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Risk of Low Energy Availability, Disordered Eating, and Menstrual Dysfunction in Female Recreational Runners

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RISK OF LOW ENERGY AVAILABILITY, DISORDERED EATING, AND MENSTRUAL

DYSFUNCTION IN FEMALE RECREATIONAL RUNNERS

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by

Marissa Ashley Miles

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CENTRAL WASHINGTON UNIVERSITY

Graduate Studies

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ABSTRACT

RISK OF LOW ENERGY AVAILABILITY, DISORDERED EATING, AND MENSTRUAL DYSFUNCTION IN FEMALE RECREATIONAL RUNNERS

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Running is characterized by high physiological demands with an emphasis on weight, which may lead to a greater risk of developing low energy availability (LEA) and/or disordered eating (DE). Recreational runners are a population that is often overlooked due to a lack of resources readily available to them. **Purpose:** This study investigated (1) the prevalence of menstrual dysfunction, risk of DE and LEA and (2) compare the risk of DE, training volume, and weight dissatisfaction between female recreational runners at risk for LEA versus not at risk for LEA. **Methods:** Female recreational runners (n= 1,923) completed an online questionnaire that included the Low Energy Availability in Females Questionnaire (LEAF-Q) to evaluate LEA risk, and the Disordered Eating Screening Assessment (DESA-6) to evaluate DE risk. **Results:** 53.04% of participants are at risk for LEA from a score of ≥ 8 on the LEAF-Q, 42.5% are at risk for DE from a score of ≥3 on the DESA-6, and 61.7% reported menstrual dysfunction. **Conclusion:** Female recreational runners have a high risk for LEA and DE and may not receive the needed treatment due to a lack of resources. This reinforces the need for further education and preventative measures around LEA, MD, and DE amongst recreational female runners.

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CHAPTER I

INTRODUCTION

Low energy availability (LEA) refers to a lack of energy available to support optimal health and physiological functions (e.g. bone remodeling, menstruation, muscle repair and growth) caused by inadequate energy intake and/or increased exercise energy expenditure (EEE).[1] Although difficult to measure precisely, laboratory-based studies in active females have suggested that LEA is defined as <30 kcal-kg FFM-1 day, and that a minimum energy availability (EA) of 45 kcal kg FFM-1 day is necessary for optimal health.[2] LEA has negative physiological consequences on menstrual health, bone mineral density, metabolism, mental health[1,3], and performance and is referred to as Relative Energy Deficiency in Sports (RED-S) which symptoms expand on the Female Athlete Triad.[3] LEA is a concern for both male and female athletes due to a greater energy expenditure from exercise, pressure to perform their best, and social influences on body weight.[4] Therefore, identifying LEA in athletes is essential for ensuring healthy and optimal menstrual function, bone mineral density, metabolism, mental health, and performance.

Athletes competing in sports with an emphasis on leanness or low body weight have been suggested to be at a greater risk for developing LEA and/or disordered eating (DE) due to their perceived notion of leanness equating to optimal performance.[1,5] Female athletes, especially at the sub-elite and elite levels, are estimated to have a higher prevalence of DE/eating disorders (ED), in comparison to male athletes.[6] DE/ED risk is increased when psychological risk factors such as body dissatisfaction are present which could result in athletes restricting calories to achieve a desired body goal, thus increasing their risk for LEA.[6] However, LEA does not always include DE patterns, but when it does it puts an athlete at a greater risk for developing physical and mental consequences.[4]

Previous research suggests females participating in endurance sports such as long-distance running have a higher incidence of menstrual dysfunction (MD) than females in non-endurance sports and non-athletes.[7] MD is another repercussion caused by LEA.[1,3] When left untreated, MD can impact bone health increasing the risk for stress fractures.[8] A recent study found that 76% of high school runners reported DE or ED, while 45.9% reported MD.[9] Similarly, Heikura et al. examined metabolic and reproductive hormonal function, and injury and illness rate in distance athletes and found that 40% of females were amenorrheic and had a greater incidence of bone injuries compared to eumenorrheic females.[10] The LEAF-Q may be used to assess menstrual function in female athletes, due to its admissible specificity and sensitivity score in evaluating reproductive health.[11]

Training volume throughout the life of an athlete is dynamic, depending on training stage (pre/post season, current season).[12] As fluctuations in the intensity and duration of training occur, the hormones related to satiety and hunger are affected.[12] Howe et al. concluded when the training volume and intensity are elevated, there is an increase in appetite suppressing hormones.[12] Thus, increasing the risk of LEA and complications, due to the lack of hunger cues and decrease in overall caloric consumption.

Various training styles, weight satisfaction, and presence of DE can affect energy availability, an issue that has been highlighted in recent research, especially in female athletes.[6,12,13] These health concerns in conjunction with the heightened probability of MD among female runners necessitates the exploration and analysis of variables that may influence or predict menstrual patterns in this population. Furthermore, studies examining MD, weight satisfaction, risk of DE and LEA, and training volume are still lacking, especially in female recreational runners, who may often be overlooked. Thus, the purpose of this study is to investigate (1) the prevalence of MD, risk of DE and LEA, and (2) compare the risk of DE, training volume, and weight satisfaction between female recreational runners at risk for LEA versus not at risk for LEA.

