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# Relative Energy Deficiency in Sport (RED-S) Risk Factors Among Collegiate Athletes

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RELATIVE ENERGY DEFICIENCY IN SPORT (RED-S) RISK FACTORS AMONG COLLEGIATE ATHLETES

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BACKGROUND: Low energy availability is a topic of concern for recreational and elite athletes alike due to its negative impact on both physiology and performance. The introduction of the Relative Energy Deficiency in Sport model by the International Olympic Committee in 2014 highlighted the widespread effects of poor fueling on an athlete’s overall health. Unfortunately, RED-S is not typically detected until the athlete has already suffered significant health or performance detriments from inadequate calorie intake. PURPOSE: The purpose of this study is to examine the prevalence of risk factors associated with RED-S among collegiate athletes and evaluate the potential need for further RED-S screening and intervention measures at the university level. METHODS: The participants include 38 collegiate athletes who participate at the NCAA Division I level. The study involves two methods of data collection: a survey and a bone density scan. The survey was distributed electronically using Qualtrics and bone density was evaluated by dual-energy x-ray absorptiometry (DXA). Responses were summarized and analyzed using a series of one-way ANOVA’s. RESULTS/CONCLUSIONS: The results from the survey and the DXA scans indicate the presence of RED-S among the subjects, with 64.5% of female participants (n=31) scoring above the cutoff for increased RED-S risk. Those with greater days missed due to injury and illness tended to have higher LEAF-Q scores than those who had fewer absences; however, the findings were not statistically significant (all $p > 0.05$). These findings underscore the need for coaches, trainers, and practitioners to identify and monitor athletes who are particularly at risk for RED-S, helping to ensure the health and safety of the athletes during their collegiate careers and beyond.

KEYWORDS: RED-S; relative energy deficiency; Female Athlete Triad; low energy availability; female athletes; bone mineral density

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H.K.M.

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# CHAPTER I: INTRODUCTION

Diet and exercise have long been the prescribed answer to achieving desired body composition. This is typically understood as *eat less, exercise more*. While caloric deficit does result in weight loss, a chronic negative energy balance can lead to low energy availability (LEA), which can be detrimental to the health and performance of the elite and recreational athlete alike (Slater et al., 2016). For the collegiate athlete, limited food options, an increase in practice workload, and heightened pressure to perform can create a scenario for low energy availability to develop. When considered alongside the high rate of eating disorders among athletes, specifically in females (Bratland-Sanda & Sundgot-Borgen, 2013), the increase in exercise energy expenditure provides even greater risk for LEA to develop.

Energy availability refers specifically to the difference in energy intake minus energy expended during exercise. LEA occurs when there is not enough energy remaining after exercise to maintain optimal metabolic health (Loucks et al., 2011). This can result in a variety of neuroendocrine changes which occur to either preserve energy for essential functions or draw required energy from stored reserves (Misra, 2014). As a result, nutrients are diverted away from the most energetically expensive systems (Wade & Schneider, 1992), such as the reproductive system, leading to menstrual irregularity (De Souza et al., 2007) and loss of bone mass (Ihle & Loucks, 2004; Papageorgiou et al., 2017). Together, these three components – LEA, menstrual status, and bone health – create the Female Athlete Triad (Triad), a model developed to characterize the high prevalence of fracture seen among female athletes (Otis et al., 1997).

There have been many studies supporting the interrelationship between the three Triad components, as well as studies indicating the effects of LEA on immune response (Hagmar et al., 2008), musculoskeletal injury (Rauh et al., 2014), and athletic performance (Vanheest et al., 2014; Tornberg et al., 2017). Though less studied than the female population, males are not immune to the effects of LEA (De Souza et al., 2019; Tenforde et al., 2016), and can experience disruptions of hormone levels (Hooper et al., 2017; Wheeler et al., 1984) and lowered bone mineral density (Barrack et al., 2017). This has led to the creation of the Male Athlete Triad (Nattiv et al., 2021) which includes LEA, functional hypothalamic hypogonadism, and osteoporosis.

Due to the variety of symptoms that result from LEA, as well as its effects on males, the International Olympic Committee introduced the term Relative Energy Deficiency in Sport (RED-S) to expand on the Triad (Mountjoy et al., 2014). This term includes 10 performance and 10 physiological components that may develop from, and therefore indicate, a low energy availability which greatly increases the number of risk factors for the Triad. Though Triad literature has previously indicated that cardiovascular, psychological, and performance detriments can occur with LEA (Otis et al., 1997), RED-S includes other symptoms that have not been previously included, raising awareness of the extent to which LEA can affect physiology and performance. Because of the widespread impact of RED-S on the health and wellbeing of athletes, it is essential that a LEA is detected early on to provide intervention before long-term damage occurs. This is most simply and cost-effectively done by questionnaire and, while there are multiple questionnaires that classify fracture risk based on Triad symptoms (Tenforde et al., 2017; Melin et al., 2014), there is not currently a validated screening method for RED-S, which makes screening male athletes particularly difficult (Sim & Burns, 2021). Therefore, the purpose of this descriptive study was to examine the prevalence of risk factors associated with RED-S among a cohort of collegiate athletes. Our hope was to evaluate the potential need for intervention, inform future research, and gain an understanding of the prevalence of RED-S characteristics across a group of athletes.

# CHAPTER II: METHODS

## Sample

Participants were athletes competing in various collegiate sports at a NCAA Division I university. A total of 38 athletes completed the entire survey, including 31 females and 7 males between the ages of 18 and 23 (see Table 1 for demographic information). A total of 13 female participants and 1 male participant reported t-scores from the DXA scan.

## Survey

The survey was distributed through the Director of Sports Nutrition to limit coercion and ensure all athletes were invited to participate. Participation in the electronic survey was anonymous to all parties, including sport coaches and members of the research team. The survey was created and distributed electronically the athletes using Qualtrics (Qualtrics, Provo, UT). Informed consent was provided prior to participating and the study protocol and survey instruments were approved by the Institutional Review Board. The survey contained a total of 53 questions which were developed to address both Triad and RED-S related symptoms. The questions addressed general information demographic and descriptive data such as sex, height, weight, and ethnicity. Sport-specific questions were included to gain a better understanding of the participant's experience in their sport, time spent training each week, and the general nature of their training. The survey the addressed questions regarding RED-S specific symptoms (see Appendix A for the full survey). These questions were based on surveys developed in previous RED-S research (Heikura et al., 2018; Koltun et al., 2019; Foley-Davelaar et al., 2020). The final portion of the survey included questions from the Low Energy Availability in Females Questionnaire, or LEAF-Q (Melin et al., 2014), which addresses Triad specific issues. The

LEAF-Q is a validated screening method which has been shown to reliably detect the presence of LEA in females (Luszczki et al., 2021).

**DXA**

The second portion of the study was performed to evaluate bone mineral density in a subset of survey participants. LEA has been shown to negatively impact bone mineral density (Cobb et al., 2003) which can lead to fracture. Participants were given the opportunity to volunteer for a dual-energy x-ray absorptiometry scan (DXA) in addition to the survey. A sign-up for the DXA scan was distributed via email by the Director of Sports Nutrition, with the scans taking place in the exercise physiology lab. Participants were given an informed consent and a pre-participation screening form upon arrival at their appointment. Those who had received a DXA scan within the last year were not allowed to participate. Participants then received a DXA scan and were provided with a printout of their results at completion, with t-score being used to determine bone mineral density, as outlined by Jain and Vokes (2017), and the participants were asked to report their t-score as part of their electronic survey if they chose to do so. This allowed the researchers to examine the relationship between survey responses and bone mineral density scores.

