general types of injuries that affected physical activity within the past year), lifetime incidence of stress fractures (including asking number of stress fractures) gastrointestinal function, and menstrual function.

The LEAF-Q assesses participants based on self-reported physiological symptoms associated with LEA. It is a validated screening tool with 78% sensitivity, 90% specificity for identifying LEA and 0.79 test-retest reliability (24). The introduction includes 10 items about age, gender, height, weight, recent weight loss, and physical activity amount and type. The next questions are divided into three subsections: injuries, gastrointestinal function, and menstrual function. Answer options include Likert-type ordinal scales and optional open responses. The injury section assesses injury occurrences in the past year resulting in an absence from training. Additional questions regarding training days lost and type of injury are asked. Gastrointestinal function evaluates gaseousness, bloating, cramps, and stomachaches not associated with menstrual functions. Bowel movement frequency and description is also queried. The menstrual function section asks about contraceptive use and the purpose of oral or hormonal contraceptives. It also includes questions regarding age of menarche, duration and frequency of menstruation, time since last menstrual cycle, and the presence of exercise-related changes in menstruation. Total LEAF-Q scores can range from 0-49. A score ≥8 is considered 'at risk' for LEA. LEAF-Q subsection scores include GI function (score range 0-12, ≥2 indicates GI impairment); injuries (score range 0-6, ≥ 2 indicates increased injury risk); and. Menstrual function (score range 0-21, ≥ 4 indicates MD).

The DESA-6 assesses self-reported disordered eating behaviors unique to athletes. The DESA-6 is a validated tool with a sensitivity of 92% and a specificity of 85.96% (17). Questions are asked about injuries, fear of weight gain, weight satisfaction, and diet behaviors.

Statistical Analysis
All data was self-reported and collected via an online Qualtrics survey. Data was analyzed using Microsoft Excel and SPSS Version 28 (IBM Corp., Armonk, NY). Body mass index (BMI) was calculated from self-reported height and weight data. Interval and ratio data are presented as mean ± standard deviation. Interval and ratio variables were assessed for between-groups differences using independent samples t tests. Cohen's d effect sizes were calculated and interpreted according to the following scale < 0.1 trivial; 0.1-0.3 small effect; 0.3-0.5 moderate effect; > 0.5 large effect (3). Nominal data was assessed for between-group differences using the chi-squared test of independence**.** Logistic regression models were conducted using SPSS to

explore risk factors for ≥ 2 lifetime incidence of SF. Odds ratios and confidence intervals were used to examine associations in the logistic regression model. *P* values less than 0.05 were considered statistically significant for all analyses**.**

RESULTS

A total of 3,499 females completed the initial survey. Four hundred and fifty-eight females were included in this analysis based on the qualifications of being a non-competitive recreational runner, age 18-25 years old with a biological or assigned sex of female, and a minimum weekly mileage > 10. Those who were older than 25 years old, current, or previous collegiate athletes, or running competitively at the time of the survey were excluded from this analysis. The number of participants included is in line with other studies that used the LEAF-Q with participants ranging from 202-524 (6-8).

Incidence of Stress Fractures (SF): Fifty-one percent (n = 232) of participants reported having at least one stress fracture in their lifetime and 33% (n=149) of participants reported ≥ 2 lifetime stress fractures (≥ 2 SF). Participants were grouped and compared with respect to the presence or absence of multiple lifetime SF. Characteristics of the total sample and respective groups (≤1 SF vs. ≥ 2 SF) are presented in Table 1. The prevalence of individuals identified as 'at risk' for LEA by the LEAF-Q was significantly higher in the ≥ 2 SF compared to the ≤ 1 SF group (<0.01). Mean total LEAF-Q score and mean subsection scores (injury, GI, and menstrual function, respectively) were significantly higher in participants who reported a history of ≥ 2 SF compared to ≤ 1 SF (Table 1). Fifty-nine percent (n=271) of total participants were classified as having MD (≥4 on LEAF-Q menstrual subsection), and the ≥ 2 SF were more likely to have MD compared to the ≤ 1 SF group (p = <0.01; χ^2 =47.14). However, there was not a statistically significant difference in incidence of secondary amenorrhea (defined as the absence of menstruation for three consecutive months or longer, not due to pregnancy, breast-feeding, or any type of hormonal contraception or implant, hysterectomy and/or ovaries removed (4, 26, 40)) between groups. There was a higher incidence of self-reported intentional food restriction in order to lose weight (p<0.01) and current eating disorder (p<0.01) in the ≥ 2 SF group vs ≤ 1 SF group. However, fear of weight gain in the off-season (p = 0.59) and weight dissatisfaction in the past three months (p = 0.21) did not differ between groups (Table 1). Typical weekly running mileage did not differ between groups.

