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Relative Energy Deficiency in Female Collegiate Track and Field Athletes.

Niamh Kearney

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____
Dan Benardot, PhD, DHC, RD, LD, FACSM
Committee Chair

____
Desiree Wanders, PhD
Committee Member

____
Nomeli Nuñez, PhD
Committee Member

____
Date

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Niamh Kearney
175 Applewood Heights,
Greystones,
Co..Wicklow,
Ireland

The director of this thesis is:
Dan Benardot, PhD, RD, LD, FACSM
Professor
Department of Nutrition
The Byrdine F. Lewis School of Nursing and Health Professions
Georgia State University
Atlanta, Georgia 30302

VITA

Niamh Kearney
175 Applewood Heights
Greystones,
Co. Wicklow
Ireland

2011-2015	Georgia State University Bachelor of Science in Nutrition Scholarship Athlete: Cross Country/Track & Field
2015-2016	Georgia State University Master of Science in Health Professions Nutrition Concentration
2015-2016	Graduate Assistant: Georgia State University Athletics, Academic Department

ABSTRACT

Title: Relative Energy Deficiency in Female Collegiate Track & Field Athletes.

Background: Energy deficiency and its consequences have long been studied in female athletes because of it's potential for increasing risks of illness and injury. Sustaining an energy deficient diet while training and during competition may result in muscle loss and reduction in performance. Studies suggest that athletes competing in sports focusing on appearance or a lean physique are at high risk for energy deficiency. In 2014, the IOC developed the concept of 'Relative Energy Deficiency in Sport' (RED-S) to include new components not previously included in the Female Athlete Triad. A study has not yet been completed applying the RED-S paradigm in collegiate track and field athletes.

Objective: The purpose of this study was to examine the prevalence of RED-S in female collegiate track and field athletes. It was hypothesized that the majority of collegiate track and field athletes experience RED-S. It was also hypothesized that a greater percentage of distance runners experience RED-S than other track and field athletes, including throwers, jumpers, and sprinters. The components of RED-S assessed were menstrual function, bone health, and energy expenditure.

Methods: This study was a descriptive cross-sectional study, obtaining data through the use of a questionnaire and a relative energy expenditure index on a population of 12 female collegiate track and field athletes. Data were obtained through the use of a LEAF-Q questionnaire, a three-day food and exercise recall, and body composition analysis.

Results: The 12 athletes were a combination of distance runners (n=5), throwers (n=2), and sprinters (n=5). Average subject characteristics were: age (20.6 ±1. 44 years), height (165.6 ±7.5cm), weight (63.58 ± 16.97kg), and body fat percentage (20.9± 7.2). Average energy intake over three days was 2146 kcal (±627), and the average predicted energy expenditure was 2380 kcal (±458). Average hours spent in a catabolic (52.8 ± 24.0), highly catabolic (37.5 ± 25.0), anabolic (19.2 ± 24.0), and highly anabolic state (12.4 ± 21.0). Subjects were in a negative energy balance state the majority of the days analyzed, and 75% of the population had at least one day of dietary recall below 45 kcal/kg FFM/day. Spearman's rho analysis found a significant inverse correlation between Day 1 hours spent in optimal energy balance (± 400 kcal) and body fat percent (p=0.024, r_s= -0.643), and significant positive correlation between Day 1 hours spent in optimal energy balance (± 400 kcal) and fat free mass percentage (p=0.03, r_s=0.625). Spearman's rho analysis also found an inverse correlation between Day 1 hours spent in an energy deficit (<-400 kcals) and fat free mass percentage (p=0.03 r_s= -0.626), and a positive correlation between Day 1 hours spent in an energy deficit and body fat percentage (p=0.026, r_s=0.636). Seven out of twelve participants scored ≥ 8 on the LEAF-Q putting them at risk for RED-S.

Conclusion: The study highlights the misleading effect of averaging multiple days of dietary recall on energy balance. When participant's dietary recalls were assessed day by day the majority of hours were spent in a catabolic state, however when the three days of the recall were averaged the severity of the hours spent in a catabolic state lessened. The associations in this study are consistent with previous studies evaluating the relationships between energy balance deficits and body composition, indicating that longer duration spent in an energy deficit is associated with lower lean and higher fat mass. The findings from the LEAF-Q show that 58% of participants were at risk for RED-S, and half of all participants had or were experiencing menstrual dysfunction.

Relative Energy Deficiency in Female Collegiate Track & Field Athletes

By
Niamh Kearney

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Department of Nutrition
Georgia State University

Master's Thesis Advisory Committee:
Dan Benardot, PhD, DHC, RD, LD, FACSM (Chair)
Desiree Wanders, PhD
Nomeli Nuñez, PhD

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LIST OF ABBREVIATIONS

AN	Anorexia Nervosa
Avg	Average
BMD	Bone Mineral Density
BMI	Body Mass Index
BN	Bulimia Nervosa
cm	Centimeters
DE	Disordered Eating
ED	Eating Disorder
FFM	Fat Free Mass
GI	Gastrointestinal
Hrs	Hours
IOC	International Olympic Committee
IGF-1	Insulin-Like Growth Factor 1
IRB	Institutional Review Board
kcal	Kilocalories
kg	Kilograms
lbs.	Pounds
LEAF-Q	Low Energy Availability in Female Athletes Questionnaire
LH	Luteinizing Hormone
NCAA	National Collegiate Athletic Association

PI	Primary Investigator
RED-S	Relative Energy Deficiency in Sport
RMR	Resting metabolic Rate
SPSS	Statistical Package for the Social Sciences
TEF	Thermic Effect of Food
T3	Triiodothyronine
USDA	United States Department of Agriculture

CHAPTER I

INTRODUCTION

Background: Relative Energy Deficiency in Sport

Energy deficiency has long been reported in athletes, and in particular it has been widely prevalent in athletes in weight sensitive sports such as gymnastics, wrestling, diving, and cross country running[1]. Energy deficiency can be related to many factors such as an athlete intentionally restricting energy intake to make a certain weight class or lean physique, or because of an eating disorder or disordered eating, or unintentionally due to a knowledge deficit in nutrition education[1]. Sustaining an energy deficient diet while exercising causes an athlete to be in a catabolic state, leading to muscle mass breakdown and an increase in body fat percentage[2]. Maintaining energy balance within a relatively narrow range (+/- 400 kcal) has been linked to higher fat free mass and lower body fat percentage[2]. Previously, the "Female Athlete Triad" has been the term used to describe female athletes with one or more components of the triad, which includes disordered eating, amenorrhea, and osteoporosis[3]. In 2014, the International Olympic Committee (IOC), introduced a new term, "Relative Energy Deficiency in Sport" (RED-S) to replace the Female Athlete Triad, so that male athletes, recreational athletes, and a broader range of health concerns and consequences would be included[1]. The IOC concluded that the Female Athlete Triad failed to incorporate all those individuals experiencing symptoms of energy deficiency, as well as limiting the consequences of consuming an energy deficient diet to three areas. RED-S includes a broader range of potential health and performance consequences for both male and female athletes.

Who is at Risk?

Athletes at risk for RED-S include, potentially, all active individuals and particularly those exercising strenuously and elite athletes with a high level of competitive stress. Energy deficiency and its related consequences have been studied in recent years, with some studies suggesting that athletes participating in sports with weight classifications or lean physiques are at a greater risk for developing energy deficiencies, disordered eating, and other energy deficient-related consequences. A number of earlier studies found that female track and field athletes and, in particular, female distance runners are at high risk of having conditions related to RED-S[4]. Some studies have reported that there is no significant difference between lean sports and other sports when it comes to risk for developing energy deficiency and having RED-S components. Studies have found that a large proportion of athletes experience components of RED-S, but are unaware of the health and performance consequences they may experience in the short and long term[1].

