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

Leah Louise Dambacher
leah.dambacher@cwu.edu

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

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Leah Louise Dambacher

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We hereby approve the thesis of

Leah Louise Dambacher

Candidate for the degree of Master of Science

APPROVED FOR THE GRADUATE FACULTY

______________ ______________________________
Dr. Kelly Pritchett, Committee Chair

______________ ______________________________
Dr. Robert Pritchett

______________ ______________________________
Dr. Abigail Larson

______________ ______________________________
Dean of Graduate Studies

ABSTRACT

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

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Collegiate female distance runners may be at risk for low energy availability (LEA) due to increased exercise energy expenditure with or without decreased energy intake. Furthermore, this population has increased risk of disordered eating (DE), which can lead to LEA and negative health consequences, such as menstrual dysfunction (MD). The purpose of this study was to: 1) investigate risk of LEA and DE and 2) compare DE, training volume, and weight dissatisfaction among female collegiate runners at risk vs not at risk for LEA. Female runners (n = 287) who competed on an NCAA Division I, II, or III cross-country and/or track team completed an online questionnaire (45 questions). The questionnaire included the Low Energy Availability in Females Questionnaire (LEAF-Q) which examines incidence of stress fractures, occurrence and frequency of menstrual cycles within the previous 12 months, contraceptive use, and gastrointestinal function. The Disordered Eating Screening Assessment (DESA-6) was used to examine risk of DE and weight dissatisfaction. 54.5% (n = 156) of runners were at risk for LEA (score $\geq$ 8 on LEAF-Q), and 40.8% (n = 117) were at risk for DE (DESA-6 score $\geq$ 3), and 56.5% (n = 162) reported MD (LEAF-Q subsection MD score $\geq$ 4). Athletes “at risk” for LEA had significantly higher DESA-6 scores than athletes “not at risk” for LEA ($p < 0.001$). Athletes “at risk” for LEA had significantly greater weight dissatisfaction than those not at risk for LEA ($X^2_{3, 156} = 15.92$, $p = 0.001$). Higher weekly training volumes was not associated with risk for LEA ($X^2_{2, 156} = 4.20$, $p = 0.112$). Consistent with previous literature, a substantial percentage of collegiate female runners were found to be at risk for LEA, DE, and report MD. These findings demonstrate that risk for DE, MD, and weight dissatisfaction are associated with risk for LEA.

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CHAPTER I

INTRODUCTION

Endurance athletes, such as distance runners, have a high risk for disordered eating (DE) habits and low energy availability (LEA), thus leading to health and performance complications exacerbated by insufficient energy intake.[1] LEA has been shown to have negative health and performance consequences for endurance athletes.[2,3] Chronic energy restriction and increased exercise energy expenditure result in impaired energy availability (EA). EA is the energy left over to support normal health and physiological function (e.g. regular menses, endocrine production, bone remodeling, etc.) after energy expenditure from exercise has been accounted for in relation to fat-free mass.[4,5] The LEA threshold in female athletes is defined as < 30 kcal/kg FFM/day^{-1}, with subclinical LEA typically defined as 30-45 kcal/kg^{-1} FFM/day.[4] Amongst collegiate-aged female athletes, there is a substantial risk for the negative effects of intentional or unintentional energy deficits.[6] Specifically, disordered behaviors can lead to LEA in these athletes.[7]

In competitive athletes, DE habits can persist due to the emphasis placed on body size or composition for perceived advantages in performance, and sociocultural pressure. Further, DE can progress to a diagnosable eating disorder (ED), with a multitude of health consequences relating to the potential for Relative Energy Deficiency in Sport (RED-S).[7] Female endurance athletes are known to have a higher rate of DE behaviors and higher risk for developing diagnosed ED than the general population and male endurance athletes.[8] In addition, endurance athletes are at a greater risk for DE due to the fact that leanness is often emphasized and idealized in sports such as distance running.[8] DE behaviors and restriction can stem from poor body image and the heightened risk for weight dissatisfaction in pursuit of an idealized body weight and composition.[9] While female elite endurance athletes have a higher incidence of DE compared to other athletes, college-aged runners may experience among the highest DE habits, even in the absence of a clinical ED diagnosis.[10] Although sometimes independent of one another, LEA often occurs in conjunction with DE/ED and each condition poses significant health risks among this population.[7]

Ackerman et al. found female athletes with LEA are more likely to exhibit the negative health consequences of RED-S, a syndrome of health and performance impairments, than those with adequate EA. Long-term LEA is characterized by metabolic adaptations and changes in physiological functions, important for several body systems.[2,4] As EA decreases, whether intentionally or unintentionally, female athletes can experience amenorrhea and osteoporosis as long-term consequences.[2,11] In a study examining risk of LEA among elite cross-country runners, 79.5% of females were considered high risk for LEA and 41.3% of female runners reported menstrual dysfunction (MD).[12] Similarly, Beermann et al. reported 41% of female collegiate cross-country runners to have clinical LEA as determined by two measures of EA.[6] Finally, Rogers et al. found 55% of female athletes to be at risk for LEA and 80% to demonstrate symptoms of RED-S, and a strong relationship between the two.[13] LEA, whether inadvertent or intentional, can result from the high energy demands consequent to substantial training loads.[9,10] Training behaviors that exceed energy intake can be the unintentional result of a high-volume training program, such as distance running at a collegiate level, or the unhealthy manipulation of exercise load as seen with DE behaviors.[10]

Recent research has highlighted health concerns associated with DE leading to deficient energy availability, and a host of significant health concerns such as MD in female athletes. Training volume, weight periodization, and presence of DE can affect EA and menstrual function.[3,5] Understanding the risk of MD and the relationship between DE and LEA is crucial for health and performance outcomes, yet research examining these variables among female collegiate endurance athletes is lacking. Therefore, the purpose of this study is to investigate: (1) the risk of DE, LEA, and reported MD, and (2) the relationship between risk for LEA with DE, MD, training volume, and weight satisfaction among female collegiate runners.

CHAPTER II

LITERATURE REVIEW

Disordered Eating in Athletes

Disordered eating (DE) behaviors can stem from obsession with reaching performance goals and pressure for meeting body weight standards, thus leading to over-training, and over-compliance through restriction and dieting.[14] DE is problematic eating behaviors (eg. restrictive or compulsive eating, skipping meals, compulsive exercise) that fail to meet the *DSM-5* (*Diagnostic and Statistical Manual of Mental Disorders*) criteria for an eating disorder (ED).[7] In many ways, strict diet manipulation secondary to weight and body dissatisfaction has been normalized among female endurance athletes, as seen with such a high prevalence of unhealthy dietary habits in this population.[10] In a study examining ED risk among NCAA Division I cross country and track distance student-athletes, 46% of female runners were at risk for EDs.[15] The prevalence of DE among female athletes is estimated to be 6-45%.[7] However, underreporting of DE symptoms, a lack of screening and subsequent identification, variations in assessment tools, and changes to diagnostic criteria of EDs makes it difficult to determine the exact prevalence of EDs/DE among athletes.[10,16] When assessing the characteristics of individuals at risk for developing disordered eating behaviors, it often stems from internalized societal pressures, poor advice from coaches, and/or lack of knowledge surrounding weight control.[14,17] Furthermore, DE and EDs can lead to inadequate energy intake in athletes, and ultimately result in low energy availability (LEA), and subsequent health and performance declines.[7,18,19]