**Data Analysis**

The results from the survey were analyzed in Qualtrics. Each response from the LEAF-Q portion of the survey was weighted according to the answer key developed by Melin et al. (2014), and each participant was given a LEAF score accordingly. This scoring key can be found in Appendix B. Because the majority of LEAF questions relate to menstrual function and hormonal contraceptive use, male respondents were excluded from the scoring portion of the survey and results. Each female was given a LEAF score based on their responses. A score ≥8 has been established as the threshold indicating low energy availability (Melin et al., 2014), with those scoring at or above the cutoff having an increased risk for Triad symptoms such as impaired reproductive function and/or bone health. A series of one-way ANOVA's was used to determine if LEAF scores differed by survey responses to days missed due to illness, injury, or prior suspected stress fracture.

# CHAPTER III: RESULTS

Table 1 summarizes the sex, age, race/ethnicity, and sport participation of the 38 collegiate athletes, with the BMI calculations for female participants in Table 2. Using the established LEAF score cutoff value of ≥8, we found that 64.5%, or 20 of 31, females were at higher risk for developing RED-S and Triad related symptoms, as shown in Figure 1. Table 3 indicates the relationship in females between days missed due to injury and illness, t-scores, and LEAF scores for the 31 female participants.

In regard to illness, female athletes who had been sick with an upper-respiratory tract infection (URTI) 0 times had a lower average LEAF score (6.7 ± 4.1) than those who had been ill 1-2 (8.9 ± 3.4) or 3 or more times (9.0 ± 3.4). However, these differences were not statistically significant (all comparisons $p > 0.05$). Of the 25 females who reported having a URTI within the past year, higher absences due to illness tended to correspond with higher mean LEAF scores (1-3 days = 8.5 ± 3.4, 4-7 days = 9.0, 7-14 days = 14.0, 14+ days = 10), although these differences were not statistically significant ($p > 0.05$). Those who reported having a URTI but missing no days of practice because had a mean LEAF score of 9.0 ± 3.3. The lowest average LEAF score, and the only group that was categorized as low-risk for RED-S, are those who did not have a URTI within the past year, with athletes in all other groups having a mean score of 8 or higher. Table 4 indicates the percent of females who had a LEAF score ≥8 and the corresponding number of days missed due to injury or illness.

In regard to injury, females who reported more days missed due to injury had a higher mean LEAF-Q score than those who had missed no days due to injury. The lowest mean LEAF-Q was seen in the group with no absences due to injury (7.9±4.0), with an increase seen between 1-2 times (8.5±3.6) and 3-5 times (11±2.8). The four females who had 5 or more absences had a mean score of 9.5 ± 0.6. However, the ANOVA indicated that these differences were not statistically significant ($p > 0.05$). Using the DXA data, mean t-score tended to increase with the number of injury absences; however, these differences were not statistically significant ($p > 0.05$).

Females with a previous suspected stress fracture had a higher mean t-score (1.2±0.9) than those without a previous suspected fracture (0.6±1.1), with very little difference in mean LEAF score seen between the group with (8.6±4.2) and without a previous suspected stress fracture (8.5±3.4). However, the ANOVA indicated that none of these differences were statistically significant ($p > 0.05$). We also did not find a statistically significant relationship between reported menstrual regularity, or the number of menstrual cycles per year, and BMD.

When asked if they had normal menstruation, 55% (17) of females responded “Yes”, and 45% (13) responded “No” or “I don’t know”. 12 athletes reported having their last period 2-3 months ago, and 3 had not menstruated in 6 months or more, indicating secondary amenorrhea. 12.9% (4 of 31) of females reported having experienced primary amenorrhea, or having their first menstruation at age 15 or older. One female reported having never menstruated despite being 22 years old and currently taking an estrogen supplement prescribed by her physician. Even with primary amenorrhea, the participant’s t-score is +1.2, and BMI is 25.2 ($72.7kg/(1.7m)^2$), suggesting that a low BMD or low BMI alone may not indicate RED-S. There was also not a relationship seen between number of injuries in the past year and number of menstrual cycles.

**Table 1**

*Descriptive statistics for survey population*

| Variable | Count (n=38) | Percent | Mean |
|---|---|---|---|
| Sex | | | |
| Male | 7 | 18.9% | |
| Female | 31 | 81.1 | |
| Race/Ethnicity | | | |
| White/Caucasian | 34 | 89.5 | |
| Black/African American | 2 | 5.3 | |
| Other | 2 | 5.3 | |
| Age (years) | | | |
| 18 | 5 | 13.2 | **19.9** |
| 19 | 11 | 28.9 | |
| 20 | 11 | 28.9 | |
| 21 | 6 | 15.8 | |
| 22 | 4 | 10.5 | |
| 23 | 1 | 2.6 | |
| Sport | | | |
| Track only | 7 | 18.4 | |
| Track & Cross Country | 7 | 18.4 | |
| Swimming and Diving | 11 | 28.9 | |
| Volleyball | 4 | 10.5 | |
| Soccer | 4 | 10.5 | |
| Gymnastics | 5 | 13.2 | |

**Table 2**

*Body mass index (BMI) of female participants*

| | BMI ($kg/m^2$) | Count (n=32) | Mean |
|---|---|---|---|
| Category | | | |
| | Underweight | 1 | 22.6 |
| | Normal | 26 | |
| | Overweight | 5 | |

**Table 3**

*Fracture history and absences due to injury and illness in relation to DXA t-scores and LEAF-Q scores (Females only)*

| Variable | DXA count (n=13) | Mean DXA t-score | LEAF count (n=31) | Mean LEAF-Q score |
|---|---|---|---|---|
| Absences due to injury | | | | |
| None | 5 | 0.26 (0.6) | 14 | 7.9 (4.0) |
| 1-2 times | 6 | 1.02 (0.8) | 11 | 8.5 (3.6) |
| 3-4 times | 2 | 1.20 (2.7) | 2 | 11.0 (2.8) |
| 5+ times | - | - | 4 | 9.5 (0.6) |
| Previous suspected fracture | | | | |
| Yes | 2 | 1.6 (0.9) | 7 | 8.6 (4.2) |
| No | 11 | 0.6 (1.1) | 24 | 8.5 (3.4) |
| Training missed/modified due to URTI (days) | | | | |
| None | 2 | 1.05 (0.2) | 6 | 6.7 (4.1) |
| 1-3 | 6 | 0.2 (0.6) | 16 | 8.5 (3.4) |
| 4-7 | - | - | 1 | 9.0 (-) |
| 7-14 | 1 | 1.2 (-) | 1 | 14.0 (-) |
| 14+ | - | - | 1 | 10.0 (-) |
| Other[a] | 4 | 1.3 (1.7) | 6 | 9.0 (3.3) |

[a]Group reported having a URTI, but no days of practice were missed or modified because of it.