Logistic regression analysis indicated increased odds of multiple SF was associated with a higher total LEAF-Q score, self-reported intentional food restriction for weight loss, and self-reported current eating disorder (Table 2.). Interestingly, MD (LEAF-Q menstrual subsection score ≥ 4) was not associated with multiple SF (Table 2.). Decreased odds of multiple SF was associated with higher exercise volume in hours/week (Table 2.).

Incidence of Low Energy Availability (LEA): Participants were classified as 'at risk' for LEA based on total LEAF-Q score (Total score ≥8). Descriptive characteristics and LEAF-Q scores for the total sample and 'at risk' and 'not at risk' groups, respectively, are presented in Table 3. There were no significant differences between groups on measures of BMI or hours of exercise per week. Females classified as 'at risk' for LEA were significantly more likely to have a higher lifetime history of multiple SF and have three or more injuries in the past 12 months that interfered with running. Expectedly, females 'at risk' for LEA also had higher total LEAF-Q scores and Injury, GI, and Menstrual Function subsection scores (see Table 3).

Table 1. Participant Descriptive Characteristics for Runners with ≤ 1 Lifetime Incidence of Stress Fractures (SF) and ≥ 2 Lifetime Stress Fractures.

	All Participants (n=458)	**≤1 Lifetime SF (n=309; 67%)**	**≥2 Lifetime SF (n=149; 33%)**	**p-value(*d*)**
% at Risk of LEA	60%	49%	82%	<0.01*
Years	23.1 ± 1.8	23.2 ± 1.8	22.9 ± 1.9	0.10
Height (cm)	165.1 ± 10.0	165.3 ± 9.3	164.7 ± 11.5	0.57
Weight (kg)	60.7 ± 9.7	60.1 ± 9.8	61.8 ± 9.2	0.08
BMI	22.4 ± 4.2	22.1 ± 3.8	23.1 ± 4.9	<0.01* (*d*=0.26)
Exercise per Week (hours)	6.2 ± 2.4	6.5 ± 2.4	5.6 ± 2.3	<0.01* (*d*=-0.38)
Weekly Running Mileage	31.9 ± 13.6	31.0 ± 14.5	33.6 ± 11.5	0.06
LEAF-Q Total Score	10.0 ± 6.1	8.3 ± 5.3	14.0 ± 5.8	<0.01* (*d*=1.08)
LEAF-Q Injury Subsection	0.9 ± 1.9	0.7 ± 1.8	1.4 ± 2.2	<0.01* (*d*=0.39)
LEAF-Q GI Function Subsection	3.6 ± 2.5	3.0 ± 2.4	5.0 ± 2.3	<0.01* (*d*=0.83)
LEAF-Q Menstrual Function Subsection	5.6 ± 3.8	4.6 ± 3.6	7.6 ± 3.5	<0.01* (*d*=0.83)
MD (≥4 on Menstrual Subsection)	59% (n=271)	48% (n=149)	82% (n=122)	(χ^2 =47.14) <0.01*
Oral Contraceptive Use	29% (n=131)	22% (n=68)	42% (n=63)	(χ^2 =20.24) <0.01*
Current Amenorrhea	6% (n=29)	5% (n=16)	9% (n=13)	(χ^2 =2.13) 0.14
Food Restriction for Weight Loss	51% (n=233)	41% (n=127)	71% (n=106)	(χ^2 =36.30) <0.01*
Current Eating Disorder	36% (n=165)	23% (n=70)	64% (n=95)	(χ^2 =73.70) <0.01*
Fear of Weight Gain	45% (n=208)	46% (n=143)	44% (n=65)	(χ^2 =0.29) 0.59
Weight Dissatisfaction	65% (n=298)	33% (n=102)	39% (n=58)	(χ^2 = 1.55) 0.21

Data are mean ± SD; cm, centimeters; kg, kilograms; BMI, Body Mass Index. LEAF-Q, Low Energy Availability in Female Questionnaire; LEAF-Q ≥ 8 indicates 'at risk' of LEA, LEAF-Q < 8 indicates 'not at risk'. Injury ≥ 2 indicates increased risk of injury. GI function ≥ 2 indicates GI impairment. Menstrual function ≥ 4 indicates menstrual dysfunction (MD). * Indicates significant difference.