Risk Factors for Disordered Eating

The prevalence of DE among female athletes, and female runners specifically, is higher than non-athlete counterparts at nearly every age and competition level.[20–22] In a recent study examining NCAA Division I female runners' experiences of perceived body image norms and DE, several themes were identified as contributing to the risk of DE behaviors.[17] Among these themes were factors such as the perceived ideal body composition for runners, the desire to reach a specific weight, and the potentially problematic culture of the sport regarding both peer and coach influences. The nature of the athlete mentality, (eg. high-achieving and perfectionist tendencies), thin societal body ideals, and the notion that running is considered a "lean sport" in a highly competitive environment intensifies the risk for DE and restriction among these athletes.[23]

Performance/leanness. Running, like other endurance sports, is considered a "lean" or "aesthetic" sport, in which body weight may be erroneously associated with perceived performance benefits.[24] Thus, a common theme exists among female collegiate runners that being "lighter or leaner" will result in faster running times.[17] This can present as an athlete seeking a specific body composition and/or weight goal, in pursuit of these expected advantages.[7,19,25] In order to achieve these weight or body composition goals, often unnecessary dietary restriction and consequently under-fueling for training demand may occur, and lean-sport athletes may be more susceptible to these unhealthy habits.[7,14,23] Furthermore, athletes participating in sports with an emphasis on leanness for perceived performance improvements suffer from these sociocultural pressures to meet specific body criteria.[26] In a recent study investigating restrictive eating and EDs, it was found that lean-sport athletes reported higher rates of both DE behaviors and ED diagnoses than non-lean athletes, in both elite and non-elite athletes.[27] As noted in Beermann et al. collegiate runners may face challenges in meeting the energy demands of their sport for several reasons, notably with high training volumes and additional pressure for leanness.[6]

Weight Dissatisfaction. In the pursuit of a specific weight or a leaner body composition, and concurrent manipulation of energy intake, athletes can fall into a difficult cycle in which they are continually dissatisfied with both body image and weight status.[28] These constant appearance and performance-related body image concerns may play a role in the development of DE behaviors.[28] Among elite, recreational, and noncompetitive female athletes, those competing in aesthetic sports reported higher levels of body dissatisfaction and greater DE indicators, further emphasizing the desire and control for a specific physique among leanness focused sports like running.[24]

Athletes in weight-sensitive sports are likely to have a lower perceived ideal body weight than those in less weight-sensitive sports which could body dissatisfaction.[29] In a study examining the association of DE with emotion regulation, greater body dissatisfaction and emotion regulation difficulties significantly predicted higher DE risk.[29] Furthermore, a substantial 40% of collegiate cross-country runners were found to desire a lower body weight.[29] Prnjak et al. reported the pursuit of body satisfaction to be a mediator between perfectionism and dieting among female athletes, highlighting that both perfectionism and body satisfaction play an integral role in the development of DE symptoms.[30]

Perfectionism. The competitive environment of collegiate running adds to the pressure of not only performance expectations, but the subsequent weight ideals.[17] This further adds to the academic and social challenges that college athletes face daily, which leads to an element of perfectionism to reach these ideals.[29] This characteristic can build upon restriction and is a primary psychological risk factor for DE among athletes.[7] While a perfectionist personality trait could be advantageous to obtaining training goals and can be associated with dedication to the sport and performance, it can also be considered problematic, and associated with psychopathological conditions such as DE and EDs.[30] Collegiate athletic involvement indicates a strong relationship between perfectionism and DE, signifying perfectionism as a risk factor for the development of DE behaviors.[31]

Disordered Eating Assessments and Limitations

DESA 6. Early identification of DE behaviors is imperative to prevent progression into a clinical eating disorder. The Disordered Eating Screen for Athletes (DESA-6) is a validated screening tool used to identify DE among all levels of athletes of all sports, with a sensitivity of 92% and specificity of 85.96%.[32] This tool has been used by physicians, athletic trainers, psychologists, and registered dietitians to screen athletes with the goal of preventing the health consequences associated with both DE and a clinically diagnosed ED. The DESA-6 assesses the frequency and severity of injuries, fear of weight gain, happiness with current weight, the intensity of dissatisfaction with current weight, the presence of dieting, and the presence of pressure to lose weight.[32] Athletes who score $\geq$ 3 are considered to be "at risk for DE", and those who score $<$ 3 are considered "not at risk for DE". However, there are limitations to utilizing the DESA-6 in the identification of DE risk. For instance, the nature of a self-reported survey is susceptible to the possibility for human errors and response biases. Moreover, there is currently no universally accepted definition for DE, unlike the diagnosis for EDs via the *Diagnostic and Statistical Manual of Mental Disorders* (*DMS-5*).[32] Therefore, it should be noted that the DESA-6 is not a diagnostic tool for identification of a clinical ED.

Other validated tools to assess an ED and DE include the Eating Disorder Examination (EDE-Q), Eating Attitudes Test (EAT-26), and the Eating Disorder Inventory (EDI).[32,33] However, these screening tools have not been validated for use as DE screening tools for athletes, specifically.[34] Among female collegiate athletes in particular, assessment tools such as

Female Athlete Screening Tool (FAST) or the Athletic Milieu Direct Questionnaire (AMDQ) can be used for EDs/DE screening.[33,35] Screening tools such as these provide widely accessible administration, and can be used to identify and long-term consequences of DE, such as LEA.[33,35] Compared to these assessment tools, the DESA-6 is the shortest and therefore most efficient to screen the risk of DE among athletes.[32]

Low Energy Availability

Energy availability (EA) is the energy left over to support normal health and physiological function (e.g. regular menses, endocrine production, bone remodeling, etc.) after energy expenditure from exercise has been accounted for in relation to fat-free mass.[4,5] Energy availability (EA) can be influenced by a shift in overall dietary energy intake and/or an increase in the energy expended through exercise. Therefore, if the total energy intake is insufficient to support the high energy demands for the sport, the athlete runs the risk of being in a state of low energy availability (LEA).[36] LEA in female athletes is defined as < 30 kcal/kg FFM/day^{-1}, with subclinical LEA typically defined as 30-45 kcal/kg FFM/day^{-1}.[4] Endurance sports such as distance running have significant energy demands due to an increased training volume, which poses challenges to matching energy intake.[5,19] Long-term LEA is characterized by metabolic adaptations and negative impacts on physiological functions (hematological, gastrointestinal, cardiovascular, immunological, psychological, and endocrine).[4,5] As EA decreases, whether intentionally or unintentionally, female athletes may experience amenorrhea and osteoporosis as long-term consequence.[2,11] While preventing LEA is paramount to avoiding various health and performance consequences that may coincide, there exist challenges to measuring and assessing EA.[37]

Assessment of Low Energy Availability

EA and identification of LEA can either be directly measured, or detected by assessment of risk through qualitative screening tools.[38] Though sometimes impractical, EA can be calculated by assessment of energy intake compared with exercise energy expenditure (EEE), in relation to fat-free mass. Estimating EA has limitations including a lack of universal protocol for assessment, and errors in estimation that potentially stem from a lack of necessary resources for examination.[37] The calculation requires fat-free mass, energy intake and the energy cost of exercise; all of which include their own limitations and possible recall biases.[37–39] Direct calculation of EA relies on dietary recall for the estimation of energy intake, however the use of food records may not accurately reflect actual intake due to recall bias, recording inaccuracy, and the likely underreporting of food and portions.[40] Additionally, estimating the daily EEE is limited to the accuracy of training records, heart rate monitors, accelerometers, O_2 consumption, METS, etc.[37] The protocols for calculating energy expenditure in the current available literature vary dependent upon the sport and setting.[37] Furthermore, direct measurement of current EA may only provide a snapshot of energy intake and expenditure levels, diminishing the practicality of its use in identification of chronic LEA, and the health and performance consequences involved.[41]