**Table 4**

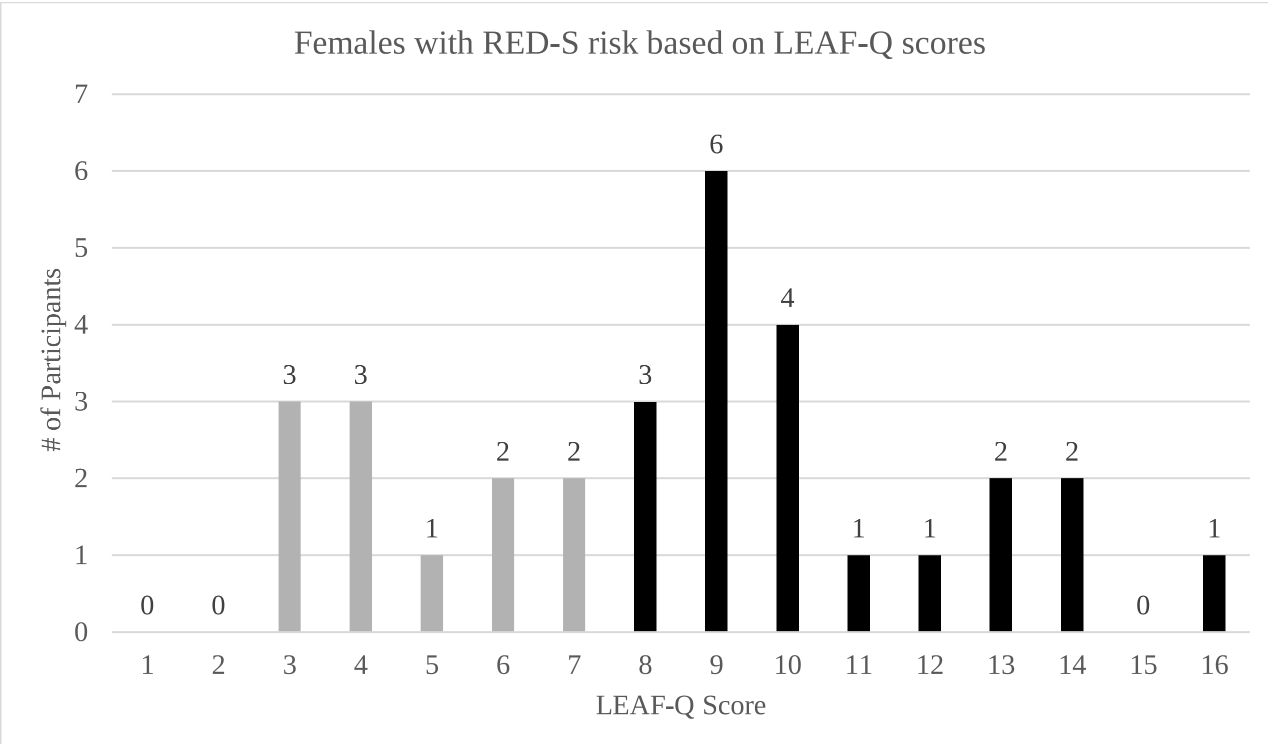
*Fracture history and absences due to injury and illness in relation to percent of respondents with a LEAF score ≥8 (females only)*

| Variable | Count (n=31) | % with LEAF-Q score ≥8 |
|---|---|---|
| Absences due to injury | | |
| None | 14 | 50% |
| 1-2 times | 11 | 63.6% |
| 3-4 times | 2 | 100.0% |
| 5+ times | 4 | 100.0% |
| Previous suspected fracture | | |
| Yes | 7 | 57.0% |
| No | 24 | 66.7% |
| Training missed/modified due to URTI (days) | | |
| None | 6 | 33% |
| 1-3 | 16 | 62.5% |
| 4-7 | 1 | 100% |
| 7-14 | 1 | 100% |
| 14+ | 1 | 100% |
| Other[a] | 6 | 83.3% |

[a]Group reported having a URTI, but no days of practice were missed or modified because of it.

**Figure 1**

*Females with RED-S risk based on LEAF-Q scores*




*Note.* The LEAF-Q scores for the female participants, as totaled from survey responses. A score of 8 or higher indicates and increased risk for LEA and RED-S. 64.5% (20 of 31) athletes scored 8 or higher and are at risk for experiencing the health and performance detriments associated with RED-S.

# CHAPTER IV: DISCUSSION

The results from this study indicate that a significant portion of these female athletes may be at risk for developing RED-S, and the consequent health and performance detriments that are associated with the condition, based on the LEAF-Q. In this study, nearly two out of every three women were placed at an increased risk for LEA related issues.

Overall, 64.5% of females had a LEAF score ≥8, which is similar to the 64.7% of LEAF-Q respondents found to be at risk in a study of female soccer players (Luszczki et al., 2021). This percentage is also consistent with the prevalence of females (63%) found to have LEA based physiological measures collected by Melin et al. (2015). Based on these previous results, it would seem the majority of females participating in high-level sports have at least some underlying features of RED-S.

Those with higher LEAF-Q scores also tended to have a greater number of days missed due to injury and illness; however, the differences were not statistically significant, likely due to the low sample size of the current study A prior study investigating collegiate distance runners found a significantly higher number of injuries in athletes who had a LEAF score ≥8 (2.57±1.98) than those who did not score above the threshold for LEA (0.33±0.51). This included an increased injury rate in males who were classified as “at risk” with a modified LEAF threshold of 3.2 (Schimek et al., 2021). Drew et al. (2017) found LEAF-Q score to be significantly correlated ($p=0.04$) with illness rate among female Olympic athletes, with the highest attributable fractions in the population indicating that removing the LEA variable would remove 76% of illnesses. It was also found that females who scored ≥8 on the menstrual portion of the LEAF-Q were at a significantly greater risk ($p=0.03$) for illness than those with a menstrual score <8, suggesting an interrelationship between endocrine function and immune response (Stelzer &

Arck, 2016). Heikura et al. (2017) found that amenorrheic females (AME) had lower EA compared to eumenorrheic females (AME=32 ±12 kcal/kgFFM/d, EUM=35 ± 9). Likewise, the AME group had more days missed due to combined injury and illness (AME=58±48 days, EUM=32±35 days) and bone injuries alone (AME=32±41 days, EUM=7±18 days). This indicates the potential link between LEA, menstruation, and injury and illness rate, emphasizing the important role of nutrition during periods of heavy training when the immune system may be particularly susceptible to illness (Nieman, 1995).

While BMD was found to be higher in the group with a previous suspected stress fracture, the relationship was not statistically significant in this subset of our sample. The higher BMD seen is opposite of what would be expected based on previous studies. Lower mean BMD was found by Kelsey et al. (2007) to correlate with fracture history, who found that athletes with a history of fracture were five times more likely to develop a stress fracture during the two-year follow-up study. A two-fold increase in fracture risk was also seen in collegiate athletes placed as “moderate risk” for the Triad, with a four-fold increase in fracture risk occurring in “high-risk” athletes (Tenforde et al., 2017). This same study found that oligomenorrhea/amenorrhea score and prior stress fracture score were independent predictors for future fracture. Though it was difficult to see significant relationships between individual responses and BMD in this study due to the small number of reported t-scores, higher LEAF scores have been shown to be correlated with lower BMD Z-scores (Meng et al., 2020). Whether recurrent fracture occurred due to a genetic predisposition to low BMD or because of an external factor, such as LEA, these studies would suggest that athletes with a fracture history may need to be more carefully monitored to reduce their susceptibility to subsequent bone stress injuries.

RED-S may be a concern among Division I athletes regardless of sex. The male participants in this study also reported experiencing some symptoms that may be related to RED-S, including time missed due to injury and multiple upper-respiratory tract infections. Currently, no validated scoring system has been developed to assess for LEA in males. However, the LEAF has been adjusted in some studies to include only the gastrointestinal and injury sections, with a modified cutoff score of 7 drawn from the average scores for “at risk” females in the same categories. Using this adapted screening method, it was found that 54% of elite male cross country runners were at risk for LEA, compared to 79.5% of females (Jesus et al., 2021). Though prevalence of LEA is not as high in males, many males do exhibit symptoms associated with RED-S. A separate, sport-specific energy availability questionnaire and clinical interview (SEAQ-I) was developed by Keay et al. (2018) to assess for LEA in road cyclists. Using the questionnaire, 44% of males were placed at risk for RED-S, with a lower score found to be correlated with lower lumbar spine BMD Z-score. These findings further suggest a relationship between LEA and lowered BMD in male athletes, particularly in endurance athlete. An adjusted LEAF-Q is currently being developed to indicate low energy availability in males (LEAM-Q), and may help fill the gap in male-specific RED-S screening methods (Mountjoy et al., 2018).