CHAPTER II

LITERATURE REVIEW

Energy Availability and RED-S

Energy availability (EA) is the difference between energy intake and exercise energy expenditure that is expended through exercise in relationship to fat free mass.[1] Chronic energy restriction and/or excessive energy expenditure via exercise can decrease EA. This means that energy intake is not meeting the demands for exercise or basic physiological functions.[3] Optimal EA in females is defined as having greater than 45 kilocalories per kilogram of fat free mass a day[3], while subclinical LEA for females is between 30 kcal·kg−1 fat-free mass·day−1 and 45 kcal·kg−1 fat-free mass·day−1.[3] Clinical LEA in females is having less than 30 kcal·kg−1 fat-free mass·day−1.[3] Once EA is less than 45 kcal·kg−1 fat-free mass·day−1 negative physiological consequences may occur[3], and when EA is less than 30 kilocalories per kilogram of fat free mass a day, this is when many systems of the body could be negatively affected.[3] The physiological consequences that occur from being in a LEA state is known as relative energy deficiency in sport (RED-S) which impacts the endocrine system, cardiovascular system, menstrual function, hematological function, bone health, metabolism, growth and development, gastrointestinal, immunological, and psychological.[3]

Compared to the general public, athletes have higher energy demands from exercise and may possibly engage in body manipulation for their sport, which could increase their risk of LEA leading to RED-S.[4] In addition, RED-S negatively impacts sporting performance, injury risk, training response, muscular strength, and endurance performance.[3] Endurance and female athletes may be at a greater risk of LEA compared to strength and male athletes.[4] This could be related to social influences on body weight.[4] Furthermore, athletes who have LEA are at an increased risk for MD and RED-S symptoms when compared to athletes with adequate EA.[14]

However, assessing EA by evaluating exercise energy expenditure and energy intake has limitations. Currently, there is no definitive protocol that is used to assess EA; therefore, reliability and validity may be questionable in some of the protocols used in studies.[3] To assess energy intake, self-reported surveys are used as an easy way to gain information.[3] However, human error is always a concern when using self-reported measurements. Assessing exercise energy expenditure can also be difficult to measure due to the differentiation in training and competition status of an athlete.[3] Tools such as fitness watches or heart rate monitors are not always accurate nor reliable, so using these tools should be taken with caution when reliability and validity is taken into consideration.

One tool that is used to assess risk of LEA is the Low Energy Availability in Females Questionnaire (LEAF-Q). This questionnaire has a sensitivity score of 78% and a specificity score of 90%, indicating accuracy of determining current EA, reproductive function, and/or bone health.[11] The LEAF-Q is broken up into different sections evaluating different physiological functions (gastrointestinal (GI), menstrual, and injury) in female athletes related to LEA symptoms. The first section of the questionnaire asks for demographic information (name, height, weight, age, current smoker, medications, average training, education, profession, mailing address, email address, and cell phone number).[11] The injury subsection section asks questions regarding injuries (number of days absent from training due to injury, type of injuries).[11] The gastrointestinal subsection assesses gaseous/bloating/cramping/stomach aches not related to menstruation, frequency of bowel movements, description of stool).[11] The menstrual function subsection assesses contraceptive use (use of oral and/or any other hormonal contraceptive, age of first period, first period come naturally, normal menstruation, periods ever stop for three or greater months consecutively not related to pregnancy, menstruation changes when there is a change in exercise frequency/duration/intensity).[11] When scoring the LEAF-Q, for each question response there is a score that ranges from 0 to 4 points.[11] After scoring each question with the help of the key, the combined total will indicate LEA risk.[11] A score of 8 or more indicates risk of LEA and a score less than 8 indicates low risk for LEA.[11] In addition, each section of the LEAF-Q (injuries, gastrointestinal, menstruation) are also individually scored to evaluate dysfunction in each section.[11] A score of 2 or higher in both the injury and gastrointestinal sections indicates dysfunction in their respective categories.[11] Therefore, a score of less than 2 would indicate a low risk for injuries and/or gastrointestinal dysfunction.[11] A score of 4 or higher in the menstruation section indicates MD.[11] Thus, a score of less than 4 would indicate normal menstruation.[11] There are some limitations when using the LEAF-Q. Any self-reported survey comes with the risk of human error and misreporting or not accurately reporting information.[11] The LEAF-Q cannot differentiate the difference between pathological eating behavior versus normal eating behavior.[11] This would include the questionnaire not being to determine if the LEA is due to DE/ED behaviors, or a lack of knowledge regarding fueling. Lastly, women with conditions that affect menstruation like PCOS, may need further evaluation when assessing EA.[11]

Current literature using the LEAF-Q in endurance athletes have found an increased risk of LEA. In a study examining elite male and female cross-country runners and their risk of LEA using the LEAF-Q, 79.5% of females, 54% of males, and 64.3% of both male and female athletes were at risk of LEA.[15] Another study revealed that 55.8% of female elite aesthetic athletes and 35.1% female recreational aesthetic athletes were at risk for LEA after taking the LEAF-Q.[16] In addition, 55% of elite and pre-elite athletes from a variety of sports who took the LEAF-Q were at risk of LEA.[17] Moreover, 80% displayed at least one symptom related to RED-S.[17] Lastly, a study looking at LEA risk in endurance female athletes had an LEA risk of 65%.[18]