While direct measurement of EA can be used to diagnose clinical and subclinical LEA, there remains some uncertainty surrounding the exact thresholds for diagnosis, and the practicality of EA measurement outside of a well-controlled laboratory environment.[41] The threshold for LEA in female athletes is currently recognized as < 30 kcal/kg FFM/day^{-1}, however mismatches between physiologic impairments at varying EA levels have been identified, and the level of athlete as well as the timeframe of measurement and time spent in LEA should be considered.[41,42] It is thought that an EA between 30-45 kcal/kg FFM/day^{-1} may be tolerated only for short periods of time with healthy weight loss before these metabolic and physiological adaptations are observed.[43]

Low Energy Availability in Females Questionnaire (LEAF-Q)

Tools that assess the specific risk factors and manifestations of LEA have been used in varying athletic populations and may be more reasonable for some populations, such as female athletes. The Low Energy Availability in Females Questionnaire (LEAF-Q) is a validated and reliable way to identify those at risk for LEA and the female athlete triad. The questionnaire has a sensitivity of 78% and a specificity of 90%, and Cronbach's Alpha = 0.61-0.79, proving a reliable resource in assessing injuries, gastrointestinal symptoms, and reproductive function and contraceptive use, all of which identify female endurance athletes at risk for LEA.[44] Assessment of LEA symptoms makes the LEAF-Q an acceptable and useful screening tool, however it is important to note that it is not a complete diagnostic tool for energy deficiency or LEA.[5] Like any self-reported survey, there exist risk for false positives or false negative screenings, when considering potential acuity of symptoms, and may be susceptible to response bias.[44]

Etiology of Low Energy Availability

Over training, weight periodization, EDs and DE, lack of nutrition knowledge, and limited access to food resources are all potential contributors to the development of LEA.[45] Ultimately, high levels of EEE without a corresponding increase in energy intake, whether intentional or unintentional, can lead to the problematic adaptions seen with LEA and as outlined in the Relative Energy Deficiency in Sport model (RED-S).[5] Changes to energy intake may be in pursuit of optimal body composition or due to weight dissatisfaction and associated dieting behaviors or DE habits which can lead to insufficient intake.[14] However, LEA can exist independently, or alongside ED/DE, and is not always a result of disordered eating behaviors.[7,45]

Lack of nutrition knowledge or misinformation regarding proper fueling practices may also contribute to energy deficiency among athletes.[46] Unhealthy coach-athlete relationships that include body shaming or manipulation of diet in the setting of substantial energy expenditure may contribute to chronic underfueling.[18,46] Furthermore, inadvertent or intentionally high training loads may be the basis for LEA in athletes.[45] Collegiate athletes in particular may face a substantial increase in training demands during the transition from high school to college athletics, and frequently dietary intake is insufficient to meet these demands.[6] Conversely, exercise dependance, or intentional addition of exercise outside of structured training regimens can be a contributor to LEA, increasing the risk for RED-S consequences.[25,47] In runners and athletes in sports emphasizing leanness and a smaller body size, compulsive exercise plays a strong role in the risk of DE, and ultimately LEA.[10,37] When the consequences of LEA are observed among athletes, often training and competition must be suspended or reduced in order to increase EA.[5,10,37]

Consequences of Low Energy Availability

As previously noted, LEA is the basis of several physiological impairments that can occur secondary to energy deficiency, which are outlined in the model of RED-S.[5,48] RED-S, an expansion of the Female Athlete Triad, is a condition of impaired physiological functions caused by LEA which includes impairments in the reproductive system, bone mineral density, endocrine function, immunity, cardiovascular health, and protein synthesis.[48] It is paramount to understand the risk factors and effects surrounding RED-S to protect these physiological functions, performance outcomes, and ultimately the health of the athlete.[19] When an athlete is in a state of

LEA, the body shifts prioritizes major physiological functions leading to metabolic and physiologic adaptations that subsequently reduces resting energy needs.[4] Compared to athletes with adequate EA, Ackerman et al. found that athletes with LEA had an increased risk for menstrual dysfunction and RED-S symptoms.[2] Furthermore, in a study assessing Female Athlete Triad risk, RED-S, and EA among female collegiate cross country and track runners, there was an overall decrease in resting metabolic rate throughout two seasons, suggesting inadequate EA.[49] A majority of these athletes were indicated to be at risk for both the Triad and RED-S, with 67% resulting with clinical LEA levels.[49]

Further consequences of LEA secondary to health impairments include detriments to overall athletic performance, such as decreased training response, impaired judgement, decreased coordination and concentration, irritability, and depression.[2,19] Protein synthesis can also be impaired, leading to negative effects on muscular protein synthesis, due to a reduction of anabolic hormones.[45] Furthermore, Melin et al. suggests long-term LEA, compared to short- and medium-term, creates potential direct performance decrements such as impaired recovery from exercise, suboptimal stores of specific micronutrients such as iron that decrease performance markers like VO_2max, increased risk for injury and illnesses such as bone stress injury taking time away from the sport, and psychological disturbances.[19] Therefore, monitoring EA among high risk athletes is necessary to prevent physiological decrements to health, as well as the many direct and indirect implications on athletic capabilities.[19]

Menstrual Dysfunction

Disruptions in endocrine function and hormonal fluctuations, specifically a decrease in luteinizing hormone (LH), due to LEA may lead to menstrual dysfunction (MD) in female athletes.[5] MD is characterized as oligomenorrhea (irregular or infrequent menstrual periods), amenorrhea (absence of a menstruation), or delayed menarche (past the age of 15).[50] Although sometimes overlooked due to the prevalence among these athletes, the loss or disruption of the menstrual cycle in college-aged athletes can be harmful.[25] Estrogen levels are suppressed in the absence of irregularity of menses, ultimately leading to a loss in bone mineral density due to decreased restraint on bone resorption.[51] Because the timeframe of adolescence and the years of collegiate sport are imperative for the accumulation of optimal bone mineral density, disruption of this process due to endocrine disturbance may lead to bone mineral loss in adulthood, or osteoporosis.[51] Folscher et al. reported that 50% of ultra-endurance runners have changes in menstruation with an increase in training, while 48.4% reported perceiving amenorrhea to be normal with training.[1] Thus, there are many misconceptions regarding menstrual function in female endurance athletes, and because such a high percentage of female endurance athletes experience menstrual dysfunction, many may not be initially alarmed or aware that it may lead to detriments to their health and athletic performance.[25,52] In a study of NCAA Division I female collegiate athletes (n = 95), 9.5% were found to have primary amenorrhea, 18% reported secondary amenorrhea, and 35.8% reported oligomenorrhea.[52] Jesus et al. found 41.3% of female runners to be at risk for MD in a study examining risk of LEA among elite cross-country runners.[12] When examining MD among elite and recreational athletes, the estimated prevalence of MD is between 37-71.1%.[12,38,53] MD as a symptom of LEA in athletes may lead to other health consequences in the future, such as poor bone mineral density which may lead to injuries.[5,27] While there is currently some conflicting research regarding the connection between MD and injury rate, Rauh et al. found that when compared to eumenorrheic athletes, those with MD had higher odds and were more susceptible to injury (OR 2.9, 95% CI 1.4-1.6).[54] Furthermore, the findings of Reed et al. demonstrated that although EA may not discriminate for disruptions to regular menstrual patterns, EA was found to be lower in athletes with amenorrhea compared to eumenorrheic athletes, and thus as EA decreases, the risk for MD increases.[55]

Conclusion

Endurance athletes such as distance runners, and specifically female athletes of collegiate age, have a high prevalence of DE and may be at an elevated risk for LEA.[1,6,7] These athletes encounter risk factors for DE such as societal ideals surrounding body image, a risk for weight dissatisfaction in the pursuit of leanness, perfectionism, and influences for dieting by their peers, teammates, and coaches.[7,10,14,17] Further, LEA can occur in the presence or absence of DE behaviors, and athletes are inherently at a high risk for the development of LEA due to nutritional knowledge gaps, high training volumes and EEE, and insufficient energy intake to meet these demands.[5,7,45] Chronic LEA is the primary risk factor for RED-S, from which many health and performance impairments can stem, namely compromised metabolism, MD, bone health, risk for injury, and impaired strength and recovery.[5,19] Female endurance athletes are among the highest risk for LEA, yet few studies have examined these factors in regard to risk factors such as DE, MD, and weight dissatisfaction.[12,25] More research aimed at studying the risks and prevalence of LEA and DE among female collegiate runners is warranted to increase awareness and education among athletes, coaches, and practitioners.