The use of the LEAF-Q and supplemental RED-S questions in the survey provided a clearer picture of each participant’s athletic and health history than one questionnaire alone. The anonymous nature of the survey also removed pressure to participate and encouraged honest responses that the participant’s may not have been comfortable answering otherwise. The DXA data, though only collected in a subset of the sample population, provided valuable data for a key component of both Triad and RED-S research. Limitations of the study included the self-reported survey questions and t-scores, which may limit the reliability of the responses due to the bias of self-report. The small sample size, particularly for the male population and the DXA results, limited our statistical power to detect true statistically significant results. Future studies would benefit from including the adiposity information provided by DXA, as well as including other physical measures such as resting metabolic rate and exercise energy expenditure. Utilizing other survey methods, such as the Three Factor Eating questionnaire, may be beneficial in identifying cognitive dietary restraint, which has been associated with lower energy intake and lower lumbar BMD z-score (Wood et al., 2021).

The symptoms of LEA are relatively common among the survey sample herein, and whether a chronic negative energy balance is intentional or unintentional among the athletes, it may need to be corrected before irreversible damage occurs. For example, educating female athletes on self-monitoring for changes in menstruation would be a simple yet effective method to assess for endocrine and menstrual function. When asked "Do you have normal menstruation?", one female marked "I don't know". The same participant then reported that they have not menstruated "in a few years" despite taking synthetic hormones via oral contraceptives. This indicates that female athletes may not be aware of what is "normal" and "abnormal" for reproductive health, potentially having never experienced "normal" menstruation. A survey distributed to 306 females at an ultramarathon event found that 48.4% of participants believed it was normal to stop menstruating during heavy training. 283 participants (92.5%) had never heard of the Triad, and only 3 (1%) were able to name all three components. Despite this, 44.1% of the females were classified as "at risk" for the Triad based on their LEAF scores (Folscher et al., 2015), indicating the lack of Triad and RED-S awareness among the physically active population.

In conclusion, we found approximately 64% of the current female sample had LEAF-Q scores at or above 8. This may place them at increased risk of RED-S and the female athlete triad. Increasing RED-S awareness through the availability of educational tools, along with access to treatment resources, may help athletes recognize RED-S related symptoms before more serious health and performance complications arise. Regularly screening for RED-S among both male and female athletes may improve the detection and monitoring of LEA-related changes, helping ensure the health of the athlete during their collegiate career and beyond.

## CHAPTER V: EXTENDED LITERATURE REVIEW

### Introduction

Relative Energy Deficiency in Sport (RED-S) is a relatively new concept in the field of exercise physiology. However, the model was developed from a substantial base of literature centered around the Female Athlete Triad (Triad). The contraindications of low energy availability have been studied for decades, including its effects on increased fracture risk. The purpose of this literature review is to examine the central factor of the RED-S model, which is low energy availability, as well as investigate the Triad and RED-S screening methods that are currently available to practitioners.

### Triad and Fracture

To monitor stress fracture prevalence Kelsey et al., (2007) evaluated 127 female distance runners over the course of two years. At the initial data collection, the athletes completed a questionnaire regarding menstrual function, oral contraceptive use, history of fracture, sport participation history, nutrient intake, and history of eating disorder. Height and weight were also gathered to calculate for BMI and body composition, including bone mineral density, was measured via dual-energy x-ray absorptiometry (DXA). After the baseline measurements were taken, participants were then asked to report any stress fractures that occurred for the duration of the two-year study. Participants also returned annually for follow-up densitometry and anthropometric measurements. At baseline it was found that 31% of participants had experienced a previous stress fracture, 57% reported a history of menstrual irregularity, and 40% had used an oral contraceptive at some point. During the two-year study, 18 of the 127 runners in the study had at least one stress fracture, with four of the runners experiencing a second fracture in that time. It is important to note that the women with a history of fracture were five-times more likely to develop a fracture during the follow up than women who had no history of stress fracture. Other factors that had a statistically significant ($p<0.10$) association with increased fracture rate included lower whole-body bone mineral density, lower daily calcium intake, younger age of menarche, lower lean body mass, and lower weight. Items typically thought to be associated with increased fracture risk, such as menstrual irregularity and body fat percentage, were not found to be associated with an increase in fracture risk. This study mainly evaluated the Triad components and their relationship to fracture, which include low energy availability, menstrual dysfunction, and fracture (Otis et al., 1997).

To further the study of the Triad and fracture incidence, Ackerman et al., (2015) examined the relationship between fracture risk, menstrual status, and bone strength and structure in athletes. The cross-sectional study involved 175 females between the ages of 14 and 25 who ran at least 20 miles per week or engaged in >4 hrs/wk of aerobic weight-bearing activity. Of these athletes, 100 were classified as oligomenorrheic and 35 were classified as eumenorrheic. There were also 40 non-athletes included in the study, with non-athletes being defined as those who exercise for less than 2 hours per week. Information obtained from the participants included fracture history, menstrual history, and exercise/athletic activity within the past 12 months. Volumetric bone mineral density was measured via high-resolution peripheral quantitative computed tomography, or HR-pQCT. This was done to obtain both the density and the microarchitecture of the bone. Other measured factors included REE via indirect calorimetry, blood calcium and Vitamin D levels, and bone age via hand radiographs. The researchers found that the amenorrheic group (AA) had lower BMI, lower percent ideal body weight, and lower fat mass than the other two groups. Lean mass in the AA group was lower than the eumenorrheic (EA) group, and body fat percent for the AA group was lower than the non-athlete group.

Resting energy expenditure was also lower in the AA group compared to the EA group. The AA group also had higher Vitamin D levels and a higher rate of history of eating disorder than the other two groups. HRpQCT results showed the AA group had lower percent cortical area and thickness, greater cortical porosity, and lower total vBMD than the non-athlete group. Fracture rate calculated after the average age of menarche, age 12.5, revealed 31% of AA athletes, 5.9% of EA athletes, and 0 non-athletes had had a stress fracture. It was also found that the AA athletes who had history of fracture had lower whole body and spine BMD z-scores than the AA athletes who had no fractures. No differences in BMD z-scores were seen between the EA and non-athlete groups. In weight bearing bones, such as the tibia, the AA group had a higher total and trabecular area and cortical porosity than the non-athletes, but higher than the EA group. This suggests that the tibia is protected by the bone-strengthening nature of weight-bearing exercise. However, AA athletes are not seeing the increase in overall BMD or improvement in the stiffness that they should be seeing over non-athletes.

To expand fracture research beyond the Triad components, Ackerman et al., (2018) examined the prevalence of the physiological and performance detriments associated with RED-S as outlined by the International Olympic Committee (2014). The study included questionnaire responses from 1,184 female athletes ages 15-30 who had participated in 4 or more hours of physical activity per week for at least six months. Due to the lack of validated RED-S surveys, the questionnaire was based on a selection of validated and standard surveys that assess for individual components of RED-S. This included questionnaires related to eating disorders, menstrual function, bone health, hematological health, metabolic health, growth and development, cardiovascular risk, and gastrointestinal health. Changes in performance were also assessed, with participants answering yes/no questions related to decreased training response, decreased coordination, decreased concentration, impaired judgement, depression, and irritability. The results of the survey indicated that nearly half of the athletes, 47.3%, screened positive for low energy availability on at least one of the screening tests. For physiological components, athletes with LEA were found to have an increased prevalence of bone, metabolic, cardiovascular, psychological, hematological, and gastrointestinal issues than those with normal EA. For performance related components, the LEA group had a greater incidence of decreased training response, impaired judgement, decreased coordination, decreased concentration, irritability, depression, and decreased endurance performance than the adequate EA group. Interestingly, the low EA group had significantly higher mean BMI than the adequate EA group ($23.8 \pm 3.9$ vs. $22.2 \pm 3.5$, $p<0.0001$). This suggests that LEA cannot always be assessed visually; athletes with a normal BMI but a low body fat percentage may be at risk for LEA and the physiological and performance detriments associated with the condition.