Menstrual Dysfunction

Arguably the most objective component that suggests an athlete has RED-S is menstrual dysfunction (MD).[3] One way to evaluate MD is using the LEAF-Q.[11] MD is defined as a score $\geq$ 4 on the menstruation section of the LEAF-Q.[11] Scores that are < 4 indicate normal menstruation.[11] When MD is left untreated, it can impact bone health, increasing the risk for stress fractures or osteoporosis because estrogen and luteinizing hormone levels decrease, thus increasing the loss of bone.[4,8] Jesus et al. found that 41.3% of female elite cross country runners reported MD.[15] In addition, 52.2% of these athletes also experienced some type of injury.[15] A study examining Female Athlete Triad risk factors suggested that 45.9% of high school runners reported MD.[9] Similarly, another study by Folscher et al., reported that 44.1% of female ultra-runners competing in the Comrades Marathon were at risk for the Female Athlete Triad.[19] Furthermore, 48.8% of these athletes perceived amenorrhea to be normal with training.[19] In another study, Meng et al. looked at LEA risk and its contributing consequences in recreational and elite female athletes in aesthetic sports.[16] They found that more than half of their elite female athlete participants experienced MD when engaging in high intensity training long term.[16] Additionally, when compared to a control group, 61.5% of the elite female endurance runners experienced amenorrhea, whereas the control group all had eumenorrhea.[20] Moreover, of the elite athletes who did have amenorrhea, 100% of them were at a high risk of LEA.[20]

Disordered Eating

One method that is used to evaluate disordered eating risk is known as the Disordered Eating and Screen for Athletes (DESA-6). This tool was validated and has a sensitivity of 92% and a specificity of 85.96%.[21] Questions that are included in this survey consist of weight loss and/or gain goals, weight satisfaction, weight and performance, food restriction, injuries, and weight loss comments from anyone other than a healthcare professional.[21] After the completion of the DESA-6, each question is scored separately with points ranging from 0 to 2.[21] Once each question is scored, the total will indicate either a risk or low risk for disordered eating.[21] A score of 3 or more indicates DE risk, whereas a score less than 3 indicates low DE risk.[21] Like the LEAF-Q, the DESA-6 also has limitations. Since the DESA-6 is also a self-reported survey, human error of misrepresentation of oneself or inaccurate reporting could occur.[21] In addition to self-reported surveys, athletes could have a response bias if they feel their coaches or trainers are going to receive this information after taking the survey.[21] The DESA-6 cannot diagnose an ED, and since there is no universal definition and diagnostic criteria for DE, validity may be questioned.[21] Lastly, initial validation of the DESA-6 results could only be applied to the geographical location and type of athletes that were used to evaluate the DESA-6.[21]

DE and ED are one of the many components that make up the RED-S model.[3] More specifically, DE and ED are a negative psychological consequence of RED-S; therefore they may play a role in the development or advancement in LEA.[3] In addition, an athlete with LEA who has an ED/DE, athletic performance could decrease due to a decrease in fat and lean body mass, electrolyte abnormalities, and dehydration.[22] While DE and/or ED can contribute to LEA as part of the RED-S model, an athlete can have LEA in the absence of DE/ED.[7] Athletes who compete in weight class, aesthetic, or gravitational sports are considered to be at high risk for developing ED/DE.[6] In a study that examined ED prevalence and DE patterns, 20% of endurance athletes reported risk for ED or DE using the Eating Disorder Inventory Questionnaire and the Eating Disorder Examination Questionnaire; whereas non-athletes had a 9% prevalence of ED or DE.[7] In addition, another study that looked at DE behavior using the Eating Disorder Examination Questionnaire, found that 21.3% of female endurance athletes had DE.[18] These results could be due to a heightened emphasis on body composition and manipulation for aesthetic or competitive reasons. In a study using the Mental Health Inventory, athletes with diagnosed EDs were shown to have significantly lower self-esteem and greater body dissatisfaction, possibly continuing the cycle of DE.[13] This study demonstrates a possible relationship regarding body satisfaction and ED risk. In addition, in another study that looked at ED and weight satisfaction in elite female runners, there was an association between reported ED and weight dissatisfaction ($p < .002$).[23] With that being said, with greater body dissatisfaction it could lead an athlete to potentially develop an ED or DE habits. When comparing DE/ED's prevalence in females and males, females range from 6-45% prevalence and males range from 0-19%.[6] An environment that emphasizes body weight (losing or gaining weight) may put athletes at a greater risk for ED/DE habits.[6] Personality and athletic environment are two main factors that can impact risk of ED/DE development in an athlete.[6]

Training Methods/Volume

Training volume throughout the life of an athlete is always changing related to the stage of training they are in (pre/post season or current season). As these fluctuations in the intensity and duration of training occur, the hormones related to satiety and hunger are affected, such as ghrelin, peptide YY & glucagon-like peptide 1.[12] Alterations in these hormones could lead athletes to be at a greater risk of developing LEA complications. Athletes who engage in a higher training volume that also have a lack of hunger cues, may have a decrease in overall caloric consumption throughout the day and are at a greater risk for inadequate intake.[12] In addition, these athletes could have an increased risk of health consequences related to their inadequate intake that could lead them to have LEA.[12] Therefore, a low energy dense diet (food that does not contain a lot of calories- high fiber, high water content) combined with a high training volume would put an athlete at a greater risk of LEA because they are not consuming enough calories to match their activity level.