The Performance and Health Sequelae of RED-S

Short-term effects of low energy availability can lead to a decrease in athletic performance, increase susceptibility to illness, and increase the development of nutrient deficiencies such as anemia[1]. In the long term, health consequences due to sustaining an energy deficient diet include an effect on metabolic rate, immunity, protein synthesis, growth and development, cardiovascular health, psychological, endocrine, hematological, and gastrointestinal[1]. Components such as energy deficiency, menstrual function, and bone health have widely studied previously in track and field athletes[1]. Menstrual dysfunction is a consequence of having low energy intake among other causative variables including, hormonal imbalances, inadequate body fat stores, excessive exercise, and luteinizing hormone (LH) pulsatility[1]. Research shows that an inadequate energy intake can disrupt the LH pulsatility by affecting the gonadotropin-releasing hormone which plays a role in menstrual function[5] Low energy intake also has an impact on other metabolic hormones such as cortisol, insulin, grehlin, and leptin[1]. RED-S also has a significant impact on bone health[1]. Peak bone mass occurs at approximately 19 years old in females[1]. Estrogen is responsible for increasing the absorption of calcium into the bone[6]. With estrogen deficiency and a low energy availability, a decrease in bone mineral density can occur[7]. Likewise, an increase in cortisol due to stress, psychological or physiological, can have a negative effect on bone mineral density[8]. A reduction in bone mineral density puts athletes at greater risk for fractures and bone related injuries[1]. Energy balance, menstrual status, and bone health are three components that have been studied previously under the term the Female Athlete Triad, and majority of previous research focus on these three components. Having a component or various components of RED-S can lead to a reduction in performance, loss in muscle mass, injury, and adverse health effects in the immediate and long term future[1]. Identifying athletes at risk for

RED-S can prevent or stop the progression of these health consequences by referring the athletes to health professionals for medical advice and education.

Purpose and Hypothesis

The purpose of this study is to examine the prevalence of RED-S in female collegiate track and field athletes. It is hypothesized that the majority (>50%) of collegiate track and field athletes experience RED-S. It is also hypothesized that a greater percentage of distance runners will experience RED-S than other track and field athletes, including throwers, and sprinters/jumpers. The components of RED-S that this study will focus on will be menstrual function, bone health, gastrointestinal function, and energy expenditure.

The development and further study of RED-S is vitally important to protect the health of adolescent and adult athletes in both the short term and long term. Potential consequences of having an energy deficiency in the short term include fatigue, anemia, illnesses, and infections[1]. A study has not yet been completed applying the RED-S paradigm in collegiate track and field athletes and this is a reason for this study.

CHAPTER II

LITERATURE REVIEW

Energy Deficiency

Energy deficiency occurs when energy expenditure exceeds energy intake. This may occur in all active individuals, when the energy expended by resting metabolic rate (RMR), thermic effect of food (TEF), and physical activity exceeds the energy consumed from food and fluid[9]. This energy inadequacy may result from the athlete unintentionally or intentionally consuming insufficient energy, because of disordered eating or an eating disorder, or through purposeful dietary restriction for aesthetic or weight classifications associated with their specific sport[1]. In 2004, a study completed on NCAA Division I athletes from various sports found that the majority of female athletes reported that they wanted to lose at least 5 lbs[10]. Additionally, 25% of female athletes that responded to the questionnaire indicated that they restrict carbohydrate and fat in their diet to avoid weight gain[10]. This study found that most male and female athletes consumed under the recommended amount of carbohydrates and protein, and that male athletes were consuming excess fat[10]. This study highlights the prevalence of athletes at risk for consuming an energy deficient diet and highlights the macronutrients athletes are more likely to restrict.

Staying in an adequate energy balance has been linked to having a higher fat free mass and lower body fat percentage[2]. It has been suggested by previous research, that eating small, frequent meals have an effect on increased fat loss[11]. A meta-analysis studied this suggestion and found that increased eating frequency appeared to reduce fat mass and body fat percentage and increase fat free mass percentage[12]. Maintaining energy balance throughout the day can aid in avoiding large energy deficits and surpluses, which, can have negative effects on body composition and decrease athletic performance.

Many athletes are at risk for developing disordered eating and eating disorders[1]. Disordered eating describes similar behaviors as those with eating disorders, but they may not fit the specific criteria in order to be diagnosed with a specific eating disorder such as anorexia nervosa (AN) or bulimia nervosa (BN)[13]. According to The Academy of Nutrition and Dietetics "The most significant difference between an eating disorder and disordered eating is whether or not a person's symptoms and experiences align with the criteria defined by the American Psychiatric Association"[13]. Inadequate energy consumption may increase illness and injury risk[10]. Sustaining an energy deficient diet while training and competing at an intense level leads to overtraining, a loss in muscle mass, and a reduction in performance[14]. A study completed on elite female gymnasts and runners found a significant relationship between greater duration of hours spent in an energy deficit (<-300 kcals) and higher body fat percentage[2]. Inadequate energy intake in adult and adolescent athletes has been estimated to be less than 45 kcals/kg FFM/day[1]. Energy intake above 45kcals/kg FFM is optimal for athletes in order to supplement for their large expenditure through exercise[14]. Disordered eating, and possibly other factors, has been equated to an intake of less than 30 kcals/kg FFM/day[1]. In a recent study, it was found that of 25 athletes that were on a Division 1 Track and Field Team, 92% had energy intake below 45 kcals/kg FFM/day, with a further 52% of athletes below 30 kcals/kg FFM/day[4]. The mean intake for this specific population was 30.8 kcals/kg FFM/day, which falls significantly below the optimal energy intake of 45 kcals/kg FFM/day[4]. Energy deficiency is widespread throughout sport, and is particularly prevalent in female athletes[15]. Disordered eating is prevalent in approximately 20% of adult and 13% of adolescent female elite athletes in appearance sports[1]. In an alternate study, it was concluded that, of a population of NCAA Division I athletes competing in both lean and non-lean sports, 20% of female athletes and 16% of male athletes displayed symptomatic behaviors for an eating disorder which is similar percentages to the previous study[16].

The Female Athlete Triad

The American College of Sports Medicine defines the Female Athlete Triad as "a health concern for active women and girls who are driven to excel in sports. It involves three distinct and interrelated conditions: disordered eating (a range of poor nutritional behaviors), amenorrhea (irregular or absent menstrual periods) and osteoporosis (low bone mass and microarchitectural deterioration, which leads to weak bones and risk of fracture)"[3]. Low energy availability has a causative effect on an athlete developing the other triad components, amenorrhea and osteoporosis[17]. The Female Athlete Triad can have many negative effects in both the short term and long term. Researchers state that in the short term, it can lead to stress fractures, osteopenia, fatigue, infertility, and impaired endothelial function[18]. In the long term, athletes are at increased risk for cardiovascular disease and osteoporosis[19]. It has been reported, athletes experiencing amenorrhea have similar bone mineral density to postmenopausal women, putting them at increased risk for stress fractures and osteoporosis[20]. In 2006, a study to examine the prevalence of the female athlete triad was conducted on 112 US collegiate female athletes competing in seven different sports. The researchers grouped the athletes into lean sports versus non lean sports. It was reported that 28 athletes (25%) had disordered eating, 29 athletes (26%) had menstrual dysfunction, and two athletes (2%) had low bone mineral density. Ten athletes had two of the components of the female athlete triad, with the majority of these athletes experiencing disordered eating and menstrual dysfunction as their two components. Only one athlete had all three components of the female athlete triad. This study highlighted that there is a high prevalence of athletes with at least one component of the female athlete triad at the collegiate level. The study also found that there was no significant difference in the prevalence of female athlete triad components between groups, lean versus non lean sports[21]. Previous literature suggests that low energy intake along with menstrual dysfunction can disrupt bone formation and reabsorption, leading to low bone density and bone related disorders such as stress fractures, osteoporosis, and other skeletal disorders[1]. An energy deficient diet along with estrogen deficiency in exercising women is associated with increased osteoclast activity and decreased osteoblast activity leading to a decrease in bone formation and bone density[22]. The authors concluded the importance of female athletes avoiding an energy deficit diet, which is linked to hypoestrogenism, to avoid bone related disorders[22].