The effects of RED-S can be detrimental to the athlete, but why does an energy deficiency stress so many bodily systems at once? The main reason is endocrine and metabolic function. When nutrients are not readily available, “several adaptive neuroendocrine mechanisms come into play either to conserve energy for the most essential functions, or to allow the body to draw on its reserves to meet energy needs, (Misra, 2014)”. To study specific hormonal changes that results from an energy deficiency, Loucks & Thuma (2003), manipulated the energy balance of athletes and assessed the hormonal response. The participants include healthy, eumenorrheic women ages 18-30, with the experiment lasting a total of nine days. Three days of the study included pre-treatment data collection where daily energy expenditure and urine and blood samples were collected. Five days of the study involved treatment, with the independent variable being changes in energy intake. Participants were randomly assigned to an energy intake group each day, with an energy balance (45kcal/kgLBM/d), or an energy restriction (30, 20, or 10kcal/kgLBM/d). Energy expenditure remained the same and participants performed exercise at 70% of their VO2max until they achieved an expenditure of 15kcal/kg LBM. The lutenizing hormone concentration was then measured in each subject. The participants then completed the experiment a second time after two months. At the conclusion of the study, it was found that reducing energy availability to 20 kcal/kg LBM/d suppressed luteinizing hormone (LH) pulse frequency by 16% ($p<0.01$) and increased amplitude by 21% ($p<0.05$). An energy availability of 10 kcal/kg LBM/d suppressed LH pulse frequency by 39% ($p<0.01$) and increased pulse amplitude by 109% ($p<0.01$). There were no significant differences in LH pulse frequency or amplitude in the balanced and restricted (30 kcal/kg LBM/d) diets. These findings emphasize the detrimental effects lower energy availability can have endocrine function. Because luteinizing hormone is essential to ovulation, it is clear that a lack of LH could result in amenorrhea. The authors also note that the threshold of 30 kcal/kg LBM/d for the exercising women in the study is equivalent to the energy intake in sedentary women. Even in a short-term energy deficit the body is capable of remain high functioning without an increase in energy intake. It is the combination of increased energy expenditure from exercise and a decrease from restrictive eating that causes endocrine disruption.

Though hormonal disruptions are often easier to self-monitor in women due to changes in menstrual function, men are not immune to the effects of low energy availability. It has been shown that the male skeleton is less susceptible to the effects of low energy availability on increased bone resorption (Papageorgiou et al., 2017), and yet bones stress injuries still occur in male athletes. A study done by Barrack et al. (2017), examined the relationship between multiple Triad-related components and their effects on bone mass in male adolescents. The study included

69 males between the ages of 13 and 19, with 51 of the athletes participating in endurance running, either cross country or track, and 18 non-runners participating in ball sports. The athletes then had their height and weight measured, as well as their body composition via DXA. The participants then completed a survey regarding diet, sports participation and training volume, stress fracture history, and perceptions about their weight and body composition. The results of the survey and physiologic measures found that the runners had lower bone mineral density (BMD) z-scores, lower body weight, lower percent expected body weight, and lower BMI than the non-runner athletes. There were four main risk factors associated with lower BMD in athletes: body weight less than 85% expected weight, mean weekly running mileage >30 miles, history of a previous fracture, and consuming less than one gram of calcium per day. The risk of fracture increased from 11.1% to 42.9% to 80.0% for athletes who exhibited 1, 2 or 3-4 of the risk factors. While this study did not directly measure energy availability or hormone concentration, the findings indicate that male endurance athletes are at higher risk for developing bone stress fractures than the non-runner athletes.

**Screening Methods**

While the detrimental effects of low energy availability for both male and female athletes are clear, screening is more difficult. Though there are validated tests to measure eating disorders/disordered eating, there are no validated tests that detect low energy availability and symptoms associated with the Triad. Melin et al. (2014) developed a screening tool to identify females who were particularly at risk for the Triad based on self-reported physiological symptoms. This questionnaire was developed with females ages 18-39 who trained 5 or more days per week. The first version of the survey included 29 questions based on the symptoms most commonly associated with low energy availability, such as dizziness, injuries, cold sensitivity, gastrointestinal function, and menstrual function including the use of oral contraceptives. The survey was then distributed a second time within 2 weeks to account for test-retest reliability. Participants (n=47) then volunteered for additional screening to validate the self-reported symptoms from the survey. This testing involved assessments of energy availability based on 7-day eating logs, exercise energy expenditure as measured by a maximal exercise treadmill test, and accelerometer and heart rate monitor data collected over 7 days. The presence of an eating disorder or disordered eating behavior was determined by the Eating Disorder Inventory and Eating Disorder Examination. Reproductive function was measured by a gynecological exam. Body weight and height were measured, and fat-free mass, fat mass, and bone mass were measured via dual energy x-ray absorptiometry (DXA). The DXA scan also provided a bone density for each participant. A supine to standing blood pressure was taken and blood-hormone concentration was evaluated from a blood draw. It was found that after the two-week period between tests there was a 0.79 test-retest reliability.  Based on the results from the physiological assessments, the LEAF-Q was found to have a sensitivity of 78% and a specificity of 90%. When the two participants who were diagnosed with PCOS after the gynecological exam were removed from the results the sensitivity increased to 83%. This study provided a validated questionnaire that is an affordable, feasible, and effective method to assess for an energy deficiency without tests or quantitative measures.

The LEAF-Q was recently utilized by a soccer team to evaluate the presence of Triad/RED-S risk factors among its players. Luszczki et al. (2021) administered the questionnaire to a total of 34 participants, all of which were females age 13-18, had participated in football (American soccer) for a minimum of two years, were currently training 3 days per week, and were currently competing in one match per week. Height and weight were measured and used to calculate BMI for each subject. Resting energy expenditure (REE) was determined by indirect calorimetry, BMD and body composition were collected via DXA, and a 24-hour dietary recall was provided to evaluate energy intake and classify the participants as either above or below energy consumption standards for their age, gender, and physical activity level. The LEAF-Q was then administered to the participants (Melin et al., 2014) with a score ≥8 indicating a greater risk for low energy availability and the female athlete triad. Based on these criteria, 64.7% of the participants were classified as at risk for female athlete triad and RED-S. It was also found that 76.5% of the participants did not meet the energy recommendation standards, and those who did not meet the requirements were 10 times more likely to be placed in the Triad and RED-S "at-risk" group. The study also noted that only one athlete was classified as underweight and the difference in REE between the two groups was not statistically significant. There was also no statistically significant difference in BMD or BMD Z-score between the at-risk and no-risk groups. The researchers speculate that the lack of physiological differences between the at-risk and no-risk groups may be due to the age of the athletes. Because physiological changes occur over time, and since the mean age of participants was 15.41 ± 1.42 years, the typical changes in BMD, BMI, and REE seen in athletes struggling with RED-S may not have yet occurred. Yet the large number of athletes classified by the LEAF-Q as "at-risk" indicates that low energy availability is prevalent among the participants. This emphasizes the importance of implementing screening methods at a young age. By detecting less severe symptoms of low energy availability at an early age, such as primary amenorrhea, intervention can occur before more serious physiological damage, such as stress fracture, occurs.