Table 2. Odds ratio of variables potentially associated with ≥ 2 Lifetime Stress Fractures.

	OR	**95% CI**	**p-value**
BMI	1.04	0.99-1.10	0.13
Exercise per Week (hours)	0.86	0.78-0.95	<0.01*
LEAF-Q Total Score	1.13	1.04-1.22	<0.01*
LEAF-Q Menstrual Function Subsection	1.03	0.91-1.16	0.67
Current Secondary Amenorrhea	1.16	0.45-3.01	0.76
Food Restriction for Weight Loss	2.66	1.63-4.33	<0.01*
Current Eating Disorder	2.43	1.44-4.08	<0.01*

OR, odds ratio; CI, confidence interval; BMI, Body Mass Index. LEAF-Q, Low Energy Availability in Female Questionnaire;. * Indicates significant difference.

Table 3. Participant Descriptive Characteristics Between Runners 'At Risk' vs. 'Not At Risk' for LEA

	Total Participants (n=458)	Not at Risk for LEA (n = 185; 40%)	At Risk for LEA (n = 273; 60%)	p-value
Years	23.1 ± 1.8	23.4 ± 1.76	22.9 ± 1.9	<0.01* (*d*=-0.28)
Height (cm)	165.1 ± 10.0	164.03 ± 9.8	166.0 ± 10.2	0.03* (*d*=0.20)
Weight (kg)	60.7 ± 9.7	59.5 ± 9.6	61.5 ± 9.7	0.03* (*d*=0.21)
BMI	22.4 ± 4.2	22.3 ± 4.5	22.5 ± 4.0	0.75
Exercise per Week (hours)	6.2 ± 2.4	6.44 ± 2.4	6.1 ± 2.4	0.10
Weekly Running Mileage	31.9 ± 13.7	30.0 ± 13.9	33.2 ± 13.3	0.01* (*d*=0.23)
≥3 Injuries that Inhibited Training in the Previous 12 Months	19% (n=87)	2% (n=3)	31% (n=84)	(χ^2 =60.89) <0.01*
Incidence of Multiple SF	33% (n=149)	15% (n=27)	45% (n=122)	(χ^2 =45.50) <0.01*
LEAF- Q Total Score	10 ± 6.1	4.2 ± 2.00	14 ± 4.5	<0.01* (*d*=4.90)
LEAF-Q Injury Subsection	0.9 ± 1.9	0.1 ± 0.43	1.5 ± 2.3	<0.01* (*d*=3.26)
LEAF-Q GI Function Subsection	3.6 ± 2.5	1.8 ± 1.475	4.8 ± 2.4	<0.01* (*d*=2.03)
LEAF-Q Menstrual Function Subsection	5.6 ± 3.8	2.4 ± 1.44	7.8 ± 3.3	<0.01* (*d*=3.75)
Oral Contraceptive Use	29% (n=131)	22% (n=41)	33% (n=90)	(χ^2 =6.30) 0.01*

Data are mean ± SD; cm, centimeters; kg, kilograms; BMI, Body Mass Index. LEAF-Q, Low Energy Availability in Female Questionnaire; LEAF-Q ≥ 8 indicates 'at risk' of LEA, LEAF-Q < 8 indicates 'not at risk'. Injury ≥ 2 indicates increased risk of injury. GI function ≥ 2 indicates GI impairment. Menstrual function ≥ 4 indicates menstrual dysfunction. * indicates differences between participants 'at risk' of LEA and 'not at risk' of LEA.

DISCUSSION

This study aimed to describe the prevalence of multiple SF and increased risk of LEA among female recreational runners, 18 - 25 years of age. Our hypothesis was a higher prevalence of self-reported SF in those 'at risk' of LEA which our findings were in line with. A second aim was to compare relevant characteristics between those who reported multiple SF vs. one or none with our hypothesis being these characteristics would be more prevalent in those with multiple SF. Intentionally restricting food and current eating disorders were higher in ≥ 2 SF. However, the groups had similar typical weekly running mileage, fear of weight gain in the off-season, and weight dissatisfaction in the past three months. The third aim was to compare LEAF-Q subsection scores and specific LEAF-Q questions between those 'at risk' vs. 'not at risk' of LEA. Our hypothesis was that these subsection scores and specific questions would be higher in those 'at risk' which our finding agreed with.