Recently, a study was published examining the prevalence of the female athlete triad and energy deficiency in professional and competitive distance runners in Denmark and Sweden. Of a population of 40, 15 subjects had optimal energy availability

(≥45kcals/kg FFM/day), 17 had reduced energy availability (<45kcals/kg FFM/day), and 8 had low energy availability (<30 kcals/kg FFM/day). Subjects with a low energy availability had a 79% higher energy expenditure than those with adequate energy availability. Ten subjects were diagnosed with eating disorders and one was diagnosed with disordered eating. Furthermore, 60% (n=24) of the total population were diagnosed with menstrual dysfunction and 45% (n=18) had impaired bone health. This study highlights the extent in, which energy deficiency and its potential consequences occur in the sport of distance running[23]. In another study completed on Division 1 female athletes in 2014, it was found that lean sport athletes (cross country and acrobatics) were more likely to report a missed menstrual cycle as normal than non-lean sports[15]. Similarly, a study conducted in Australia in 2012, found that 45% of total participants, lean sports, non-lean sports, and gym/fitness activities, were unaware that amenorrhea had an effect on bone health, with 22% of those involved in lean sports stating they would not seek medical assistance if they were experiencing amenorrhea. Also, only 10% of a total of 180 participants in this study were able to name the three components of the female athlete triad. The authors concluded that very few Australian women that exercise are aware of the damaging effects of menstrual function has on bone health, and encouraged that education be in place to make them more aware so that appropriate actions are taken to delay or stop menstrual dysfunction and bone degradation[24].

Relative Energy Deficiency in Sport (RED-S)

The first use of the term ‘Female Athlete Triad’ was in 1992. Since then a new term was developed to replace the Female Athlete Triad. Relative Energy Deficiency in

Sport (RED-S) was published as a consensus of the International Olympic Committee in 2014[1]. The IOC concluded that the Female Athlete Triad is an outdated and a gender-specific term[1].It has been found that male athletes also show signs of some of the components of the female athlete triad, such as the energy insufficiency and low bone mineral density[1]. The term, RED-S, includes recreational athletes and dancers that may not consider themselves athletes, but experience energy deficiency and its related components, whereas the Female Athlete Triad did not include these populations[1]. RED-S includes new components, such as metabolic rate, immunity, protein synthesis, growth and development, cardiovascular health, psychological, endocrine, hematological, and gastrointestinal[1]. RED-S symptoms have been reported to be more prevalent in weight-sensitive sports focusing on lean physiques[1].

The National Collegiate Athletic Association Study surveyed 1445 student athletes from 11 NCAA Division I schools assessing the prevalence of eating disorders and disordered eating among athletes. From the population surveyed, 1.1% of female athletes met the criteria to be diagnosed with bulimia nervosa, and none of the athletes met the criteria to be diagnosed with anorexia nervosa. However, the study reported that 9.2% of female athletes were found to have “clinically significant problems with bulimia nervosa” and 2.85% of female athletes were found to have “clinically significant problems with anorexia nervosa”. Additionally, 10% of the female athletes reported binge eating on a weekly basis, and 5.5% of female athletes reported purging by taking laxatives or diuretics, or vomiting, on a weekly or greater basis[25]. This study displays the significance and requirement for the future study of RED-S in athletes at the collegiate level.

Relative energy deficiency can have an immediate effect on the endocrine system. Many hormones are affected by having low energy availability such as a decrease in leptin, IGF-1, insulin, and triiodothyronine (T3), and an increase in cortisol and grehlin[1]. A reduction in T3 and IGF-1 can lead to a decrease in protein synthesis in the body, leading to a reduction in muscle mass[1]. High levels of grehlin and low levels of leptin have been associated with hypogonadism with leads to decreased LH pulsatility which has an effect on menstrual function, which can lead to amenorrhea[26].

Menstrual dysfunction is particularly an area of great interest in distance runners, as it has been reported that 65% of collegiate female long distance runners report having secondary amenorrhea, one of the sequelae of RED-S[1]. In a another study, it was reported that 56% of a population of collegiate female athletes surveyed believed that missing a menstrual cycle was normal[15]. Secondary amenorrhea refers to a female who has had a menstrual cycle, but has experienced an absence of three consecutive menstrual cycles[1].

In addition to menstrual dysfunction, many distance runners experience bone related injuries such as stress fractures and stress reactions[27]. These can occur for a variety of reasons, including menstrual dysfunction, excessive exercise, inadequate intake, poor bone health, and a low body mass index. Energy deficiency can cause the body to conserve energy and neglect certain body functions. In females, energy deficiency can lead to a loss in menstrual function also known as amenorrhea when the cycle stops for 3 months or longer. In connection with amenorrhea, these female athletes have low levels of estrogen, which inhibits the formation of adequate bone density[28]. Estrogen is a hormone that promotes bone density and is found to be decreased in women that are energy deficient[29]. Low levels of estrogen have been linked with a decrease in osteoblast activity and an increase in bone turnover[29]. Additional to estrogen, cortisol plays a role in bone health also. Cortisol is a stress hormone, and has been associated with bone resorption when an individual in an energy deficiency needs to use amino acids to produce supplemental energy through gluconeogenesis[30]. Cortisol blocks the bone from absorbing calcium, which leads to a decrease in bone formation[31]. Disruption in calcium homeostasis leads to a reduction in bone mineral density[32]. Cortisol levels can increase due to physiological and psychological factors[30]. Cortisol levels are thought to increase when athletes are completing endurance training, in response to intense exercise, and possibly due to psychological arousal during or before competition[33]. In a study of 71 exercising women, it was found that cortisol levels were higher, and bone mineral density levels were lower in women that were amenorrheic[34]. Energy deficiency, menstrual function, and bone health are three inter-related components that are involved in the RED-S paradigm.

CHAPTER III

METHODS

RECRUITMENT STRATEGY

This study was reviewed and approved by the Georgia State University Institutional Review Board. Recruitment to the study entailed requesting the coach first if we could do the study on his team, and then discussing with the athletes at a team meeting the purpose and nature of the study. Interested athletes were invited to contact the student PI for an appointment to discuss the consent form and to obtain a signed consent for participation (Appendix A). IRB-approved consent was required from the athletes to include them in the study, and there was no coercion from the coach or any member of the team to participate in the study.

INCLUSION & EXCLUSION CRITERIA

Inclusion criteria for the study included being a female member of the Georgia State University Track and Field team. There were no exclusion criteria for the study. All members of the Georgia State University Women's Track & Field team were eligible to participate in the study.