The LEAF questionnaire is a validated method for female athletes, but there is no validated screening method for male athletes. As was shown in Barrack et al. (2017), males are also susceptible to bone stress injuries, particularly men who participate in long distance running. With this in mind, Krause et al. (2019) did not attempt to validate a screening method but rather set out to determine whether a modified Triad risk assessment would predict bone stress injuries (BSI) in male athletes. The researchers modified the Female Athlete Triad Coalition Consensus Statement Cumulative Risk Assessment tool by excluding late menarche and history of oligomenorrhea/amenorrhea as variables. Instead, the risk assessment included only low energy availability (EA), low body mass index (BMI), low bone mineral density (BMD), and previous BSI. The study included 156 male runners at two different universities, with one cohort participating in 2010-2013 and a second cohort participating in 2013-2017. The first cohort received a pre-participation physical examination (PPE), which contained questions about eating disorder history, history of low BMD, and history of BSI. Height and weight were also collected. The second cohort completed a similar PPE along with a nutrition assessment and DXA scan. At baseline it was found that low EA and low BMI were not common. For the athletes who received a DXA scan, 14.8% had a Z-score below -1.0, with the number increasing to 17.0% during the longitudinal study. It was also found that 30.1% of the athletes had a history of BSI at baseline. A total of 305 observations were collected, with 42 runners, or 27%, sustaining a total of 61 BSIs during the study. It was found that each point in the baseline risk assessment, or risk per person, increased risk for BSI by 37% ($p=0.0079$) and for the longitudinal risk assessment, or risk per observation, risk for BSI increased by 27% ($p=0.05$) for each point. This study indicates that it is possible to qualitatively screen for BSI risk in males despite the Triad risk assessment being developed specifically for women. By looking at combined risk factors it may be possible to identify males who are at risk for developing a BSI before it occurs. Though not the intention of the study, it is evident that males are at risk for developing stress fractures. With 27% of the athletes sustaining one or more fractures during the study, the need to develop screening methods for males as well as females is evident.

To further study the presence of RED-S among the male population, Torstviet et. al. (2019) examined the correlation between exercise dependence, eating disorder, and RED-S symptoms in men. Eating disorders (ED) and exercise dependence (EXD) have been more thoroughly studied among females and are known to increase the prevalence of RED-S biomarkers due to the combination of a restricted diet and increased exercise energy expenditure. The participants included 53 male endurance athletes between the ages of 18 and 50 with a VO2max > 55ml/kg/min. Measurements were taken over a four-day period and included body mass, height, VO2max, RMR, blood samples, DXA, and energy intake and expenditure. Questionnaires were used to assess for the presence of disorders, including the Exercise Dependence Scale (EXDS) and Eating Disorder Questionnaire (EDE-Q). The results of the measures and questionnaires indicated there is a relationship between ED and EXD, and a higher EXD was positively correlated with RED-S biomarkers. Participants with higher EXD scores had higher daily EEE and had a negative daily energy balance ($-479 \pm 657$, $p<0.05$) compared to those with lower EXD scores. The athletes with higher overall EXD scores also exhibited higher cortisol levels. When considering subscales of the EXD questionnaire, withdrawal and tolerance were negatively correlated with fasting blood glucose. Intention effect was negatively correlated with testosterone:cortisol ratio and positively correlated with cortisol:insulin ratio. This indicates that, though overall score may not have impacted hormone concentration beyond cortisol, over the long term, EXD tendencies may have negative effects on physiology and performance. This study further confirms that LEA can have significant ramifications when not addressed, and that male athletes must be included in studies addressing ED, LEA, and RED-S.

With both Triad and RED-S screening tools available, Heikura, et al., (2018) wanted to determine the effectiveness of both methods. This study on elite distance runners was developed with two goals in mind: 1) to report on measures of energy availability during the high-volume, high-intensity pre-competition season and 2) to determine the effectiveness of RED-S and Triad risk assessment tools in identifying athletes who may exhibit symptoms of low energy availability. The study included 59 elite distance athletes who competed at distances between 800m run and 50k race walk. Risk factors of relative energy deficiency were measured in the athletes by questionnaires and physiological evaluation. By doing this, the study was aimed to evaluate the correlation between low energy availability and lowered bone mineral density as well as the correlation between survey responses and physiologic measurements. To evaluate energy availability in the participants, a 7-day dietary record and training record were used to calculate calories consumed and calories expended. This allowed the researchers to have a thorough understanding of the energy balance of the athletes during a one-week period. However, low energy availability occurs because of a chronic negative energy balance and cannot be measured over the course of one week. To determine LEA, it was necessary for the study to test for other factors that result from relative energy deficiency. The other components evaluated were hormone levels from blood samples, reproductive function from questionnaires, bone mineral density and body composition from DXA, and injury and illness rate. Females were also given the LEAF questionnaire. For males, testosterone levels were used in lieu of the LEAF-Q, with males in the lower quartile of testosterone levels scoring 1 and those with normal levels scoring 0. Cumulative risk scores for RED-S were then added to the scores from the LEAF-Q and testosterone levels to determine a combined risk score. Based on the results of the questionnaires, physiological tests, and estimated EA levels from food and exercise logs, the participants were then divided into two groups: suboptimal and normal energy availability status. The results of the study showed that amenorrheic females scored significantly higher on both the Triad risk assessment and energy availability assessment than the eumenorrheic females. The amenorrheic females also scored higher on the RED-S points, with the AME group scoring 2.4 ± 0.8 whereas the EUM group scored 0.5 ± 0.7. The same was true of the males, with men with low blood testosterone levels scoring higher on both the modified Triad and RED-S risk assessments. Another significant finding of the study was that 37% of females were amenorrheic and 40% of the males had low testosterone levels. The researchers found that the Triad and RED-S tools were able to detect symptoms of low energy availability such as impaired hormone function and all-time fracture, and did so with more accuracy than the energy availability gathered from the 7-day food and exercise logs. These findings indicate that questionnaire-type assessments may be a valuable tool in preventing low energy availability without requiring quantitative data.

A second Triad screening method, the Triad Coalition Cumulative Risk Assessment, and the RED-S risk assessment tool were compared in a study by Koltun et al., (2019) to find a feasible method for fracture prevention. The study included 166 females between 18 and 35 who exercise at least 2 hours per week, had no current diagnosis or history of eating disorder, and were not taking hormonal contraceptives. Anthropometrics, DEXA scans, and three questionnaires were used to collect information such as menstrual status/history, weight changes, fracture history, eating behavior, and weight changes. The Triad Coalition Cumulative Risk Assessment Score was determined based on the presence of six risk factors: low EA with or without DE/ED, low BMI, delayed menarche, oligomenorrhea and/or amenorrhea, low BMD, and stress reaction/fracture. Each of these risk factors were then assigned a point value of either

0 for low risk, 1 for moderate risk, or 2 for high risk. Cumulative points were used to determine the overall risk of the athlete, with 0-1 points being at low risk and fully cleared, 2-5 points moderate risk and provisionally cleared, and 6 or more points high risk and restricted from play. The RED-S risk assessment was based on three levels: green light (low risk, full play), yellow light (moderate risk, provisional clearance), and red light (high risk, no start). Those categorized as high risk had a diagnosis of anorexia nervosa or a life-threatening condition that resulted from weight loss techniques. Those with three yellow lights were also classified as high risk. Yellow light conditions included substantial weight loss in one-month, abnormal menstruation, menarche > 16 years old, and history of stress fractures. The Trial Coalition tool classified 25.3% of participants as cleared to play, 62.0% as provisionally cleared, and 12.7% as restricted from play. The RED-S tool classified 71.7% of participants as cleared to play, 18.7% as provisionally cleared, and 9.6% as restricted from play. The two tools had similar results when classifying athletes as restricted from play. However, there was discrepancy between the cleared to play and provisional play groups, with agreement in only 41.6% of the athletes. Overall, the Triad Coalition scoring method was much more conservative in assigning athletes to provisional play over full clearance, whereas the RED-S method saw more athletes placed into the full clearance category.