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CHAPTER III

JOURNAL ARTICLE

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

AUTHORS
Leah Dambacher, Central Washington University
Kelly Pritchett, Central Washington University
Robert Pritchett, Central Washington University
Abigail Larson, Southern Utah University

Abstract

Collegiate female distance runners may be at risk for low energy availability (LEA) due to increased exercise energy expenditure with or without decreased energy intake. Furthermore, this population has increased risk of disordered eating (DE), which can lead to LEA and negative health consequences, such as menstrual dysfunction (MD). **Purpose:** The purpose of this study was to: 1) investigate risk of LEA and DE and 2) compare DE, training volume, and weight dissatisfaction among female collegiate runners athletes at risk vs not at risk for LEA. **Methods**: Female runners (n = 287) who competed on an NCAA Division I, II, or III cross-country and/or track team completed an online questionnaire (45 questions). The questionnaire included the Low Energy Availability in Females Questionnaire (LEAF-Q) which examines incidence of stress fractures, occurrence and frequency of menstrual cycles within the previous 12 months, contraceptive use, and gastrointestinal function. The Disordered Eating Screening Assessment (DESA-6) was used to examine risk of DE and weight dissatisfaction. **Results:** 54.5% (n = 156) of runners were at risk for LEA (score $\geq$ 8 on LEAF-Q), and 40.8% (n = 117) were at risk for DE (DESA-6 score $\geq$ 3), and 56.5% (n = 162) reported MD (LEAF-Q subsection MD score $\geq$ 4). Athletes “at risk” for LEA had significantly higher DESA-6 scores than athletes “not at risk” for LEA ($p < 0.001$). Athletes “at risk” for LEA had significantly greater weight dissatisfaction than those not at risk for LEA ($X^2_{3, 156} = 15.92$, $p = 0.001$). Higher weekly training volumes was not associated with risk for LEA ($X^2_{2, 156} = 4.20$, $p = 0.112$). **Conclusion:** Consistent with previous

literature, a substantial percentage of collegiate female runners were found to be at risk for LEA, DE, and report MD. These findings demonstrate that risk for DE, MD, and weight dissatisfaction are associated with risk for LEA.

Introduction

Endurance athletes, such as distance runners, have a high risk for disordered eating (DE) habits and low energy availability (LEA), thus leading to health and performance complications exacerbated by insufficient energy intake.[1] LEA has been shown to have negative health and performance consequences for endurance athletes.[2,3] Chronic energy restriction and increased exercise energy expenditure result in impaired energy availability (EA). EA is the energy left over to support normal health and physiological function (e.g. regular menses, endocrine production, bone remodeling, etc.) after energy expenditure from exercise has been accounted for in relation to fat-free mass.[4,5] The LEA threshold in female athletes is defined as < 30 kcal/kg FFM/day^{-1}, with subclinical LEA typically defined as 30-45 kcal/kg^{-1} FFM/day.[4] Amongst collegiate-aged female athletes, there is a substantial risk for the negative effects of intentional or unintentional energy deficits.[6] Specifically, disordered behaviors can lead to LEA in these athletes.[7]

In competitive athletes, DE habits can persist due to the emphasis placed on body size or composition for perceived advantages in performance, and sociocultural pressure. Further, DE can progress to a diagnosable eating disorder (ED), with a multitude of health consequences relating to the potential for Relative Energy Deficiency in Sport (RED-S).[7] Female endurance athletes are known to have a higher rate of DE behaviors and higher risk for developing diagnosed ED than the general population and male endurance athletes.[8] In addition, endurance athletes are at a greater risk for DE due to the fact that leanness is often emphasized and idealized in sports such as distance running.[8] DE behaviors and restriction can stem from poor body image and the heightened risk for weight dissatisfaction in pursuit of an idealized body weight and composition.[9] While female elite endurance athletes have a higher incidence of DE compared to other athletes, college-aged runners may experience among the highest DE habits, even in the absence of a clinical ED diagnosis.[10] Although sometimes independent of one another, LEA often occurs in conjunction with DE/ED and each condition poses significant health risks among this population.[7]

Ackerman et al.[2] found female athletes with LEA are more likely to exhibit the negative health consequences of RED-S, a syndrome of health and performance impairments, than those with adequate EA. Long-term LEA is characterized by metabolic adaptations and changes in physiological functions, important for several body systems.[4] As EA decreases, whether intentionally or unintentionally, female athletes can experience amenorrhea and osteoporosis as long-term consequences.[2,11] In a study examining risk of LEA among elite cross-country runners, 79.5% of females were considered high risk for LEA and 41.3% of female runners reported menstrual dysfunction (MD).[12] Similarly, Beermann et al.[6] reported 41% of female collegiate cross-country runners to have clinical LEA as determined by two measures of EA. Finally, Rogers et al.[13] found 55% of female athletes to be at risk for LEA and 80% to demonstrate symptoms of RED-S, and a strong relationship between the two. LEA, whether inadvertent or intentional, can result from the high energy demands consequent to substantial training loads.[9,10] Training behaviors that exceed energy intake can be the unintentional result of a high-volume training program, such as distance running at a collegiate level, or the unhealthy manipulation of exercise load as seen with DE behaviors.[10]

Recent research has highlighted health concerns associated with DE leading to deficient energy availability, and a host of significant health concerns such as MD in female athletes. Training volume, weight periodization, and presence of DE can affect EA and menstrual function.[3,5] Understanding the risk of MD and the relationship between DE and LEA is crucial for health and performance outcomes, yet research examining these variables among female collegiate endurance athletes is lacking. Therefore, the purpose of this study is to investigate: (1) the risk of DE, LEA, and reported MD, and (2) the relationship between risk for LEA with DE, MD, training volume, and weight satisfaction among female collegiate runners.

Methods

Subjects

College age (18-30 years) female participants who run competitively (Division I, II, III cross-country, and track athletes) were eligible to participate in this study. The first 200 participants were offered the opportunity to receive a $20 Amazon gift card for participating in and completing the online questionnaire. The questionnaire was advertised via Instagram requesting participation in the research study, and collegiate athletes were contacted via email. This study was granted approval by the Human Subjects Review Committee at Central Washington University. All participants were asked to read a sign a consent form.