Fifty-one percent (n = 232) of all participants (n=458) reported having at least one SF in their lifetime and 33% (n = 149) reported experiencing multiple SF. Females who reported multiple SF were more likely to also report higher total LEAF-Q scores, restriction of food intake, and a current eating disorder. LEAF-Q menstrual function subsection and current secondary amenorrhea did not increase the odds of multiple SF. The number of females who met the full criteria for amenorrhea may have been artificially reduced due to hormonal contraceptive use

(21, 26, 31). This seems plausible as 44% of those who reported multiple SF also reported oral contraceptive use as compared to 22% of those who reported 1 or fewer SF. While oral contraceptives increase estrogen levels, research does not support their effectiveness in improving bone mass among females with LEA who do not improve their energy status (18). It should also be noted that in the present study the incidence of amenorrhea was almost double in the multiple SF group vs. the one or fewer SF group (9% vs. 5%), however, the small number of females meeting the criteria likely reduced statistical power and this difference failed to reach statistical significance. Previous research supports the association between amenorrhea and SF risk; Heikura et al., found a 4.5 times greater incidence of bone stress injuries in female middle- and long-distance runners who were amenorrheic compared to eumenorrheic runners (11).

Even if runners do not display MD, restricting dietary energy intake may increase the risk for SF. In the present study, female recreational runners who reported multiple SF were more likely to report frequent food restriction for weight loss and the presence of an eating disorder compared to runners who reported one or fewer SF ($p<0.01$ for both). In addition, odds of reporting multiple SF were significantly higher when either of these variables were also reported. Other recent research has also found greater restrictive eating tendencies and high levels of dietary restraint in runners with a history of multiple BSI (9). Previous studies indicate, in addition to MD, chronic energy restriction leads to hypothalamic and pituitary hormonal disturbances that negatively affect bone metabolism even in the absence of amenorrhea (2, 12, 13). In a study by Ihle et al., dietary intake and exercise expenditure were controlled for 5 days in regularly menstruating young women, resulting in either balanced (45 kcal/kgLBM/day^{-1}) or varying levels of LEA (either 10, 20, or 30 kcal/kg/LBM/day^{-1}); researchers found even short-term LEA decreased biomarkers of bone formation in a dose dependent manner and bone resorption was increased with more extreme "doses" of energy restriction (13). Furthermore, Papageorgiou et al. found LEA achieved through energy restriction, rather than energy expended through exercise, has a greater adverse effect on bone formation (29). Previous research indicates high levels of cognitive dietary restraint represents a chronic daily stressor and is associated with increased cortisol levels (10) and higher cortisol levels higher are associated with menstrual irregularity and lower BMD (10, 22, 38). Based on these and findings from the present study, early intervention is warranted for mild or subclinical disordered eating attitudes to reduce SF risk.

The LEAF-Q is a common assessment tool used to determine risk for LEA. Risk for LEA and other components of REDs and the Female Athlete Triad has been previously described in various high-level female athlete populations, however, less well described is the incidence of these variables among females who engage in recreational activities. We found 60% (n= 273) of participants were classified as 'at-risk' for LEA using the LEAF-Q, which is similar to the prevalence reported in endurance athletes by Melin et al. (62.2%) and Fahrenholtz et al. (65%); however higher than reported by Sharps et al. (47.3%) among competitive and recreational female endurance runners (7, 24, 32). However, when participants in a study by Sharps et al. were divided by age, 73% (n = 54) of females aged 18-24 were found to be 'at-risk' (32).

Among females who reported multiple SF, 82% (n = 122) were categorized as 'at risk' for LEA (≥8 on the LEAF-Q). Also, those who score higher on the LEAF-Q have odds of multiple SF that are 1.13 times those who score lower. In addition, each respective LEAF-Q subsection score was significantly higher among females who reported a history of multiple SF compared to females who reported one or no SF ($p<0.01$). Eighty-two percent of females who reported experiencing multiple SF also met the criteria for MD (LEAF-Q Score ≥4 on Menstrual Subsection) compared to 48% of the ≤1 SF group. In contrast, recent findings from Karlsson, Alricsson, and Melin found only 15% of recreational female runners scored ≥ 4 on the LEAF-Q menstrual subsection (15). Clinical studies have found that females with a gynecological age <14 years are more sensitive to LEA than older females (19); as such this difference may be attributed, in part, to the older average age (32.4±4.3 years) of those surveyed in the Karlsson study (15) compared to the present study (23.1±1.8). More comparable but still lower than our findings, Jesus et al., reported MD in 42% of elite cross-country runners (n = 83; mean age 22.1 ± 4.0 yrs) (14).