PARTICIPANTS

There were approximately 12,801 NCAA Division I female Track and Field athletes in 2014[35]. With a confidence of 95% and a margin of error of 5%, this would require a sample size of 373 in order to be generalized to other collegiate track and field populations. This study used a convenience sample of 12 athletes. A total of 12 out of 29 (41%) female athletes from a Division I track and field team consented to participate in the study. No participants dropped out of the study. The athletes were a combination of distance runners (n=5), throwers (n=2), and sprinters (n=5). This population was chosen due to a limited number of RED-S studies being completed on collegiate female track and field athletes previously. Ages of participants ranged from 18-22 years of age. Each participant was given a unique identification number to provide confidentiality. Data were obtained through the use of a questionnaire and a three-day food and exercise recall. The questionnaire gathered information on illnesses, injury, GI function, and menstrual function to gain data to assess if the participants had symptoms or were at risk for RED-S. Participants also completed a three-day dietary and activity recall, which was the three days immediately before their appointment (Appendix B). For instance, if a participant had an appointment on a Thursday, their dietary and exercise recall would be Monday, Tuesday, and Wednesday.

DATA ACQUISITION PROCEDURES

All data collection took place in a lab on Georgia State University campus from the 4th through the 24th of February, 2016. All data were coded and each subject was provided their code so that personal information could be shared with them at the conclusion of the study. Data were stored on a password protected computer in a locked lab with limited access. Data stored on the computer did not have any personally identifiable information, and hard copies of the completed questionnaires were stored in a locked file cabinet in a secure lab with limited access. Tools used to collect data from participants included food intake/activity recall, relative energy expenditure index, and a LEAF-Q screening questionnaire (see Appendix C).

All subjects met once with researcher, during, which time all anthropometric data, dietary and exercise recall, and LEAF-Q questionnaire was collected. Anthropometrics including height, weight, and body composition were taken on each participant. A stadiometer was used to measure height in inches, which was later converted to centimeters. A Tanita scale, model BC-418, was used for weight and body composition, which equated for clothes worn by participants. Weight was taken in pounds and later converted to kilograms. Participants were instructed to remove shoes and socks prior to having their height, weight, and body composition taken.

Participants were asked the time (hourly) they ate and the approximate amount and type of food they ate at each meal over the past three days prior to their appointment, this was recorded on the NutriTiming® Data Entry Form (Appendix B). The Student PI aided participants with estimating the amount of food consumed by using pictures of food. Participants were also asked about their activity over the three days and to rate the intensity of the activity based on a scale, 1 (resting, reclining) to 7 (exhaustive) (Appendix B).

DATA ANALYSIS

The relative energy expenditure index assessed hours spent in a positive (anabolic) or negative (catabolic) energy balance each of the three days and also averaged the three 24-hour periods. Optimum energy balance was equated to +/- 400 kcal, with energy balance >+400kcal termed energy surplus and energy balance <-400kcal termed energy deficit. An energy deficit (<-400 kcals) has been associated with a higher body fat[2]. The program used for energy balance assessment was NutriTiming®, which estimates energy expended using the Harris-Benedict equation to predict REE and a MET-based relative intensity activity scale. Energy intake was estimated using the USDA Nutrient Database for standard reference, version 26. Food items that were reported, but were not listed in the database, were added using nutrition labels.

The LEAF-Q assessed whether athletes had components of RED-S by asking a series of questions relating to injury, GI function, and menstrual function and scored athletes based on their responses[36]. Based on the small sample size (n = 12), abnormal distribution of the data was assumed and therefore statistical analyses were conducted using non-parametric statistical methods. Descriptive statistics, Mann Whitney U test, Spearman's rho correlations, and Pearson correlations were run on the dataset. Statistical analyses were performed using SPSS, version 20.0. Statistical significance was set at $P < 0.05$.

CHAPTER IV

RESULTS

ANTHROPOMETRIC DATA

The twelve athletic participants ranged in age from 18 to 22 years, with the mean age 20.6 years. The weight range was 48kg to 107.9kg with the mean weight of participants 63.6kg. Participants ranged in height from 154.9cm to 181.6cm with the mean height 165.6cm.

Table 1: Subject Characteristics (N=12)

	Minimum	Maximum	Mean	Std. Deviation
Age	18	22	20.58	1.44
Weight (kg)	48.00	107.91	63.58	16.97
Height (cm)	154.94	181.61	165.63	7.45

The BMI of participants ranged from 18.7kg/m^2 to 37.7kg/m^2, the mean BMI was 22.96 kg/m^2. Body fat had a wide range, 5.91kg to 42.91kg, with the mean body fat 14.3kg. Likewise, body fat percentage ranged from 12.3% to 39.8%, the mean was 20.93%. Fat-free mass spread from 41.9kg to 65kg, with the mean fat-free mass 49.3kg. Fat-free mass percentage ranged from 60.2% to 87.7%, with the mean 79.1%. Total body water (TBW) of the twelve participants had a minimum of 30.7kg and maximum of 47.6kg, with the mean TBW 36.1kg.

Table 2: Subject's Anthropometric Data (N=12)				
	Min	**Max**	**Mean**	**Std. Deviation**
Body Mass Index	18.7	37.7	22.96	5.04
Body Fat (kg)	5.91	42.91	14.31	9.99
Body Fat (%)	12.3	39.8	20.93	7.17
Fat-Free Mass (kg)	41.91	65.00	49.27	7.89
Fat-Free Mass (%)	60.24	87.69	79.05	7.15
Total Body Water (kg)	30.73	47.55	36.07	5.75

ENERGY BALANCE

Table 3 shows the mean energy intake over the three days was 2146kcal (+/-624 kcal). The mean energy expenditure over the three-day period was 2380 kcal (+/-458 kcal). Energy intake ranged from 750 kcal to 3755 kcal, with energy expenditure ranging from 1663kcal to 4334 kcal. Day 1, Day 2, and Day 3 the mean caloric intakes were 1964 kcal (+/- 743 kcal), 2094 kcal (+/- 856 kcal), and 2378 kcal (+/- 855 kcal) respectively. Mean energy expenditure on Day 1 was 2305 kcal (+/-726 kcal), Day 2 was 2480 kcal (+/-581 kcal), and Day 3 was 2355 kcal (+/-452 kcal). The mean energy expenditure on Day 1 and Day 2 exceeded the mean energy intake of those individual days respectively. When the three days of energy intake and expenditure recalled were averaged, energy intake was 2145 kcal and energy expenditure was 2380 kcal, resulting in a negative total energy balance for the population.

Assessing the participant's hourly energy balance equated how many hours were spent in a catabolic (<0 kcal), highly catabolic (<-400 kcal), anabolic (>0 kcal), highly anabolic (>400 kcal) state over the three-day recall period. The mean hours spent in a catabolic state (<0 kcal) by the participants was 52.8 hours (+/-23.9 hours) of 72 total hours, which was 73% of total hours. The mean hours spent in a highly catabolic state (<-400kcals) was 37.5 hours (+/-25.01 hours), which was 52% of total hours. The mean hours spent in an anabolic state (>0 kcal) was 19.2 hours (+/-24 hours), 27% of total hours. The mean hours spent in a highly anabolic state by participants was 12.4 hours (+/-21 hours), 17% of total hours. When the 3-day recall was averaged, participants on average were spending 17 hours (+/-9.2 hours) out of the 24 hours per day (71%) in a catabolic state (<0 kcal), with 13 (+/-10.2 hours) of those hours (54%) in a highly catabolic state (<-400kcal). In comparison, participants were only spending a mean of 6 hours (+/-9.2 hours) per day (25%) in an anabolic state (>0 kcal) with 4 (+/-9.2 hours) of these hours (17%) in a highly anabolic state (>+400 kcal).