Design

A cross-sectional study was implemented in which participants completed a questionnaire of 45 questions. Questions included the following topics: type of runner (Division I, II, or III NCAA cross country and/or track) running mileage per week (low $\leq$ 30 miles, moderate 31-60 miles, and high >60 miles), incidence of stress fracture, weight control methods, weight satisfaction, history or presence of ED/DE, occurrence and frequency of menstrual cycles within the previous 12 months, contraceptive use, and gastrointestinal function. The survey was created using the Qualtrics platform. Participants completed questions embedded from the Low Energy Availability in Females Questionnaire (LEAF-Q). The LEAF-Q has been validated for use in identification of athletes at risk for LEA with a Cronbach's Alpha = 0.62-0.79 and a sensitivity of 78% and specificity of 90%.[44] The LEAF-Q gathers information regarding injury frequency in the past year, current and past menstrual function, and current gastrointestinal (GI) function. Participants who scored $\geq$ 8 were considered at risk for LEA while participants scoring < 8 were considered not at risk.[44] A subsection score of $\geq$ 2 for injuries, $\geq$ 4 for MD, and $\geq$ 2 for GI function were considered at risk for each category.[12,44] DE behaviors were assessed by questions from the Disordered Eating Screening Assessment (DESA-6), which assesses the frequency and severity of injuries, the fear of weight gain, happiness with current weight, the intensity of dissatisfaction with current weight, the presence of dieting, and the presence of pressure to lose weight. Participants who scored $\geq$ 3 were considered at risk for DE and those who scored < 3 were considered not at risk.[32] The DESA-6 has been validated to effectively identify DE among athletes of all sports with a sensitivity of 92% and specificity of 85.96%.[32] Higher DESA-6 scores are associated with risk for EDs in female as when compared to the Eating Disorder Examination (EDE-Q) ($r = 0.08$, $p < 0.001$).[32]

Procedures

Data collection for this study was performed online from November 2, 2021 to June, 1 2022. Athletes who chose to participate were directed to the Qualtrics survey via a link, and upon entering the Qualtrics site were given participation information regarding estimated time requirements, assurance of confidentiality, nature of the questions, and directions to a second survey to receive an Amazon gift card if qualified. Participants then agreed to the terms outlined in the informed consent or could choose to close their browser window. All data collected were anonymous. After completion of the survey, the initial 200 participants were directed to another Qualtrics survey to enter their first and last names and email address to receive the Amazon gift card. Email addresses could not be traced back to any of the original survey responses.

Statistical Analysis

Results from the Qualtrics Survey were analyzed using Microsoft Excel and the Statistical Package for the Social Sciences (SPSS, Version 28.0, Armonk, NY: IBM Corp). Descriptive characteristics of the participants were calculated as a mean ± standard deviations (SD) for age, weight, and height. Chi-square tests were be used to analyze nominal data, including weight dissatisfaction and training volume. Independent T-tests were used to identify differences between risk of DE (DESA-6 score), MD, injury, and gastrointestinal subsections scores and those at risk versus not at risk for LEA. A one-way ANOVA was used to determine differences in LEA risk, DE risk, MD subsection scores, injury subsection scores, and gastrointestinal subsection scores between Divisions I, II, and III. Pearson correlations coefficient (R) were used to examine the relationship between the risk of LEA with the risk of DE. $p < 0.05$ was considered statistically significant.

Results

Participant ($n = 287$) descriptive characteristics for the sample population and based on NCAA collegiate Division (I, II, or III) are presented in Table 1.

Table 1. Descriptive and training characteristics for the sample population by collegiate Division (I, II, or III)

	Sample population (n = 287)	Division I (n = 135)	Division II (n = 88)	Division III (n = 64)
Age (years)	21.30 ± 2.86	21.25 ± 2.61	22.30 ± 3.48	20.10 ± 1.76
Weight (kg)	57.07 ± 6.92	55.62 ± 5.88	58.95 ± 8.24	57.57 ± 6.39
Height (cm)	165.75 ± 6.94	165.79 ± 7.10	166.64 ± 7.06	164.42 ± 6.29
BMI (kg/m^2)	20.75 ± 2.49	20.23 ± 2.24	21.24 ± 3.08	21.20 ± 1.81
Weekly training volume (miles/week)	31-60	31-60	31-60	31-60

Data are mean ± SD. Weekly training volume is reported as most frequently reported range for each group.

LEAF-Q

The LEAF-Q was used to classify participants at risk for LEA using a total score of ≥ 8 (Melin et al., 2014). The mean LEAF-Q score for all participants was 9.2 ± 5.8, with no significant difference found between Division I, II, and III athletes (9.0 ± 6.0, 7.2 ± 4.9, 8.5 ± 5.5, respectively; $p = 0.32$). 54.4% ($n = 156$) female collegiate runners were identified as being at risk for LEA. Of those runners at risk for LEA, 58.5% ($n = 79$) were Division I runners, 50.0% ($n = 44$) were Division II runners, and 51.6% ($n = 33$) were Division III runners, as shown in Table 2. There was no difference in risk for LEA between runners categorized as low, moderate, or high weekly running mileage ($X^2_{2, 156} = 4.20$, $p = 0.11$). No significant difference was found between total LEAF-Q score and Division I, II, and III athletes ($p = 0.31$), furthermore, no significant difference was detected for NCAA division and LEAF-Q categorical scores including menstrual function, injury, gastrointestinal ($p = 1.89$, $p = 0.98$, $p = 0.12$, *respectively*).

Table 2. Prevalence of athletes at risk for LEA, LEAF-Q, and subsection (GI, menstrual function, injury) scores by collegiate division.

	Sample Population (n=287)		Division I (n=135)		Division II (n=88)		Division III (n=64)	
	At Risk	**Not at Risk**	**At Risk**	**Not at Risk**	**At Risk**	**Not at Risk**	**At Risk**	**Not at Risk**
Injury Section $\geq$ 2	73 (25.4%)	14 (4.9%)	33 (24.4%)	8 (5.9%)	25 (28.4%)	3 (3.4%)	15 (23.4%)	3 (4.7%)
GI Section $\geq$ 2	125 (43.6%)	74 (25.8%)	65 (48.1%)	34 (25.2%)	38 (43.2%)	25 (28.4%)	22 (34.4%)	15 (23.4%)
Menstrual Function Section $\geq$ 4	133 (46.3%)	29 (10.1%)	68 (50.4%)	6 (4.4%)	37 (42.0%)	14 (15.9%)	28 (43.8%)	9 (14.1%)
Total $\geq$ 8	**156 (54.4%)**	**131 (45.6%)**	**79 (58.5%)**	**56 (41.5%)**	**44 (50.0%)**	**44 (50.0%)**	**33 (51.6%)**	**31 (48.4%)**

Prevalence data are reported in as n (%), LEAF-Q and subsection scores reported as mean ± SD

GI function subsection

69.3% of all athletes (*n* = 199) reported a GI subsection score of $\geq$ 2 indicating risk for gastrointestinal symptoms. Furthermore, 35.2% (*n* = 100) of athletes reported "*rarely or never feeling gaseous or bloated*", and 53.5% (*n* = 152) reported "*rarely or never getting stomach cramps or aches unrelated to menstruation*". Among all runners, there was a mean gastrointestinal subsection score of 2.9 ± 2.2, however no significant difference in GI subsection scores between Division I, II, and III runners (*p* = 0.12) (Fig. 1).

Injury subsection

30.3% of all athletes (*n* = 87), and 25.4% of athletes at risk for LEA (*n* = 73) had a score of $\geq$ 2, indicating risk for injury (Fig. 1). Mean injury subsection score was 1.3 ± 2.0 with no significant difference between DI, DII, and DIII runner scores (*p* = 0.98). In comparison to the gastrointestinal (43.6%) and menstrual function (46.3%) subsections of the LEAF-Q, less athletes scored at risk for LEA due to a score of $\geq$ 2 in the injury subsection (25.4%). Of those at risk for LEA, 49.4% (*n* = 77) reported to have missed "*yes*" when asked "*have you had 3 or* *more injuries that have inhibited your ability to train in the past season OR did your past season end early due to injury*".