The risk factors that were most present in the Triad scoring were low EA, oligomenorrhea/amenorrhea, and delayed menarche, which is in line with triad research emphasizing the effects of low EA and amenorrhea on fracture incidence. The risk factors most present in the RED-S scoring were low EA, FHA, low BMD, and history of fracture. The authors note that the Triad assessment places greater emphasis on unmodifiable factors, such as delayed menarche, which is defined as >15. This contrasts the RED-S assessment tool which emphasizes current health status and classified delayed menarche as >16. There are also difference between the screening methods in defining amenorrhea, which can change the classification of athletes. The two screening methods provide a starting point for coaches and practitioners when assessing their athletes. Both methods restrict a similar number of athletes from play, which indicates a similar ability to identify athletes at high risk for fracture. The Triad method is more conservative, placing more athletes in the moderate risk category that would require continual supervision and clinical assessments. While this method may be more cautious, and it can also be more expensive since it requires more resources for monitoring athletes. Both methods are effective tools in identifying athletes who present with risk factors that could lead to fracture and could be valuable methods to reduce fractures in athletes.

Recognizing the need for a validated RED-S screening method, Foley-Davelaar et al., 2020 created their own questionnaire. The RED-S specific screening tool (RST) contained portions from the Pre-Participation Gynecological Exam (PPGE) and the National Eating Disorder Association’s eating disorder screen (EDS). The goal was to validate the RST against the results from the PPGE while creating a screening method that more comprehensively addressed RED-S specific components and was accessible to a wider age range. The RST included components such as menstrual history, sports, and injury from the PPGE while questions regarding disordered eating, energy availability, bone health, metabolic rate, growth, gastrointestinal health, and the psychological components were drawn from the EDS. The researchers then included supplemental questions such as stress fracture and illnesses to fully address both the physiological and psychological components of RED-S. Two versions of the RST were developed, one for males and one for females and a scoring system was developed. The individual sections of the questionnaire were then weighted according to risk, with sections most pertinent to energy availability, such as diet and nutrition, being weighted most heavily. The RST was also edited to a third-grade reading level to make the questionnaire accessible to younger athletes than the PPGE is typically used to evaluate. The participants were 39 female soccer players, ages 11-18, who completed both the PPGE and the RST at the same time. Based on their responses, the subject were then given a score for both questionnaires and classified as low, moderate, or high risk. The RST classified 23% of participants as low risk and 77% as moderate risk. The PPGE classified 77% as low risk, 18% as moderate risk, and 5% as high risk. A Pearson's correlation was performed and showed a statistical significance ($r=0.697$, $p<0.001$) between the screening methods. It was concluded that the RST developed in this study is validated against the PPGE, though it would be useful to extend the study to a larger and more diverse population. Regardless, the study highlights the lack of RED-S screening tools available to males and younger athletes, specifically pre-menstrual females. There is also the need for a screening method that is easily administered by coaches, trainers, physical therapists, and medical professionals while not requiring extensive background knowledge of exercise physiology or RED-S.

**Summary**

The literature surrounding the Female Athlete Triad and RED-S, while differing in specific risk factors, draws a single conclusion: LEA is a topic of concern for athletes regardless of age, sport, sex, or competition level. While the LEAF Questionnaire is an excellent resource for females, developing a questionnaire that is applicable to all athletes would greatly benefit the physically active community. The widespread effect of LEA, as emphasized by the RED-S model, indicates the need for a validated screening method. Providing coaches and practitioners with an accessible, feasible, and cost-effective tool would allow for LEA to be identified and addressed in athletes before more significant dysfunctions, such as hormonal imbalance and stress fracture, occur.

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## APPENDIX A: ENERGY AVAILABILITY SURVEY

Q1 Select your sex

- ○ Male
- ○ Female
- ○ Other/Prefer not to say

---

Q2 What is your current age?

________________________________________________________________

---

Q3 What is your current weight? (lbs)

________________________________________________________________

---

Q4 What is your current height? (inches)

________________________________________________________________

---

Q5 Highest weight at current height? (lbs)

________________________________________________________________

Q6 Lowest weight at current height? (lbs)

________________________________________________________________

Q7 Do you regularly use any of the following? Check all that apply

- ☐ Cigarettes
- ☐ E-cigarettes (E.g. Juul or other vape products)
- ☐ Tobacco
- ☐ I do not use any of these products

Q8 Which of the following best describe you?

- ☐ Asian or Pacific Islander
- ☐ Black or African American
- ☐ Hispanic or Latino
- ☐ Native American of Alaskan Native
- ☐ White or Caucasian
- ☐ Multiracial or biracial
- ☐ A race/ethnicity not listed here
- ☐ Prefer not to say

Q9 Are you currently taking any dietary supplements? Check all that apply

▢ Vitamin D

▢ Calcium

▢ Iron

▢ Creatine

▢ Amino Acids

▢ Other ________________________________________________

▢ I am not taking any supplements

---

Q10 Have you ever been diagnosed with anemia?

○ Yes

○ No

**End of Block: Default Question Block**

---

**Start of Block: Training**

Q11 Are you an athlete for Illinois State University?

- ◯ Yes
- ◯ No

Q12 What sport do you primarily compete in?

________________________________________________________________

Q13 Do you compete in any additional sports?

- ◯ Yes (please list additional sports) ________________________________________________
- ◯ No

Q14 How old were you when you first started competing in your sport?

- ◯ 5 or under
- ◯ 6-10
- ◯ 11-13
- ◯ 14 or older

Q15 How many years have you been seriously competing in your sport? This includes participating in the sport year round and/or competing on a national level

________________________________________________________________

Q16 What season of competition are you currently in?

- ○ Pre-season
- ○ Competition season
- ○ Post-season

Q17 How many hours per week (on average) do you spend in sport-specific training?

________________________________________________________________

Q18 How many hours per week on average do you spend cross training? (includes resistance training, plyometrics, and other activities not directly related to your sport)

________________________________________________________________

Q19 What type of cross training do you participate in? Check all that apply

- ▢ Resistance training (weightlifting, strength training)
- ▢ Plyometrics (box jumps, burpees, etc.)
- ▢ Yoga
- ▢ Cycling/spinning
- ▢ Running
- ▢ Other ________________________________________________
- ▢ I do not regularly cross train

**End of Block: Training**

---

**Start of Block: Injury**

Q20 Have you had absences in your training or missed competition due to injury in the past year?

- ○ No, not at all
- ○ Yes, once or twice
- ○ Yes, three or four times
- ○ Yes, five times or more

Q21 If yes, what kind of injury/injuries have you had within the last year?

________________________________________________________________

Q22 If yes, how many training days were missed or modified due to injury?

- ○ 1-7 days
- ○ 8-14 days
- ○ 15-21 days
- ○ 22 days or more

Q23 Have you had a stress fracture during your athletic career? If multiple, please include all fractures

- ○ Yes (specify location and type of fracture) ________________________________________________
- ○ No

Q24 How many stress fractures have you had during your athletic career?