Table 3 : Energy Intake/Expenditure and Energy Balance for the Total Population (N=12)

	Min	Max	Mean	Std. Deviation
Day 1 Kcals In	1228	3755	1964	744
Day 2 Kcals In	750	3441	2095	856
Day 3 Kcals In	1182	3537	2378	854
Average calories in	1054	3127	2146	624
Day 1 Kcal Out	1663	4334	2305	726
Day 2 Kcal Out	1895	3943	2480	581
Day 3 Kcal Out	1781	3137	2355	452
Average calories out	1888	3279	2380	458
Hours Catabolic	7.00	72.00	52.83	23.99
Hours High Catabolic	.00	68.00	37.50	25.01
Hours Anabolic	.00	65.00	19.17	23.99
Hours High Anabolic	.00	56.00	12.42	20.94
Avg of days Catabolic hours	.00	24.00	17.33	9.25
Avg of days High Catabolic hrs	.00	24.00	13.58	10.24
Avg of days Anabolic hrs	.00	24.00	6.66	9.25
Avg of days High Anabolic hrs	.00	24.00	4.33	9.22

Table 4 shows the daily caloric intake and expenditure for each of the participant's three-day dietary recalls, along with the averaged three-day daily caloric intake and expenditure. It can be observed in many of the participants that there is variability in the calories they consume day to day. For instance, participant with ID number 10, consumed 1745 kcal on Day 1, 3441 kcal on Day 2, and 2601 kcal on Day 3. On Day 2 the participant consumed almost double the calories she consumed the previous day. This trend can also be seen in many of the other participant's dietary recalls. When the three days of dietary recall are averaged it washes out the low and high energy intakes of participants. For instance, the participant with the ID number 3, had an average energy intake of 2376 kcal and energy expenditure of 2027 kcal, which would leave her in an optimum energy balance (+/-400 kcals). However, on Day 1 the participant was in a highly catabolic state (<-400kcal) as she had a daily energy intake of 1393 kcal and daily energy expenditure of 2045 kcal, leading to a negative energy balance of -652 kcal. This trend can be observed in many of the other participants also.

Table 4: Individual Energy Intake and Expenditure								
ID	Day 1 Kcal In	Day 1 Kcal Out	Day 2 Kcal In	Day 2 Kcal Out	Day 3 Kcal In	Day 3 Kcal Out	Avg Kcal In	Avg Kcal Out
1	2668	1663	3323	2148	2566	2051	2853	1954
2	1316	1861	1655	2020	2740	1781	1904	1888
3	1393	2045	2199	2156	3537	1881	2376	2027
4	3755	2457	3056	1895	2569	2037	3127	2130
5	1228	2756	750	3943	1182	3137	1054	3279
6	1491	1857	2500	2420	2146	2557	2045	2278
7	2353	1886	1372	2813	1390	2509	1705	2403
8	1639	2258	1764	2242	1461	2391	1622	2297
9	1655	1869	1921	2433	3498	1876	2358	2059
10	1745	2660	3441	3196	2601	3089	2596	2982
11	2607	2015	2045	2166	3393	2591	2681	2257
12	1719	4334	1112	2328	1453	2364	1428	3008

Table 5 represents the individual participants and the hours they spent during the 72 hours of dietary and exercise recall in either a catabolic (<0 kcal), highly catabolic (<-400 kcal), anabolic (>0 kcal), highly anabolic (>+400 kcal), or optimum energy balance (+/-400 kcal). It can be observed that 9 out of 12 participants spent at least 66% of the total 72 hours in a catabolic state, with two of the participants spending all 72 hours in a catabolic state. It can also be observed that 7 out of the 12 participants spent a least half of the total hours (36 out 72 hours) in a highly catabolic state (<-400 kcal). In comparison, only 3 out of 12 of the participants spent majority of hours in an anabolic state with two of these participants spending the majority of their hours in a highly anabolic state (>+400lkcal). The most hours spent in optimum energy balance (+/-400kcal) was by ID number 11 who spent 49 hours out of 72 hours in optimum energy balance. The lowest hours spent in optimum energy balance was a total of 4 out of 72 hours. Ten participants spent less than 36 hours in optimum energy balance.

Table 5: Individual Hourly Energy Balance					
ID	Hours Catabolic (<0 kcals)	Hours Highly Catabolic (<-400kcals)	Hours Anabolic (>0 kcals)	Hours Highly Anabolic (>+400 kcals)	Hours Spent in Energy Balance (+/-400 kcals)
1	7	0	65	56	16
2	65	38	7	0	34
3	49	25	23	12	35
4	9	0	63	56	16
5	72	68	0	0	4
6	65	29	7	0	43
7	59	53	13	6	13
8	70	60	2	0	12
9	64	42	8	5	25
10	72	65	0	0	7
11	31	9	41	14	49
12	71	64	1	0	8

Kcals/kg FFM/day

Table 6 displays the kcal/kg FFM/day for each of the 12 participants. Five participants (42%) had <30kcals/kg FFM/day for at least one of their dietary recalls, with nine participants (75%) in total having <45kcal/kg FFM/day for a least one day of their dietary recall. In comparison, when the three days of dietary intake were averaged only two participants (17%) fell below <30 kcals/kg FFM/day and six participants (50%) fell below <45kcal/kg FFM/day. This shows that by averaging it can appear that athletes have adequate energy intake as the high intake days wash out the low intake days, however when assessed day by day they are experiencing inadequate energy intake on some days.

Table 6: Calories per Kilogram of Fat Free Mass

ID number	kcal/kg FFM Day1	kcal/kg FFM Day2	kcal/kg FFM Day3	kcal/kg FFM Average
1	62.18	77.44	59.8	66.49
2	31.27	39.32	65.10	45.24
3	30.89	48.77	78.44	52.69
4	81.31	66.17	55.63	67.71
5	18.89	11.54	18.18	16.22
6	31.06	52.08	44.71	42.6
7	48.74	28.42	28.79	35.32
8	32.90	35.41	29.33	32.56
9	39.49	45.84	83.47	56.26
10	28.44	56.08	42.39	42.31
11	60.89	47.76	79.24	62.61
12	29.73	19.23	25.13	24.70

LEAF-Q

Participants answered the LEAF-Q and after their responses were equated using a scoring key based on specific responses. The higher the score the greater the athlete would be at risk for RED-S. 58% (n=7) of the participants scored ≥8 on the LEAF-Q putting them at risk for RED-S. Three distance runners (N=5), three sprinters (N=5), and one thrower (N=2) scored at risk for RED-S. The lowest RED-S score was 3, and the highest RED-S score was 20. The mean RED-S score was 8.7 (+/-5.63). Five participants (42%) scored below 8, putting them at decreased risk for RED-S. The LEAF-Q questionnaire and scoring key can be found in Appendix C. Participants responded to questions based on injury, gastrointestinal, and menstrual function. Three of the participants were taking oral contraceptives, two using them as a form of contraception and one participant using it to prevent their menstruation stopping. The age participants started menstruation was categorized into three categories, <11 years of age (n=1), 12-14 years of age (n=9), and >15 years of age (n=2). Of the twelve participants, five participants previously experienced secondary amenorrhea and one participant was currently experiencing secondary amenorrhea.

CORRELATIONS

A Mann Whitney U Test showed that the distribution of fat-free mass percentage, body fat percentage, and Day 1 hours spent in optimum, surplus, and deficit energy balance was the same when comparing those categorized at risk for RED-S (LEAF-Q score =/>8) to those that were categorized not at risk for RED-S (LEAF-Q score <8). Due to this statistical finding all correlations were conducted on the entire population and not categorized into separate groups based on their RED-S score.