Menstrual function subsection

A subsection score of $\geq$ 4 indicated MD which includes both oligomenorrhea and amenorrhea. Mean menstrual function subsection score for the population was 5.0 $\pm$ 4.1, with no significant difference in scores between DI, DII, and DIII (p = 0.15). 56.5% of all runners (n = 162) scored at risk for or reported MD. 24.4% (n = 69) of female athletes reported menarche at >15 years of age (indicative of primary amenorrhea) while five athletes reported never having menstruated. 29.3% (n = 84) of the female runners reported taking oral contraceptives, with 9.5% (n = 8) reporting oral contraceptive use to prevent or correct amenorrhea. 16.6% (n = 14) of runners reported using oral contraceptives to "regulate their menstrual cycle in relation to performance", while others used them for contraception (48.8%, n = 41), to reduce menstrual pain (10.7%, n = 9) or to reduce menstrual bleeding (8.3%, n = 7). Further questions from the LEAF-Q and respective answers are displayed in Fig. 1.

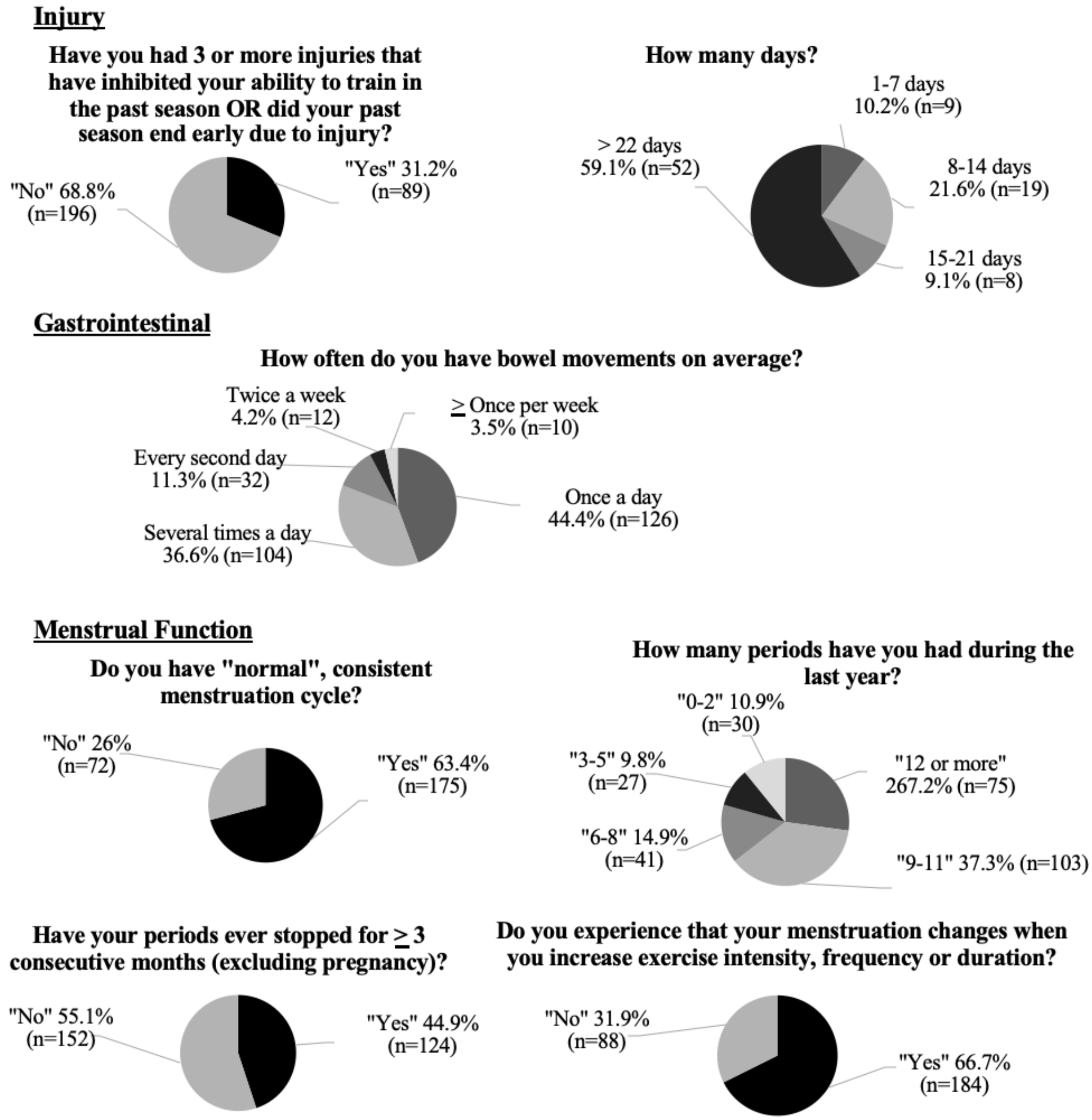

Fig. 1. Graphical representation of the LEAF-Q subsection (injuries, gastrointestinal, and the menstrual function) questions and answers.

DESA-6

A total of 59.2% (*n* = 170) runners scored < 3 indicating not at risk for DE, while 40.8% (*n* = 117) of runners were considered at risk for DE based on a score of ≥ 3 on the DESA-6. Fig. 2 displays the percentage of athletes at risk for DE based on collegiate division. There was no significant difference found between total DESA-6 score and Division I, II, and III athletes (*p = 0.53*). Furthermore, risk for DE was not associated with weekly training volume, between those running low, moderate, or high weekly mileage ($X^2_{3,\,117}$ = 1.31, p = 0.52). Questions from the DESA-6 and the participants respective answers are displayed in Fig. 3.

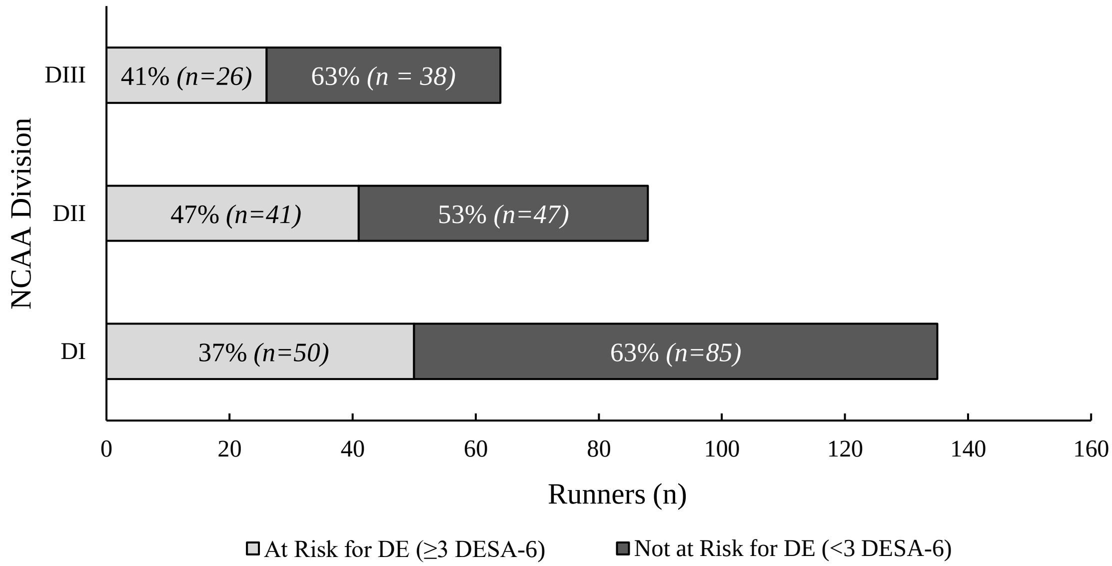

Fig. 2. Percentage of Athletes at Risk for DE by collegiate division (I, II, and III). DE = disordered eating.