Conclusion

LEA has recently been highlighted in research by affecting athletes, more specifically aesthetic athletes compared to non-athletes and strength athletes.[4] DE and ED's can increase an athlete's risk of LEA, which increases the risk of RED-S. In addition, female endurance athletes are at a greater risk for DE and ED.[6,7] Current literature primarily focuses on the population of elite athletes when looking at LEA and DE/ED.[15,17, 18, 20] Female recreational runners are at risk for LEA which could lead to RED-S, which necessitates more research in this population to promote preventive measures and make more resources available to them.

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CHAPTER III

JOURNAL ARTICLE

Risk of Low Energy Availability, Disordered Eating, and Menstrual Dysfunction in Female Recreational Runners

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Abstract

Running is characterized by high physiological demands with an emphasis on weight, which may lead to a greater risk of developing low energy availability (LEA) and/or disordered eating (DE). Recreational runners are a population that is often overlooked due to a lack of resources readily available to them. **Purpose:** This study investigated (1) the prevalence of menstrual dysfunction, risk of DE and LEA and (2) compare the risk of DE, training volume, and weight dissatisfaction between female recreational runners at risk for LEA versus not at risk for LEA. **Methods:** Female recreational runners (n= 1,923) completed an online questionnaire that included the Low Energy Availability in Females Questionnaire (LEAF-Q) to evaluate LEA risk, and the Disordered Eating Screening Assessment (DESA-6) to evaluate DE risk. **Results:** 53.04% of participants are at risk for LEA from a score of $\geq$ 8 on the LEAF-Q, 42.5% are at risk for DE from a score of $\geq$3 on the DESA-6, and 61.7% reported menstrual dysfunction. **Conclusion:** Female recreational runners have a high risk for LEA and DE and may not receive the needed treatment due to a lack of resources. This reinforces the need for further education and preventative measures around LEA, MD, and DE amongst recreational female runners.

Introduction

Low energy availability (LEA) refers to a lack of energy available to support optimal health and physiological functions (e.g. bone remodeling, menstruation, muscle repair and growth) caused by inadequate energy intake and/or increased exercise energy expenditure (EEE) (Nattiv et al., 2007). Although difficult to measure precisely, laboratory-based studies in active females have suggested that LEA is defined as <30 kcal-kg FFM-1 day, and that a minimum energy availability (EA) of 45 kcal kg FFM-1 day is necessary for optimal health (Loucks et al., 2004). LEA has negative physiological consequences on menstrual health, bone mineral density, metabolism, mental health, (Nattiv et al., 2007; Mountjoy et al., 2018) and performance and is referred to as Relative Energy Deficiency in Sports (RED-S) which symptoms expand on the Female Athlete Triad (Mountjoy et al., 2018). LEA is a concern for both male and female athletes due to a greater energy expenditure from exercise, pressure to perform their best, and social influences on body weight (Wasserfurth et al., 2020). Therefore, identifying LEA in athletes is essential for ensuring healthy and optimal menstrual function, bone mineral density, metabolism, mental health, and performance.

Athletes competing in sports with an emphasis on leanness or low body weight have been suggested to be at a greater risk for developing LEA and/or disordered eating (DE) due to their perceived notion of leanness equating to optimal performance (Nattiv et al., 2007; Hagmar et al., 2008). Female athletes, especially at the sub-elite and elite levels, are estimated to have a higher prevalence of DE/eating disorders (ED), in comparison to male athletes (Wells et al., 2020). DE/ED risk is increased when psychological risk factors such as body dissatisfaction are present which could result in athletes restricting calories to achieve a desired body goal, thus increasing their risk for LEA (Wells et al., 2020). However, LEA does not always include DE patterns, but when it does it puts an athlete at a greater risk for developing physical and mental consequences (Wasserfurth et al., 2020).

Previous research suggests females participating in endurance sports such as long-distance running have a higher incidence of menstrual dysfunction (MD) than females in non-endurance sports and non-athletes (Sundgot-Borgen & Torstviet 2004). MD is another repercussion caused by LEA (Nattiv et al., 2007; Mountjoy et al., 2018). When left untreated, MD can impact bone health increasing the risk for stress fractures (Papageorgiou et al., 2018). A recent study found that 76% of high school runners reported DE or ED, while 45.9% reported MD (Skorseth et al., 2020). Similarly, Heikura et al. (2018) examined metabolic and reproductive hormonal function, and injury and illness rate in distance athletes and found that 40% of females were amenorrheic and had a greater incidence of bone injuries compared to eumenorrheic females. The LEAF-Q may be used to assess menstrual function in female athletes, due to its admissible specificity and sensitivity score in evaluating reproductive health (Melin et al., 2014).

Training volume throughout the life of an athlete is dynamic, depending on training stage (in a training cycle vs not in a training cycle) (Howe et al., 2014). As fluctuations in the intensity and duration of training occur, the hormones related to satiety and hunger are affected (Howe et al., 2014). Howe et al. (2014) concluded when the training volume and intensity are elevated, there is an increase in appetite suppressing hormones. Thus, increasing the risk of LEA and complications, due to the lack of hunger cues and decrease in overall caloric consumption.

Various training styles, weight dissatisfaction, and presence of DE can affect EA, an issue that has been highlighted in recent research, especially in female athletes (Howe et al., 2014; Hulley & Hill 2001; Wells et al., 2020). These health concerns in conjunction with the heightened probability of MD among female runners necessitates the exploration and analysis of variables that may influence or predict menstrual patterns in this population. Furthermore, studies examining MD, weight dissatisfaction, risk of DE and LEA, and training volume are still lacking, especially in female recreational runners, who may often be overlooked. Thus, the purpose of this study is to investigate (1) the prevalence of MD, risk of DE and LEA, and (2) compare the risk of DE, training volume, and weight dissatisfaction between female recreational runners at risk for LEA versus not at risk for LEA.