Table 7: Non-Parametric Test of Null hypothesis (Mann Whitney U Test)

Null Hypothesis	Sig.	Decision
The distribution of Fat-Free Mass (%) is the same across categories of RED-S Score	0.755	Retain the null hypothesis
The distribution of Body Fat (%) is the same across categories of RED-S Score	0.639	Retain the null hypothesis
The distribution of Day 1 hrs in EB= +/-400 is the same across categories of RED-S Score	0.530	Retain the null hypothesis
The distribution of Day 1 hrs in EB> +400 is the same across categories of RED-S Score	0.755	Retain the null hypothesis
The distribution of Day 1 hrs in EB<-400 is the same across categories of RED-S Score	0.639	Retain the null hypothesis

A Spearman's rho was used to assess correlations between fat-free mass percentage, body fat percentage, and hours spent in a catabolic, highly catabolic, anabolic, or highly anabolic state. Results can be observed in Table 8. No statistical significance was found between the variables, but the data shows there is a trend between spending a longer duration of hours in a catabolic or highly catabolic state and having a lower fat free mass percentage and higher body fat percentage. Conversely, the longer duration spent in an anabolic state the higher the fat free mass percentage and lower the body fat percentage.

Table 8: Spearman's rho Correlation Between Energy Balance Over a Non-Averaged 3-day Recall Period and Body Composition (N=12)

		Hours Catabolic	Hours High Catabolic	Hours Anabolic	Hours High Anabolic
Fat-Free Mass (%)	Correlation	-0.337	-0.375	0.337	0.194
	Sig. (1- tailed)	0.142	0.115	0.142	0.272
Body Fat (%)	Correlation	0.355	0.393	-0.355	-0.215
	Sig. (1- tailed)	0.129	0.103	0.129	0.251

The same trend as seen in the Spearman's rho can also be observed when a Pearson correlation was performed on the data (Table 9), with a longer duration spent in a catabolic and in a highly catabolic state resulting in lower fat-free mass percentage, and higher body fat percentage, and the more hours spent in an anabolic state resulting in a higher fat free mass percentage, and lower body fat percentage. However, no statistical significance was found.

Table 9: Pearson Correlation Between Energy Balance Balance Over a Non-Averaged 3-day Recall Period and Body Composition (N=12)

		Hours Catabolic	Hours High Catabolic	Hours Anabolic	Hours High Anabolic
Fat-Free Mass (%)	Correlation	-0.288	-0.387	0.288	0.249
	Sig. (1-tailed)	0.182	0.107	0.182	0.218
Body Fat (%)	Correlation	0.291	0.390	-0.291	-0.250
	Sig. (1-tailed)	0.18	0.105	0.18	0.216

Table 10: Spearman's rho correlation between Day 1 Energy Balance and Body Composition (n=12)

		Fat-Free Mass (%)	Body Fat (%)
Day 1 Kcal In	Correlation	0.168	-0.161
	Sig. (2- tailed)	0.602	0.617
Day 1 Kcal Out	Correlation	-0.119	0.123
	Sig. (2- tailed)	0.713	0.704
Day 1 Hrs in EB= +/-400	Correlation	0.625*	-0.643*
	Sig. (2- tailed)	0.030	0.024
Day 1 Hrs in EB> +400	Correlation	0.188	-0.188
	Sig. (2- tailed)	0.559	0.558
Day 1 Hrs in EB <-400	Correlation	-0.626*	0.636*
	Sig. (2- tailed)	0.03	0.026
Day 1 Hrs in anabolic	Correlation	0.439	-0.451
	Sig. (2- tailed)	0.153	0.141
Day 1 Hrs in catabolic	Correlation	-0.439	0.451
	Sig. (2- tailed)	0.153	0.141
Day 1 ending kcal	Correlation	0.175	-0.172
	Sig. (2- tailed)	0.587	0.594

A Spearman's rho was used to assess correlations between fat free mass percentage, body fat percentage, and daily energy intake, expenditure, hours spent in optimum energy balance, energy surplus, and energy deficit, hours spent in anabolic and catabolic, and the ending calories for the day. This correlation was completed for each of the three days. There was a significant correlation between participants who spent a longer duration of hours in an optimum energy balance (+/-400 kcal) and a higher fat free mass percentage ($p=0.03$, $r_s=0.625$) and lower body fat percentage ($p=0.024$, $r_s= -0.643$) on Day 1 of dietary and exercise recall (Table 10). Statistical significance was also found between those participants who spent longer durations in an energy deficit (<-400 kcal) having lower fat free mass percentage ($p=0.03$ $r_s= -0.626$), and higher body fat percentage ($p=0.026$, $r_s=0.636$) on Day 1 (Table 10).

A spearman's rho correlation on Day 2 data showed that those participants that had higher energy expenditure had lower fat free mass percentage ($p=0.003$, $r_s= -0.776$) and higher body fat percentage ($p=0.003$, $r_s=0.785$) (Table 11). There also was a trend between those participants who spent a longer duration of time in an optimal energy balance and having a higher fat free mass ($p=0.065$, $r_s= -0.549$) and lower body fat percentage ($p=0.077$ $r_s=0.529$), though no statistical significance was found (Table 11).

Table 11: Spearman's rho correlation between Day 2 Energy Balance and Body Composition (N=12)			
		Fat-Free Mass (%)	**Body Fat (%)**
Day 2 Kcal In	Correlation	-0.077	0.067
	Sig. (2- tailed)	0.812	0.837
Day 2 Kcal Out	Correlation	-0.776*	0.785*
	Sig. (2- tailed)	0.003	0.003
Day 2 Hrs in EB= +/-400	Correlation	-0.549	0.529
	Sig. (2- tailed)	0.065	0.077
Day 2 Hrs in EB> +400	Correlation	0.244	-0.244
	Sig. (2- tailed)	0.445	0.444
Day 2 Hrs in EB <-400	Correlation	0.086	-0.070
	Sig. (2- tailed)	0.790	0.829
Day 2 Hrs in anabolic	Correlation	0.066	-0.067
	Sig. (2- tailed)	0.837	0.837
Day 2 Hrs in catabolic	Correlation	-0.066	0.067
	Sig. (2- tailed)	0.837	0.837
Day 2 ending kcal	Correlation	0.154	-0.165
	Sig. (2- tailed)	0.633	0.609

A significant correlation was found on Day 3, when those participants who had higher energy expenditure had lower fat free mass percentage (p=0.002, r_s= -0.797) and higher body fat percentage (p=0.001, r_s=0.813) when a spearman's rho was used to analyze the data (Table 12).