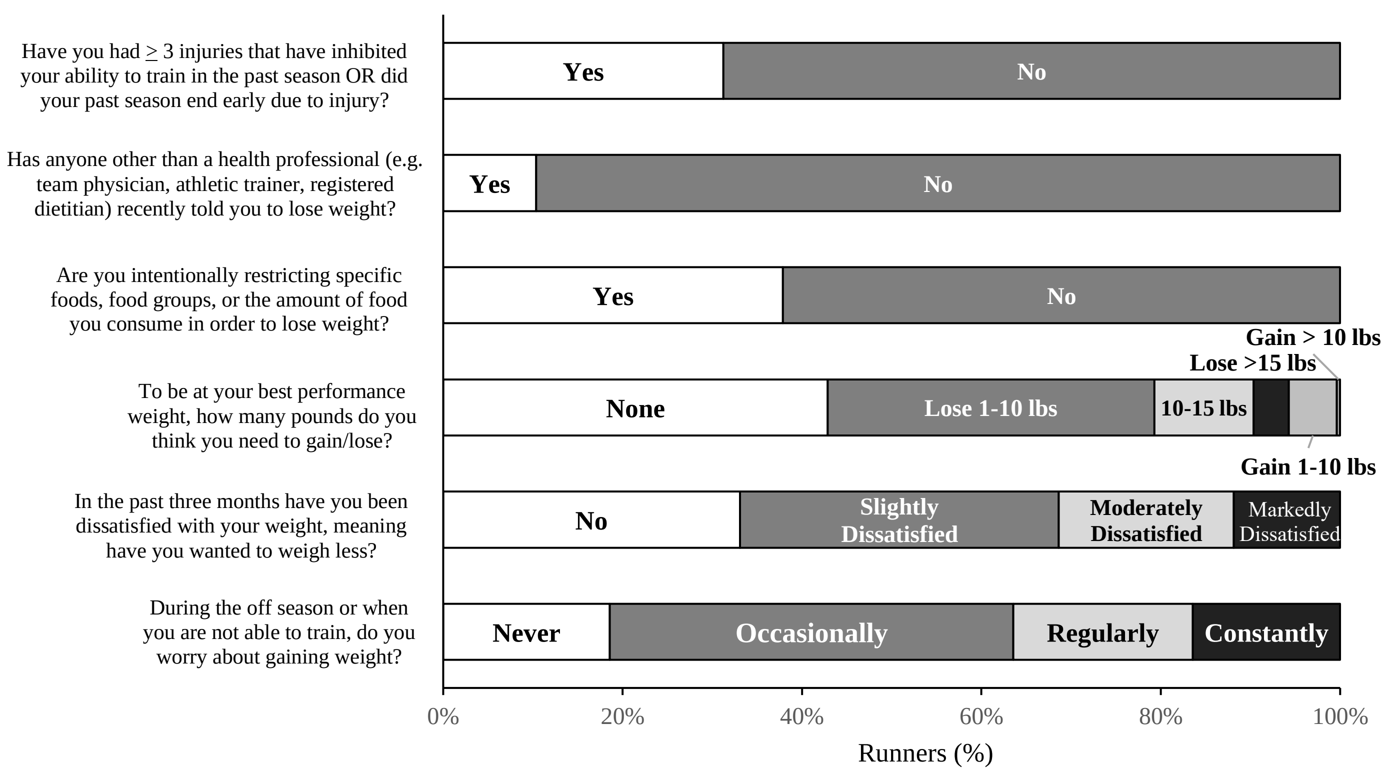

Fig. 3. Participant responses to the DESA-6 questions (n = 287)

Associations between risk of LEA, DE, and Weight Dissatisfaction

There was a positive correlation between LEAF-Q scores and DESA-6 scores (*r* = 0.51, *p* < *0.001*). Athletes who were considered at risk for DE had significantly higher LEAF-Q scores for each category than athletes not at risk for DE (*p* < *0.001*). Of those athletes at risk for DE (*n* = 117), 77.8% (*n* = 91) were also at risk for LEA. Runners at risk for LEA were more likely to report greater weight dissatisfaction than athletes not at risk for LEA ($X^2_{3, 156} = 15.92$, *p* = 0.001). Total LEAF-Q and subsection scores of those at risk for DE and not at risk for DE are presented Table 3.

Table 3. LEAF-Q total, and subsection (GI, menstrual function, injury) score and prevalence of athletes at risk for LEA among athletes at risk and not at risk for DE.

	Whole Sample (n=287)		**At Risk for DE (n=117)**		**Not at Risk for DE (n=170)**		***p***
LEAF-Q							
Injury Section ≥ 2	87 (30.3%)	2.4 ± 2.2	69 (58.9%)	2.4 ± 2.2	18 (10.6%)	0.5 ± 1.4	*<0.001**
GI Section ≥ 2	199 (69.3%)	3.5 ± 2.2	92 (78.6%)	3.5 ± 2.2	107 (62.9%)	2.5 ± 2.1	*<0.001**
Menstrual Function Section ≥ 4	162 (56.5%)	6.2 ± 3.9	87 (74.4%)	6.2 ± 3.9	75 (44.1%)	4.2 ± 4.0	*<0.001**
Total ≥ 8	**156 (54.4%)**	**12.2 ± 5.6**	**91 (77.8%)**	**12.2 ± 5.6**	**65 (38.2%)**	**7.2 ± 4.9**	***<0.001****

n (%) of athletes at risk or not at risk. Subsection scores are displayed as mean ± SD.
**indicates significant difference in LEAF-Q or subsection scores between at risk for DE vs. not at risk for DE.*

Discussion

The aim of the current study was to investigate the risk for LEA and DE and to compare risk for DE, training volume, and weight dissatisfaction among female collegiate runners at risk vs not at risk. In the current study, over half of female collegiate runners were identified as being at risk for LEA based on LEAF-Q scores (54.4%), and over half of the participants reported MD. Athletes at risk for LEA had significantly higher DESA-6 scores and were more likely to have greater weight dissatisfaction. However, there was no difference in risk for LEA between low, moderate, and high weekly running mileage. Therefore, DE, MD, and weight dissatisfaction may increase the risk for LEA development, and may be used as warning signs when screening athletes for LEA.

Based on the LEAF-Q, we found that 54.4% of the collegiate runners were at risk for LEA, which is lower than the 62.2% of female endurance athletes reported by Melin et al.[44], but comparable to findings in both competitive and recreational female endurance runners (n = 248) that found 47.3% of athletes to be at risk for LEA.[56] Other studies using the LEAF-Q to identify LEA risk in female endurance athletes have suggested that 65-79.5% were at risk for LEA.[12,25] Although these studies utilized the LEAF-Q to determine risk for LEA, the discrepancies between risk prevalence may be due to a difference in sample size, or population of athletes (i.e. collegiate, recreational, versus elite athletes). As noted by Beermann et al.[6], the collegiate athlete faces specific barriers to meeting adequate energy intake and nutritional requirements. Furthermore, the nature of a collegiate endurance sport increases the risk of LEA due to demanding training volumes, changing environments with travel, challenging schedules, potentially limited access to food, and increased nutrient requirements.[6, 19, 57, 58] These factors are concerning among this population as, short-, medium-, and predominantly long-term LEA can lead to many indirect and direct decrements to health and athletic performance.[19]

Of note, the current study did not use a direct measurement of energy availability (EA), given the difficulty with accurately assessing and identifying LEA, and the feasibility of measuring EA. Direct evaluation of EA may be beneficial for short-term identification of LEA, however this method requires an accurate assessment of body composition, energy intake (EI), and exercise energy expenditure (EEE).[41] Furthermore, the difficulties around accurately assessing EI and EEE have been previously noted due to a lack of universal protocol for assessment and errors in estimation that may stem from a lack of necessary resources.[37] The calculation of EI and EEE are subject to limitations such as recall biases, underreporting and failure to capture long-term intake when using food records, errors in estimation of EEE in complex activities when using training records and heart rate data.[37–39] Therefore, the LEAF-Q offered a more practical assessment tool to examine a more expansive population in identifying LEA risk and reproductive dysfunction in this cross-sectional study. The LEAF-Q has been validated to effectively screen the at-risk population of elite female endurance athletes with a sensitivity of 78% and specificity of 90%.[44] Nevertheless, it should be noted that the LEAF-Q cannot be used as a diagnostic tool, and that there is potential for both false positives and false negatives when using this questionnaire to identify LEA risk.[5,44] Compared to the prevalence of athletes at risk for LEA (54.4%) in the current study, other studies utilizing measured EA have suggested a wide prevalence of LEA (29-66%) among female collegiate runners.[6,49,59,60]