Methods

Subjects

Female recreational runners (running a minimum of 21 miles per week), between the age of 18 through 40 years-old of any ethnicities were recruited for this study. Participants were recruited by virtual flyers posted on Instagram. Runners who wish to participate in the study was sent via email or direct message the link to the survey. The first 200 participants to complete the survey received a $20 Amazon gift card. This study was granted approval by the Human Subjects Review Committee at Central Washington University.

Design

A cross-sectional study was conducted where participants completed a 45-question survey using the Qualtrics system. Questions included: self-reported age, height and weight, type of runner (collegiate vs recreational), exercise duration and mileage per week (≤ 30 miles a week, 31-60 miles a week, ≥ 61 miles a week), other types of exercise (bicycling/spinning, weightlifting, swimming, Pilates, cross-fit, cross-country skiing, running), occurrence of stress fractures, weight control methods, weight dissatisfaction, self-reported diagnosis of ED/DE, menstrual function, contraceptive use, and gastrointestinal function. Questions from the LEAF-Q were embedded into the survey (Melin et al., 2014). Participants who score ≥ 8 are considered at risk for LEA while participants scoring < 8 are considered low risk. Additionally, a score of ≥ 4 on the menstrual subsection, ≥ 2 on the GI and injury subsections of the LEAF-Q indicates risk for MD, GI disturbances, and injury. We chose to use the LEAF-Q because it has a sensitivity score of 78% and a specificity score of 90%, indicating accuracy of determining current EA, reproductive function, and/or bone health (Melin et al., 2014). DE behaviors will be assessed using the DESA-6, which was also embedded in the survey. Participants who score ≥ 3 are considered at risk for DE while participants scoring < 3 are considered low risk (Kennedy et al., 2021). This DESA-6 is a validated tool that has a sensitivity of 92% and a specificity of 85.96% (Kennedy et al., 2021).

Procedures

Female runners who choose to participate were sent the Qualtrics survey link. Before consenting to take the survey, participants were informed the purpose of the study, eligibility requirements, estimated duration of survey length, anonymity and confidentiality, potential risks, and directions on how to receive their $20 Amazon gift card if they were one of the first 200 respondents. After reading the overview of the survey, participants can choose to proceed with the rest of the survey or exit out of their internet browser. After the completion of the survey, participants who chose not to accept the Amazon gift card were directed to the end of the survey. Participants who chose to be entered for the Amazon gift card, were redirected to another survey asking for their first and last name and email address for receiving the gift card. Email addresses cannot be traced back to any original survey responses.

Statistical Analysis

Results from the Qualtrics survey were analyzed using Microsoft Excel and SPSS Statistical Package for the Social Sciences (SPSS, Version 28.0, Armonk, NY: IBM Corp). Descriptive characteristics of the participants were calculated as a mean $\pm$ standard deviations (SD) for age, height, weight, and BMI. Chi-square tests were used to analyze nominal data, including risk of DE with weight dissatisfaction, and risk of LEA with training volume and questions on the DESA-6. Independent t-tests were used to analyze differences in descriptive characteristics, DE, MD, occurrence of injuries, GI disturbances, and weight dissatisfaction between runners at risk for LEA and those not at risk. Mode was calculated for the most frequently reported mileage range. $P \leq 0.05$ was considered statistically significant.

Results

Participant Characteristics

Recreational female runners (*n* =1,923) met the qualifications of running a minimum of 21 miles per week, between ages 18 and 40 years, and completed the Qualtrics survey adequately. Runners most frequently reported weekly mileage range was 31 to 60 miles per week. Participant self-reported descriptive characteristics are displayed in Table 1.

Table 1. Participant descriptive characteristics between runners at risk vs. not at risk for LEA

	Sample population (*n* = 1923)	**Not at risk for LEA (*n* = 903)**	**At risk for LEA (*n* = 1020)**	***p*-value***
Age (years)	29.67 (4.95)	30.27 (4.82)	29.14 (5.01)	*< .001**
Height (cm)	166.40 (9.67)	165.93 (8.75)	166.24 (11.24)	*< .05**
Weight (kg)	61.95 (9.37)	60.97 (8.78)	62.83 (9.79)	*< .001**
BMI	22.54 (4.07)	22.33 (4.04)	22.72 (4.10)	*< .05**

*Data are mean (+ SD); LEAF-Q, Low Energy Availability in Female Questionnaire; LEAF-Q ≥ 8 indicates risk of LEA, LEAF-Q < 8 indicates not at risk; cm, centimeters; kg, kilograms; BMI, Body Mass Index. * indicates differences between athletes at risk vs. not at risk for LEA.*

Risk of Low Energy Availability

Based on a score ≥ 8 on the LEAF-Q, 53.04% (*n* = 1,020) of participants were at risk of LEA. Additionally, 61.7% (*n* = 1,187) of participants reported MD. Female runners at risk for LEA had significantly higher MD scores than athletes not at risk for LEA ($p < .001$, respectively). The use of hormonal contraceptives was reported in 19.6% (*n* = 377) of runners surveyed. More than half of female runners (63.02%, *n* = 1,212) reported changes in menstruation as exercise intensity, duration, or frequency was increased. Over three-quarters (77.1%, *n* = 1,482) of runners had less than twelve periods per year. The thought that the absence of a menstrual cycle was a normal part of training, common in female runners, and/or not harmful was prevalent in 38.8% (*n* = 747) of recreational runners. Table 2 displays mean LEAF-Q and subsection scores (GI, menstrual, injury) between those at risk and not at risk of LEA.