Table 12: Spearman's rho correlation between Day 3 Energy Balance an Body Composition (N=12)

		Fat-Free Mass (%)	Body Fat (%)
Day 3 Kcal In	Correlation	0.154	-0.182
	Sig. (2- tailed)	0.633	0.571
Day 3 Kcal Out	Correlation	-0.797*	0.813*
	Sig. (2- tailed)	0.002	0.001
Day 3 Hrs in EB= +/-400	Correlation	-0.106	0.084
	Sig. (2- tailed)	0.774	0.795
Day 3 Hrs in EB> +400	Correlation	0.277	-0.301
	Sig. (2- tailed)	0.383	0.341
Day 3 Hrs in EB <-400	Correlation	-0.292	0.322
	Sig. (2- tailed)	0.357	0.307
Day 3 Hrs in anabolic	Correlation	0.352	-0.378
	Sig. (2- tailed)	0.261	0.225
Day 3 Hrs in catabolic	Correlation	-0.352	0.378
	Sig. (2- tailed)	0.261	0.225
Day 3 ending kcal	Correlation	0.343	-0.375
	Sig. (2- tailed)	0.276	0.230

CHAPTER V

DICUSSION AND CONCLUSION

This study sought to determine the prevalence of RED-S in female collegiate track & field athletes. 58% of participants scored =/>8 on the LEAF-Q, putting them at risk for RED-S. This rejects the null hypothesis that the majority of track & field athletes would be at risk for RED-S. Despite the small sample of participants in this study, this statistic show the need for a RED-S screening process for female collegiate track and field athletes. If athletes at risk for RED-S go unnoticed, they are at risk for developing the many consequences included in the RED-S terminology that occur due to energy deficiencies. No difference was found between the disciplines of track & field athletes when considering their risk of having RED-S, with three sprinters (n=5), three distance runners (n=5), and one thrower scoring (n=2) =/>8 on the LEAF-Q putting them at risk for RED-S. This finding does not reject the null hypothesis that a greater number of distance runners will be at risk for RED-S than sprinters and throwers. Additional to the RED-S score, six of the twelve participants were or previously had experience secondary amenorrhea, which closely compares to previous research reporting that 65% of collegiate female distance athletes experience secondary ammenorrhea[1].

This study highlights the effect of averaging multiple days of dietary recall can have on perceived results. When participant's dietary recalls were assessed day by day the majority of hours were spent in a catabolic state, however when the three days of the recall were averaged the severity of the hours spent in a catabolic state lessened. A day of high energy intake can mask out the other days of low energy intake by providing an average energy intake that appears to fall in optimum energy balance with average energy intake lying +/-400 kcal within energy expenditure. However, these athletes are experiencing days of energy deficit, which can build up over time to cause health consequences such as those included in the RED-S terminology. In this specific population, it is important to consider the results of this study and assess athlete's energy balance hourly, day by day, to provide a more precise estimate of energy intake and expenditure.

The associations in this study are consistent with previous studies evaluating the relationships between energy balance deficits and body composition, indicating that longer duration spent in an energy deficit energy balance is associated with lower lean mass and higher body fat percentage[2]. Spearman's rho analysis found a significant inverse correlation between Day 1 hours spent in optimal energy balance (± 400 kcal) and body fat percent ($p=0.024$, $r_s= -0.643$), and significant positive correlation between Day 1 hours spent in optimal energy balance (± 400 kcal) and fat free mass percentage ($p=0.03$, $r_s=0.625$). Spearman's rho analysis also found an inverse correlation between Day 1 hours spent in an energy deficit (< -400 kcals) and fat free mass percentage ($p=0.03$ $r_s= -0.626$), and a positive correlation between Day 1 hours spent in an energy deficit and body fat percentage ($p=0.026$, $r_s=0.636$). A trend between spending a longer duration of hours in a catabolic or highly catabolic state and having a lower fat free mass percentage and higher body fat percentage was also observed, though no significance was found.

Due to the small sample size, the data collected can be generalized to the Georgia State Track and Field team specifically, and can serve as a reference for other female collegiate track and field teams. Screening for RED-S in track and field athletes, and specifically distance runners who may be at higher risk due to the aesthetic image sometimes expected of them, needs to be improved to decrease the risk for RED-S and its consequences.

STUDY LIMITATIONS

A limitation to this study was the small sample size (n=12). Another limitation to the study was the three-day dietary and exercise recall as it is possible that the study participants underreported/over-reported energy intake or improperly estimated portion size, which is a known limitation to all dietary recalls. A study on elite gymnasts found that 61% of respondents underreported energy intake[37]. Additionally, it is possible that some food items were unreported due to the participant forgetting certain components of their food intake as many participants found it difficult to remember their recall the day that was three days prior to their appointment. Also, energy expenditure varied greatly from participant to participant with some participants completing their recall on high intensity exercise days, whereas others completed their recall on days with no or low exercise. In future research studies, it would be beneficial to obtain data from different exercise intensity days such as one day of low activity, one day of moderate activity, and one day of high intensity activity. Lastly, due to the sensitive topic of the study, it is possible that there was selection bias as some of the invited subjects that did not participate in the study may have chose not to participate due to possibly experiencing some of the components that were being studied.

FUTURE RESEARCH

Future research studying the prevalence of RED-S in male collegiate athletes would be vitally important to highlight the scope of male athletes at risk while it also could be compared to the prevalence of RED-S in female colligate athletes. Also, a study on the prevalence of RED-S in different collegiate sports, for example weight-sensitive sports versus other sports would be an important area of research for the RED-S paradigm versus previous literature that studied the prevalence of the Female Athlete Triad in different sports. Lastly, future studies could look at the prevalence of those with RED-S in high school and professional athletes compared to that of colligate athletes. Other data that could be collected to strengthen future studies would be to assess immunological, menstrual, bone health, cardiovascular, metabolic, and hematological lab values in relation to energy balance.

CONCLUSIONS

Previously, it has been recommended to average three-day recalls in order to get an optimal estimate of energy intake[38]. This study highlights the effect of averaging multiple days of dietary recall can have on the perceived energy balance status. When participant's dietary recalls were assessed day by day the majority of hours were spent in a catabolic state, however when the three days of the recall were averaged the severity of the hours spent in a catabolic state lessened. The associations in this study are consistent with previous studies evaluating the relationships between energy balance deficits and body composition, indicating that longer duration spent in a negative energy balance is associated with lower lean and higher fat mass and longer duration of time spent in an optimal energy balance is associated with a higher fat free mass and lower body fat percentage[6]. The findings from the LEAF-Q show that 58% of participants were at risk for RED-S, and half of all participants previous had or were currently were experiencing menstrual dysfunction. The identification of athletes with RED-S is vitally important to halt the progression of health related consequences such as menstrual dysfunction, decreased bone density, and other health consequences[1]. The use of a screening tool such as the LEAF-Q can serve as a quick assessment tool to highlight those athletes that need additional medical attention by using a scoring scale to rank athlete's answers based on current health status and past medical history.

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Appendix A

Georgia State University
Byridine F. Lewis School of Nursing and Health Professions
Department of Nutrition
Informed Consent

Title: Relative Energy Deficiency in Female Collegiate Track & Field Athletes

Principal Investigator: Dan Benardot, PhD, RD, LD, FACSM

Student Investigator: Niamh Kearney

I. Purpose
You are invited to participate in a research study. The purpose of the study is to investigate the energy intake and expenditure in female track & field athletes. There is little information on diet, energy intake, and expenditure in female track & field athletes. You are invited because you are a track & field athlete and member of the Georgia State Women's Track & Field team. A total of 29 players will be recruited for this study. 90 minutes of your time will be needed on a day that works for you and the research staff.

II. Procedures
If you decide to participate, you will be assessed in several ways that include:

1. Height
2. Weight
3. Diet, activity questions (completed by yourself followed by a talk with student investigator)
4. Injury, gastro intestinal, and menstrual questions (completed by yourself)

All of the tests and questionnaires will be done in such a way that protects your identity. You will be given a code number. Only that code number and not your name will be used on all of the forms to make sure that your results cannot be traced to you. The test procedures are explained more fully here.