Previous research has found that females who exercise ≥12 hrs/week experience a higher incidence of BSI compared to females who exercise less (1). Results from the present study indicate much lower exercise durations in recreational runners (6.2 ± 2.4 hours/week). In addition, exercise duration was significantly *lower* in females who reported ≥2 SF ($p<0.01$) compared to females who reported ≤1 SF. When those 'at risk' of LEA were compared to those 'not at risk', running mileage was higher in the 'at-risk' group ($p=0.01$) but exercise duration did not significantly differ ($p=0.10$). It should be noted that exercise duration and mileage do not necessarily speak to total exercise volume, as exercise intensity must also be considered as should activity associated with daily living. Additional survey questions and/or more direct measures of exercise and non-exercise energy expenditure may be necessary to assess the relationship between exercise, LEA, and SF incidence.

Limitations to the present study exist and should be addressed. The primary limitation to the present study is the reliance on self-reported information as the primary variables of interest. Self-reported incidence of SF, and variables associated with the LEAF-Q and dietary behaviors may be inaccurate due to unintentional error, misinterpretation of questions, internal biases, or sample bias. In addition self-reported SF, current and previous menstrual patterns, and eating disorders may not necessarily reflect a medical diagnosis. The survey specifically asked if and how many stress fractures the participants had. However, these were not confirmed with past medical imaging or medical records. Requiring imaging or medical records would have limited the ability to conduct this research. While self report does present internal validity limitations, these results point to a need to conduct future, higher quality studies that use imaging data. The LEAF-Q also carries the risk of a false positive or a false negative 'at-risk' designation (7). False positives may occur when participants have health conditions, unrelated to LEA, that inflate the LEAF-Q score. Using survey tools to estimate the prevalence of those 'at risk' of LEA likely captures individuals that, although at risk, may not actually have LEA if more direct measures were available. However, false negatives may also occur, for example, in the event contraceptive use artificially induces regular menstruation. Finally, the LEAF-Q was designed for and initially validated in female competitive athletes. Some of the questions inherent to the survey do not generally capture the nature of recreational exercise. For example, in the injury section of the

LEAF-Q a question asks, "*have you had 3 or more injuries that have inhibited your ability to train this past season or did your past season end early due to injury*?"; this question does not apply to recreational, noncompetitive athletes who do not have a defined training regimen or competitive "season" and may have been interpreted in a variety of ways by the recreational runners we sampled. Further, purposeful research intended to assess the validity and reliability of the LEAF-Q in recreational athletes should be conducted. Minor rewording of some of the questions may be necessary for optimal use in recreational female athletes. Another limitation to the present study is the incomplete assessment of exercise energy expenditure, as such a potential relationship between exercise intensity, energy expenditure, risk of LEA, and SF history could not be fully explored. Future research should also examine exercise motivation, or reasons why one engages in exercise and incidence of SF, as previous research has found a relationship between LEAF-Q and Exercise Addiction Inventory scores in competitive female endurance athletes (7).

Over half of the young (18 - 25 y.o.) adult female recreational runners in the present study reported experiencing at least one SF and one-third reported two or more SF. Females who reported two or more lifetime SF were more likely to self-report an eating disorder, restriction of food intake, and be categorized by the LEAF-Q as 'at-risk' for LEA. Odds of reporting two or more SF significantly increased when there was a higher total LEAF-Q score, an eating disorder, and reported food restriction. Results from the present study complement findings from other studies indicating exercise volume, running mileage, and BMI are not strongly associated with increased odds of multiple SF occurrence. These findings emphasize the importance of early identification of risk factors for SF such as dietary restriction, eating disorders, and LEA using tools like the LEAF-Q and DESA-6. Practitioners and coaches should prioritize screening for these factors to reduce the risk of SF and associated complications in this population. The LEAF-Q is a way for them to do so in a time-efficient manner.

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