Table 2. Mean LEAF-Q and subsection scores (GI, menstrual, injury) for athletes at risk and not at risk of LEA

	Sample population (*n* = 1923)	**At risk for LEA (*n* = 1020)**	**Not at risk for LEA (*n* = 903)**	***p*-value***
Total LEAF-Q (≥8)	9.06 (5.73)	13.39 (4.24)	4.16 (2.07)	*< .001**
Menstrual function (≥4)	5.27 (3.77)	7.80 (3.29)	2.42 (1.64)	*< .001**
Injury (≥2)	0.70 (1.53)	1.18 (1.84)	0.15 (0.78)	*< .001**
GI (≥2)	3.09 (2.37)	4.41 (2.28)	1.59 (1.38)	*< .001**
DESA-6 (≥3)	2.38 (2.0)	3.12 (2.09)	1.55 (1.64)	*< .001**

*Data are mean (± SD); LEAF-Q, Low Energy Availability in Female Questionnaire score ≥ 8 indicates risk of LEA; DESA-6, Disordered Eating and Screening in Athletes score ≥ 3 indicates risk of DE. * indicates differences between athletes at risk vs. not at risk for LEA.*

Relationship Between Mileage and LEAF-Q Scores

Risk of LEA was compared between three groups of women based on weekly running mileage (low mileage: ≤ 30 miles a week (*n* = 594), medium mileage: 31-60 miles a week (*n* = 1228), high mileage: ≥ 61 miles a week (*n* = 101)) to examine risk of LEA in regard to weekly training volume. Athletes at risk for LEA were more likely to report higher weekly running volume ($X^2_{2, 1923} = 6.44$, $p<.05$). The most frequently reported weekly mileage range for both athletes at risk and not at risk for LEA was 31 to 60 miles per week.

Risk of Low Energy Availability with Disordered Eating and Weight Dissatisfaction

Based on a score ≥ 3 on the DESA-6 questionnaire, 42.5% (*n* = 817) of the participants were at risk of DE. Female runners who were at risk for LEA had significantly higher DESA-6 and weight dissatisfaction scores than athletes not at risk for LEA ($p < .001$, respectively). Athletes at risk for LEA were more likely to be dissatisfied with their weight ($X^2_{3, 1923} = 124.40$, $p < .001$) (Table 3). Athletes at risk for DE were more likely to be dissatisfied with their weight ($X^2_{3, 1923} =$ 485.37, $p < .001$) (Table 3).

Table 3. Prevalence of weight dissatisfaction and responses to DESA-6 responses between athletes at risk vs. not at risk for LEA

	Sample Population (*n* = 1923)	**At risk for LEA (*n* = 1020)**	**Not at risk for LEA (*n* = 903)**	**Chi-Square Test *p***
Weight dissatisfaction	1390 (72.3%)	832 (59.9%)	558 (40.1%)	*< .001**
≥ 3 injuries during past season	357 (18.6%)	319 (89.4%)	38 (10.6%)	*< .001**
Worry about weight gain during off season	1650 (85.8%)	928 (56.2%)	722 (43.8%)	*< .001**
Lose ≥ 15 lbs to be at best performance weight	183 (9.5%)	137 (74.9%)	46 (25.1%)	*< .001**
Following diet to achieve best performance weight	871 (45.3%)	527 (60.5%)	344 (39.5%)	*< .001**
Told to lose weight by someone other than health professional	473 (24.6%)	342 (72.3%)	131 (27.7%)	*< .001**

Data are n (%); LEA, Low Energy Availability; DESA-6, Disordered Eating and Screening

*Assessment in Athletes. *p values indicate differences between at risk vs. not at risk for LEA.*

Discussion

This study investigated the prevalence of MD, risk of DE and LEA, and the relationship between risk of LEA with DE, training volume, and weight dissatisfaction in female recreational runners. Our study suggested that over half of female recreational runners that participated in this study were at risk for LEA and reported MD. Furthermore, athletes at risk for LEA were more likely to be at risk for DE, MD, report a higher weekly running volume, and greater weight dissatisfaction.

The current study found that 53.0% of recreational runners were at risk for LEA based on LEAF-Q scores. Other research using the LEAF-Q has suggested that the prevalence of LEA risk in female endurance athletes is between 35.1 – 79.5% (Folscher et al., 2015; Meng et al., 2020; Jesus et al., 2021; Rogers et al., 2021; Fahrenholtz et al., 2022). However, some of these studies examined pre-elite/elite (Folscher et al., 2015; Meng et al., 2020; Jesus et al., 2021; Rogers et al., 2021; Fahrenholtz et al., 2022) versus recreational athletes (Black et al., 2018; Meng et al., 2020; Dervish et al., 2022). Our results suggested that over half of the recreational runners surveyed were at risk for LEA, which is higher than 35.1% (n=40) of recreational aesthetic sport athletes reported by (Meng et al., 2020). However, Black et al. (2018) found a higher prevalence of LEA risk of 63.2% (n=24) in female recreationally active individuals than our study. Discrepancies in prevalence of risk among studies may be due to differences in sample size and/or populations examined, due to the lack of research on recreational female runners specifically. When LEA is left untreated, physiological consequences which impacts the endocrine system, cardiovascular system, menstrual function, hematological function, bone health, metabolism, growth and development, gastrointestinal, immunological, and psychological is referred to as relative energy deficiency in sport (RED-S) (Mountjoy et al., 2018). RED-S can negatively impact performance by an increase in injury risk, decreased training response, decreased muscular strength, and decreased endurance performance (Mountjoy et al., 2018). Furthermore, female athletes with LEA are at an increased risk for MD in comparison to athletes not at risk for LEA (Ackerman et al., 2019).