In addition to LEA risk, the LEAF-Q can be used to identify MD in female athletes.[38] Over half of the runners in the current study reported MD, with the highest prevalence of reported MD in Division I athletes when compared to Division II and III athletes (50.4%, 42%, and 43.8% respectively, $p = 0.15$). Approximately one third of the female runners reported taking oral contraceptives, with 9.5% reported using oral contraceptive to "*prevent or correct amenorrhea*", and 16.6% to "*regulate their menstrual cycle in relation to performance*". It should be noted that the use of oral contraceptives poses a risk for masking underlying MD, which could potentially lead to a false negative screening of LEA via the LEAF-Q.[25] Furthermore, this population may be unaware of the negative health consequences associated with MD as a result of LEA.[25] Despite the well-known link between LEA and MD as seen in both the Female Athlete Triad and the RED-S model[1,38,44] 18% of athletes reported the absence of a menstrual cycle to be "*a normal part of training and/or NOT harmful*". Thus, this lack of awareness necessitates educational interventions for athletes, coaches, and medical professionals in regard to reproductive function as marker of health.[25]

In the current study, 40.8% of surveyed athletes were at risk for DE, supporting the findings of Dervish et al.[56] which found 40% (n = 209) of competitive and recreational female endurance runners to be at risk for DE when using the Female Athlete Screening Tool (FAST). In contrast, Fahrenholtz et al.[25] found 21.3% of athletes reported DE behaviors when utilizing the Eating Disorder Evaluation Questionnaire (EDE-Q). The discrepancy between the aforementioned study and our results may be, in part, due to the recall timeline and nature of questions presented. For example, the EDE-Q measures symptoms of EDs only within the past 28 days, and the DESA-6 assesses DE risk based on both current and typical behaviors, as well as those within the past three months, potentially detecting for a greater prevalence of DE risk.

Similar to the findings of Kuikman et al.[61], DE risk was positively correlated with LEA risk in the current study suggesting that female collegiate runners with LEA are more likely to show DE tendencies. To the authors' knowledge, the current study is the first to implement both the LEAF-Q and DESA-6 concurrently to determine the prevalence of LEA and DE risk within female athletes.[32] Furthermore, Folscher et al.[1] found 27% and 44% of ultramarathon runners at risk for DE and LEA respectively, whereas the present study demonstrated a higher prevalence of DE and LEA in female collegiate runners. In a similar study examining LEA and DE in competitive and recreational female runners, 47.3% of athletes were at risk for LEA per the LEAF-Q, and 40% were found to be at risk for subclinical DE when utilizing the FAST.[56] Comparable to our findings, Fahrenholtz et al.[25] reported that higher LEAF-Q scores were associated with higher DE scores among competitive female endurance athletes when using the

EDE-Q. Some of the differences in presence of DE and LEA reported in the literature may be due to varying assessment instruments used, specifically when considering measured EA versus quantifying the risk for LEA.[37,38] Furthermore, while the etiology of LEA is multifactorial and can stem from over training, weight periodization, and/or intentional energy deficits, DE behaviors oftentimes lead to the problematic physiological adaptations seen with LEA.[7, 19, 45]

Weekly reported running volume was not found to be associated with risk for LEA, which may be a result of the relative homogeneity of the sample, the similar training volumes that were reported among Division I, II, and III, and the large range of mileage within each category. Across the entire sample population, the most frequently reported training volume was 31-60 miles per week. Although not accounted for, these athletes may have been in varying phases of their training, since the survey was open from November through June, which covers different stages of cross country and track seasons. Though we did not find a difference in training volume between athletes at risk and not at risk for LEA, exercise dependence in collegiate athletes may also be a beneficial metric since can contribute to excess energy expenditure, and potentially LEA when concurrent with DE.[61]

However, weight dissatisfaction was found to be associated with a greater risk for LEA and DE, potentially indicating that preoccupation with and intentional changes to body weight can contribute to this risk. Similarly, Berg et al.[62] found that elite female runners with a self-reported history of an eating disorder reported a higher prevalence of weight dissatisfaction (62.5%). These factors indicate that along with risk for LEA and DE, the collegiate female runner population is particularly vulnerable to body weight dissatisfaction. High levels of body weight dissatisfaction concurrent with DE tendencies may influence energy restriction and progression to clinical EDs and LEA.[62]

This is one of the first studies to examine risk of LEA and DE and potential differences between NCAA Collegiate Divisions I, II, and III female collegiate runners. Other studies examining risk of LEA and DE have focused primarily on Division I runners[6,20,49,60], or other Division I female athletes[18,63], with only one sampling Division II athletes.[64] The prevalence of LEA risk among the whole sample was consistent with the identified LEA risk among NCAA Division I, II, and III athletes (58.5%, 50.0%, and 51.6% respectively, $p = 0.32$). Differences in access to health and nutrition resources may exist among NCAA Collegiate Divisions[16]; however, in the current sample, there were no statistically significant differences found in total LEAF-Q score, LEAF-Q subcategory score, or DESA-6 score between Division I, II, and III female collegiate runners.

Limitations

Despite providing further insight into the risk for LEA and DE among female collegiate cross-country/track runners, this study is not without limitations. The present study was a cross-sectional design, which limits assumptions of causality. Moreover, studies based on self-reported data such as the current questionnaire are susceptible to response bias and the possibility of type 1 error. As previously mentioned, the LEAF-Q is vulnerable to both false negative and false positive screenings regarding the MD and the implications of oral contraceptive use. Furthermore, the fact that the survey was taken during a single time point may not account for differences in risk for LEA and weekly training volume that could be observed between phases of training (i.e. pre-season, competition, or off season). Lastly, although the DESA-6 has been validated for use in identification of DE behaviors among all levels of athletes, it has not yet been widely used to detect individuals at risk for DE, and there is limited literature detailing its use in female runners.

Conclusion

This study confirms that a large proportion of female collegiate runners are at high risk for LEA (54.4%) and DE (40.8%), however there was no difference in risk between collegiate Divisions (I, II, or III), and risk of LEA was not related to weekly running volume. Furthermore, athletes at risk for LEA were more likely to be at risk for DE, report MD, and greater body weight dissatisfaction. Coaches and practitioners should be educated on the signs of DE, MD, and weight dissatisfaction as they may warning signs for the development of LEA, and the potential associated health and performance effects if left untreated. Therefore, these findings warrant early identification, education, prevention, and intervention strategies to support health and athletic performance. Understanding and awareness around reproductive health, injury history, signs of unhealthy eating behaviors, and negative physiological and performance decrements of LEA are fundamental in the prevention of LEA. Runners at risk for LEA or DE should be referred to a registered sports dietitian for an assessment as an increase in energy intake and/or a decrease in exercise exergy expenditure are necessary for treatment of LEA. Lastly, more studies are needed to investigate this population of female collegiate runners and the role of DE, weight dissatisfaction, training volume, and how they contribute to risk of LEA. More research is warranted into potential differences in student-athlete resources and access to registered dietitians among NCAA Divisions, and the potential impact this may have in the prevention and treatment of LEA.

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