- ○ 1
- ○ 2
- ○ 3 or more (include number if more than 3) ________________

---

Q25 How old were you when the stress fracture(s) occured? (if multiple, please include each age fracture occurred)

________________________________________________________________

---

Q26 How many times have you had an upper-respiratory infection in the past year? (cold and flu, NOT including COVID-19)

- ○ None
- ○ 1-2
- ○ 3 or more times (include number if more than 3) ________________

---

Q27 How many days of training were missed or modified due to upper respiratory infection? (NOT including COVID-19)

○ 1-3 days

○ 4-7 days

○ 1-2 weeks

○ 2 or more weeks

○ Other ________________________________________________

**End of Block: Injury**

---

**Start of Block: Gastrointestinal Function**

Q28 Have you been diagnosed with any conditions that may contribute to gastrointestinal distress? (IBS, Crohn's disease, Celiac disease, lactose intolerance, etc.)

○ Yes (please specify) ________________________________________________

○ No

Q29 Do you feel gaseous or bloated in the abdomen? (not related to menstruation)

- Yes, several times a day
- Yes, several times a week
- Yes, once or twice a week or more seldom
- Rarely or never

Q30 Do you get abdominal cramps or stomach aches? (not related to menstruation)

- Yes, several times a day
- Yes, several times a week
- Yes, once or twice a week or more seldom
- Rarely or never

Q31 How often do you have bowel movements on average?

- ○ Several times a day
- ○ Once a day
- ○ Every other day
- ○ Twice a week
- ○ Once a week or more rarely

---

Q32 How would you describe your normal stool?

- ○ Normal (soft)
- ○ Diarrhea-like (watery)
- ○ Hard and dry

**End of Block: Gastrointestinal Function**

---

**Start of Block: Oral Contraceptives**

Q33 Do you currently use oral contraceptives? (birth control pills)

- ○ No
- ○ Yes

---

Q34 If yes, why do you use an oral contraceptive? (check all that apply)

- ☐ Contraception
- ☐ Reduction of menstruation pains
- ☐ Reduction of bleeding
- ☐ To regulate menstrual cycle in relation to performance
- ☐ Otherwise menstruation stops
- ☐ Other ________________________________________________

Q35 If no, have you used an oral contraceptive in the past?

- ○ Yes
- ○ No

Q36 If yes, when and for how long?

________________________________________________________________

Q37 Do you use any other kind of hormonal contraceptives?

○ Yes

○ No

---

Q38 If yes, what kind? (check all that apply)

▢ Hormonal patches (E.g. Xulane or Twirla patch)

▢ Hormonal coil (IUDs such as Mirena, Liletta, Skyla)

▢ Hormonal ring (E.g. Nuvaring, Annovera)

▢ Hormonal implant (E.g. Nexplanon or Implanon)

▢ Other ________________________________________________

**End of Block: Oral Contraceptives**

---

**Start of Block: Menstrual Function**

Q39 How old were you when you first menstruated (had your first monthly period)?

- ○ 11 years or younger
- ○ 12-14 years
- ○ 15 years or older
- ○ I don't remember
- ○ I have never menstruated

---

Q40 Did your first menstruation come naturally (by itself)?

- ○ Yes
- ○ No
- ○ I don't remember

---

Q41 If no, what method of treatment was used to start menstruation?

- ○ Hormonal treatment
- ○ Weight gain
- ○ Reduced amount of exercise
- ○ Other ________________________________________________

Q42 Do you have normal menstruation?

- ◯ Yes
- ◯ No
- ◯ I don't know

Q43 When did you last menstruate?

- ◯ 0-4 weeks ago
- ◯ 1-2 months ago
- ◯ 3-4 months ago
- ◯ 5 months ago or more

Q44 Do you menstruate regularly (every 28th to 34th day)?

- ◯ Yes, most of the time
- ◯ No, mostly not

Q45 For how many days do you usually menstruate?

- 1-2 days
- 3-4 days
- 5-6 days
- 7-8 days
- 9 days or more

Q46 Have you ever had problems with heavy menstrual bleeding?

- Yes
- No

Q47 How many menstrual cycles have you had in the last year?

- 12 or more
- 9-11
- 6-8
- 3-5
- 0-2

Q48 If "no" or "I don't know", when was your menstrual cycle?

- ○ 2-3 months ago
- ○ 4-5 months ago
- ○ 6 months ago or more
- ○ I'm pregnant and therefore do not menstruate

Q49 Has menstruation ever stopped for 3 consecutive months or longer?

- ○ No, never
- ○ Yes, it has happened before
- ○ Yes, that is the situation now

Q50 Do you feel that your menstruation changes with an increase in exercise frequency, intensity, or duration?

- ○ Yes
- ○ No

Q51 If yes, how? (check all that apply)

- ▢ I bleed less
- ▢ I bleed fewer days
- ▢ My menstruations stop
- ▢ I bleed more
- ▢ I bleed more days

---

Q52 Do you notice changes in menstruation during the offseason, preseason, and competition season?

- ○ Yes (please specify) ________________________________________________
- ○ No

**End of Block: Menstrual Function**

---

**Start of Block: DXA**

Q53 If you participated in the DXA portion of the study include the T-score here. Please include + or - (e.g. +0.5)

________________________________________________________________

# APPENDIX B: LEAF-Q SCORING KEY

Scoring Key

**Q20** - (0) No, not at all; (1) Yes, once or twice; (2) Yes, three or four times; (3) Yes, five times or more

**Q22** - (1) 1-7 days; (2) 8-14 days; (3) 15-21 days; (4) 22 days or more

**Q29 -** (3) Yes, several times a day; (2) Yes, several times a week; (1) Yes, once or twice a week or more seldom; (0) Rarely or never

**Q30** - (3) Yes, several times a day; (2) Yes, several times a week; (1) Yes, once or twice a week or more seldom; (0) Rarely or never

**Q31** - (1) Several times a day; (0) Once a day; (2) Every second day; (3) Twice a week; (4) Once a week or more rarely

**Q32** - (0) Normal; (1) Diarrhoea-like; (2) Hard and dry

**Q34** - (0) Contraception; (0) Reduction of menstruation pains; (0) Reduction of bleeding; (0) To regulate the menstrual cycle in relation to performances (1) Otherwise menstruation stops

**Q39 -** (0) 11 years or younger; (0) 12-14 years; (1) 15 years or older; (0) I don't remember; (8) I have never menstruated

**Q40** - (0) Yes; (1) No; (1) I don't remember

**Q41** - (1) Hormonal treatment; (1) Weight gain; (1) Reduced amount of exercise; (1) Other

**Q42** - (0) Yes; (2) No; (1) I don't know

**Q43 -** (0) 0-4 weeks ago; (1) 1-2 months ago; (2) 3-4 months ago; (3) 5 months ago or more

**Q44** - (0) Yes, most of the time; (1) No, mostly not

**Q45** - (1) 1-2 days; (0) 3-4 days; (0) 5-6 days; (0) 7-8 days; (0) 9 days or more

**Q46** - (0) Yes; (0) No

**Q47** - (0) 12 or more; (1) 9-11; (2) 6-8; (3) 3-5; (4) 0-2

**Q48 -** (1) 2-3 months ago; (2) 4-5 months ago; (3) 6 months ago or more; (0) I'm pregnant and therefore do not menstruate

**Q49 -** (0) No, never; (1) Yes, it has happened before; (2) Yes, that's the situation now

**Q50** - (1) Yes; (0) No

**Q51 -** (1) I bleed less; (1) I bleed fewer days; (2) My menstruations stops; (0) I bleed more; (0) I bleed more days