The LEAF-Q was also used to evaluate MD, injury risk, and GI disturbances in the current study. In another study, 61.7% of recreational runners reported MD which is higher than other studies examining recreational athletes (43.9%) and is between studies examining elite athletes (37%-71.1%) (Heikura et al., 2018; Meng et al., 2020; Jesus et al., 2021). Heikura et al. (2018), found 37% of elite female distance athletes (n=13) reported MD using the LEAF-Q, which is lower than our findings in recreational runners. Fahrenholtz et al. (2022) found that 29% (n=58) of elite endurance athletes reported using hormonal contraceptives, which is comparable to our study of 19.6% of recreational runners. The difference in prevalence of MD could be from a high response of athletes reporting changes in menstruation as exercise intensity, duration, or frequency is increased. Additionally, more than three quarters of athletes had less than twelve periods per year. Therefore, a high score for these questions could have increased MD scores on the LEAF-Q, resulting in a higher MD prevalence overall, when compared to other studies. 38.8% of recreational runners thought the absence of a menstrual cycle was a normal part of training, common in female runners, and/or not harmful. Thus, the lack of knowledge about menstruation and high prevalence of MD demonstrates the need for further education about MD in recreational female runners. Arguably MD is the most objective condition that suggests a female athlete has RED-S (Mountjoy et al., 2018). When MD is left untreated, estrogen and luteinizing hormone levels decrease, thereby increasing the loss of bone and risk for stress fractures or osteoporosis (Papageorgiou et al., 2018; Wasserfurth et al., 2020).

Using the LEAF-Q to evaluate injury prevalence, 18.6% of female athletes reported some form of injury. Furthermore, 89.4% of runners at risk for LEA reported three or more injuries during their past season. Meng et al. (2020) reported an injury prevalence of 23.7% in recreational and 30.8% in elite aesthetic athletes when using the LEAF-Q. Additionally, elite female athletes who were at risk of LEA had a higher prevalence of injuries compared to individuals not at risk for LEA after using the LEAF-Q (Meng et al., 2020). Another study using the LEAF-Q had reported a higher injury prevalence in female elite runners at 55.6% (Jesus et al., 2021). Additionally, those who reported having a stress fracture as their injury were also at risk for LEA (n = 6 females, n = 4 males) (Jesus et al., 2021). When examining GI function using the LEAF-Q, 69.9% of athletes in the current study reported GI disturbances. Similarly, Meng et al. (2020) reported GI disturbances in 59.6% of recreational aesthetic sport athletes while Jesus et al. (2021) reported a prevalence of 74.7% in aesthetic sport athletes. Furthermore, female runners at risk for LEA had higher GI scores on the LEAF-Q when compared to those not at risk for LEA (4.41 (2.28) vs 1.59 (1.38), $p < .001$). Fahrenholtz et al. (2022) found that elite athletes who reported more food intolerances had a higher total LEAF-Q score due to their GI score, but the authors speculate as to whether the GI issues were related to food intolerances or were a consequence of LEA.

DE and ED are a negative psychological consequence of RED-S; therefore, they may play a role in the development or advancement in LEA (Mountjoy et al., 2018). To our knowledge, our study is the first to use the Disordered Eating and Screening Assessment (DESA-6) to evaluate DE in recreational runners (Kennedy et al., 2021). We chose to use the DESA-6 over other questionnaires due to its high sensitivity (92%) and specificity (85.96%) (Kennedy et al., 2021). The DE risk prevalence in the current study of 42.5% is comparable to the reported DE/ED prevalence in female athletes in the literature (6-45%, respectively) (Wells et al., 2020). Another study examining DE in elite athletes using the Eating Disorder Examination Questionnaire (EDE-Q), found a DE risk prevalence of 21.3% (Fahrenholtz et al., 2022). Furthermore, Berg et al. (2022) found that 32% of elite female runners who competed at the US Olympic Trials self-reported a past or current ED diagnosis. Lastly, using the female athlete screen tool (FAST), Dervish et al. (2022) found that 41% of female recreational runners were at risk for DE and 8% were at risk for ED. Athletes who compete in weight class, aesthetic, or gravitational sports are considered to be at a high risk for developing ED/DE (Wells et al., 2020). Therefore, weight-focused/aesthetic athletes who have DE or an ED may be at an increased risk for LEA.

While DE and/or ED can contribute to LEA as part of the RED-S model, an athlete can have LEA in the absence of DE/ED due to lack of knowledge around fueling needs or increased exercise energy expenditure (Sundgot-Borgen & Torstveit, 2004; Fahrenholtz et al., 2022). However, DE/ED can be a common cause of LEA in athletes (Wells et al., 2020). In the current study, athletes who were at risk for LEA had significantly higher DESA-6 scores when compared to athletes who were not at risk for LEA. Furthermore, based off questions from the DESA-6, runners at risk for LEA were more likely to report three or more injuries during the past season (89.4%), worried about weight gain during off season (56.2%), believed they needed to lose fifteen or more pounds to be at their best performance weight (74.9%), followed a diet to achieve their best performance weight (60.5%), and were told to lose weight by someone other than a health professional (72.3%). Similarly, endurance athletes at risk for LEA had a higher risk for DE when using the EDE-Q (Fahrenholtz et al., 2022). Furthermore, Dervish et al (2022) found a positive correlation between DE/ED risk using the FAST and LEA risk using the LEAF-Q in female endurance runners. Therefore, the use of screening tools such as the DESA-6 may be a useful tool for assessing not only risk for DE, but potentially identifying athletes at risk for LEA. Thereafter, the need for a referral to a registered dietitian-nutritionist (RDN) and other medical professionals is warranted after an athlete is considered to be at risk for LEA and/or DE.

An environment that emphasizes body weight (losing or gaining weight) may put athletes at a greater risk for ED/DE habits (Wells et al., 2020). We found that female runners who were either at risk for DE or at risk for LEA had significantly higher weight dissatisfaction scores. Another study examining elite female runners, found that athletes with a self-reported history of an eating disorder had a higher prevalence of weight dissatisfaction (62.5%) (Berg et al., 2022). Similarly, Hulley and Hill (2001) found that elite female runners who had a diagnosed ED demonstrated significantly greater body dissatisfaction than athletes with no ED. Another study examining female soccer players found higher body dissatisfaction using the Eating

Disorder Inventory 2 (EDI-2) in athletes with lower measured EA compared to athletes with adequate EA (Reed et al., 2013). Endurance female athletes especially, may be at a greater risk for LEA due to social influences on body weight (Wasserfurth et al., 2020). With that being said, greater body dissatisfaction could lead an athlete to potentially develop an ED or DE habits which could lead to LEA.

Training volume is constantly changing for athletes depending on the phase of training. Fluctuations in training intensity and duration can amount to changes in hormones related to satiety and hunger, such as ghrelin, peptide YY & glucagon-like peptide 1 (Howe et al., 2014). Alterations in hunger and satiety hormones that decrease appetite could lead athletes to be at a greater risk for developing LEA. For example, one study found a decrease in EA from pre-season to mid and post-season (Reed et al., 2013). In the current study, female athletes at risk for LEA reported running more miles weekly compared to female runners not at risk in the current study. Our results are comparable to findings of Heikura et al. (2018) with those at risk of LEA reporting higher running volume when compared to those not at risk (115 km vs 84 km, respectively). Meng et al. (2020) found elite female athletes who were at risk for LEA exercised longer than those not at risk (37.5 hours and 33 hours, respectively), while another study in elite/pre-elite athletes found the same trend with those at risk for LEA (17.2 hours) versus those not at risk (14.8 hours) (Rogers et al., 2021). Thus, athletes who engage in a higher training volume that may also have a lack of hunger cues, which could lead to a decrease in overall energy consumption throughout the day and increase the risk for LEA (Howe et al., 2014).

The present study was conducted using an online questionnaire, so data was based on self-reported information from our participants. When using self-reported data there is always the possibility of inaccurate information or response bias. EA is difficult to measure precisely, and research suggests that using qualitative screening tools (LEAF-Q and DESA-6) may provide an accurate means for assessing risk of LEA and DE compared to using diet records (Heikura et al., 2018). However, the LEAF-Q could provide a false positive for LEA that may be related injuries, GI issues (i.e. irritable bowel syndrome), or for MD that is not attributed to LEA given that it does not ask about MD related to certain conditions or medications (i.e. pregnancy, polycystic ovary syndrome, hormone imbalances) (Rogers et al., 2021). Furthermore, oral contraceptive use may mask MD in an athlete with LEA (Fahrenholtz et al., 2022). In addition, the DESA-6 is a new tool that warrants more research to be completed in athletes. Another limitation was not including more demographic questions in our survey. With the large response rate, we could have examined differences between race, ethnicity, geographical region, and/or level of education. By evaluating this information, results could be better applied to specific demographic characteristics.

Conclusion

In conclusion, the current study suggests that recreational runners are at an increased risk for LEA and DE. Furthermore, DE, MD, training volume, and weight dissatisfaction may increase the risk for LEA in recreational runners. However, LEA may be overlooked in recreational athletes, and they may not receive the necessary treatment for LEA due to a lack of available resources. Our results reinforce the need for further education and preventative measures around LEA, MD, and DE amongst recreational female runners. Therefore, the need to screen female runners for LEA is essential to not only the athlete's performance, but their physical and mental well-being as well. The LEAF-Q and DESA-6, although acknowledging some limitations of these surveys, may serve as a practical assessment tool for practitioners to assess risk of LEA in runners. Furthermore, educational handouts addressing the red flags and consequences of LEA would be a valuable resource for obstetrics and gynecology (OBGYN) and primary care offices. Physicians then should refer outwards to a RDN if LEAF-Q and/or DESA-6 scores indicate risk for LEA or DE. Future research examining the effects of educational tools that address health related consequences of LEA in recreational runners is essential, due to the high prevalence in the current study. Additionally, more research is needed to examine factors such as DE, training volume, and weight dissatisfaction that may increase the risk of LEA when using other methods of assessment (i.e. calculated EA, blood biomarkers related to LEA) among female recreational runners.

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