1. **Measurement of Height:** You will have your height measured. You will be asked to stand straight with no socks or shoes for the measurement, which takes approximately 15 seconds. There is no risk or discomfort associated with this measurement. Robert Bergia will take your height.
2. **Measurement of Weight:**A scales will be used to assess your weight. You will stand on the machine with your shoes and socks removed. There is no discomfort associated with this test which will take approximately 1 minutes. There is no harm associated with the assessment. Niamh Kearney will be performing the body weight assessment in 455 Petit Science Center.
3. **Measurement of Diet/Fluid Intake and Energy Expenditure:** You will complete a questionnaire and interview. These will help us understand what you eat, drink, and your activities that burn energy during a normal day. If you complete the

GSU APPROVED IRB NUMBER: H16313
IRB APPROVAL DATE: 01/08/2016
IRB EXPIRATION DATE: 01/07/2017

questionnaire in advance, we may ask you some questions to make sure the questionnaire is correct and complete. For instance, if you indicated that you ate a hamburger, you may be asked if you had ketchup or lettuce. This will ensure the questionnaire is complete. The total time required to complete the questionnaire with interview will take 30to 40 minutes. There are no risks associated with this task.

4. **Questionnaire containing questions on previous/current injuries, menstrual cycle, and digestive system.** You will fill out a questionnaire by yourself asking questions about previous injuries you may have sustained, menstrual cycle, and questions about your digestive function. This questionnaire will take 20 to 30 minutes to complete.

lll. Risks
In this study you will not have any more risks than you would in a normal day of life.

IV.Benefits
Participation in this study may or may not benefit you personally. It may give you a better understanding of nutrition and energy requirements of track and field athletes. You will have access to all of the information you have provided at the end of the study. The information obtained may provide information that helps us better understand the relationships between energy intake, energy expenditure, menstrual function, and injury. This information may help to improve our understanding of why many active people find it difficult to have adequate energy intake.

V. Voluntary Participation and Withdrawal
Participation in research is voluntary. You do not have to be in this study. If you decide to be in the study and change your mind, you have the right to drop out at any time. You may skip questions or stop participating at any time. Whatever you decide, you will not lose any benefits to which you are otherwise entitled. Your decision will not have any impact on your status as a member of the Georgia State Women's Track & Field team.

VI. Confidentiality
We will keep your records private to the extent allowed by law. Only study personnel will have access to the information you provide. Information may also be shared with those who make sure the study is done correctly (GSU Institutional Review Board, the Office for Human Research Protection (OHRP). We will use a code number rather than your name on study records, which will be stored in a locked file cabinet. When your information is entered into a computer, it will be entered into a computer that is password protected. Your name and other facts that might point to you will not appear when we present this study or publish its results. The findings will be summarized and reported in group form. You will not be identified personally.

VII. Contact Persons
Contact Niamh Kearney, nkearney2@student.gsu.edu , if you have questions, concerns, or complaints about this study. You can also call if you have been harmed by the study. Call Susan Vogtner in Georgia State University Office of Research Integrity at 404-413-3513 or

svogtner1@gsu.edu if you want to talk to someone who is not part of the study team. You can talk about questions, concerns, offer input, obtain information, or suggestions about the study. You can also call Susan Vogtner if you have questions or concerns about your rights in this study.

VIII. Copt of Consent Form to Subject:
We will give you a copy of this consent form to keep.

If you are willing to volunteer for this research, please sign below.

____ ____________
Participant Date

____ ____________
Principal Investigator or Researcher Obtaining Consent Date

Appendix B

NutriTiming® Data Entry Form

Instructions: Completing this form will help us understand whether the amount of energy (calories) you consume comes close to matching the energy (calories) you expend. This form provides a way of entering your energy expended by using an 'Activity Factor', and your energy consumed by using a description of the foods and drinks you ate. The information is entered by hourly units, so you don't have to remember precisely the time you had an activity or ate some food. Rather, you are asked to enter when you had an activity, its intensity by using the activity factor scale, and how long you did it (example: I had a slow jog between 10 and 11 in the morning that lasted for 30 minutes). Use the NutriTiming Activity Factor Scale Descriptions to help you figure out the best factor to enter when describing an activity. When entering food, describe the food and the way it was prepared fully (example: chicken breast with no skin that was baked; or fried, battered chicken breast, etc), and the amount you consumed (example: 1 apple; 1 ½ cups; 15 red grapes; 1 large banana, etc.). A factor of 1.5 is considered normal daytime activity, and we will assume a factor of 1.5 unless you indicate otherwise. A factor of 1 is equal to sleep, and a factor greater than 1.5 suggests you are doing something more vigorous than normal daytime activity. Please enter a full 24 hours of all your activities and all the foods/drinks you consume. Use the example below to help you understand how to enter the information.

NutriTiming Activity Factor Scale

Factor	Description
1	**Resting, Reclining:** Sleeping, reclining, relaxing
1.5	**Rest +:** Normal, average sitting, standing daytime activity
2.0	**Very Light:** More movement, mainly with upper body. Equivalent to tying shoes, typing, brushing teeth
2.5	**Very Light +:** Working harder than 2.0
3.0	**Light:** Movement with upper and lower body. Equivalent to household chores
3.5	**Light +:** Working harder than 3.0; Heart rate faster, but can do this all day without difficulty
4.0	**Moderate:** Walking briskly, etc. Heart rate faster, sweating lightly, etc but comfortable
4.5	**Moderate +:** Working harder than 4.0. Heart rate noticeably faster, breathing faster
5.0	**Vigorous:** Breathing faster and deeper, heart rate faster, must take occasional deep breath during sentence for conversation
5.5	**Vigorous +:** Working harder than 5.0. Breathing faster and deeper, and must breath deeply more often to carry on conversation
6.0	**Heavy:** You can still talk, but breathing is so hard and deep you would prefer not to. Sweating profusely. Heart rate very high
6.5	**Heavy +:** Working harder than 6.0. You can barely talk but would prefer not to. This is as hard as you can go, but not for long
7.0	**Exhaustive:** Can't continue this intensity long, as you are on the verge of collapse and are gasping for air. Heart rate is pounding

Begin Hour	End Hour	Activity Factor	Activity Description	Food/Drink Description	Food/Drink Amount
				****Begin Example****	
12am	7am	1.0	Sleep		
7am	8am	1.5	Nothing Special	Whole Wheat Waffles (Frozen-Kellogg)	3
				Maple Syrup	2 Tablespoons
				1 % Milk	1 Cup
				Orange Juice (from concentrate)	1.5 Cups
				Coffee	2 Cups
				1 % Milk for Coffee	2 Tablespoons
10am	11am	5.0	Jog 30 minutes	Gatorade	16 Ounces
12noon	1pm	1.5	Nothing Special	Medium size beef sandwich with white	1 Sandwich
				bread, mayonnaise, lettuce, and tomato.	
				Coffee	2 Cups
				Artificial Coffee Creamer	2 Packets
				Apple Pie	1 Slice (small)
5pm	6pm	4.0	Walk 1 hour	Water	16 ounces
7pm	8pm	1.5	Nothing Special	Lasagna with ground beef and cheese	Large Plate
				Lettuce Salad with Tomatoes and Cucumbers	Medium Size Salad
				Blue Cheese Salad Dressing	1 Tablespoon
				Red Wine	1 Medium Glass
10pm	11pm	1.5	Nothing Special	Popcorn (air popped; no butter)	100 Calorie Pack

NutriTiming® Data Entry Form

Name:____ Age: ____Years Date of Birth:____/____/________
MM DD YYYY

Gender: M or F Height: ____Feet ___Inches Weight: ____ lbs.

Date Analyzed: ___/____/____ Time last meal eaten before date analyzed: _____________
M DD YYYY

Begin Hour	End Hour	Activity Factor	Activity Descriptions	Food/Drink Descriptions	Food/Drink Amounts

Appendix C

(Supplemental Digital Content 1)

The LEAF-Q

A questionnaire for female athletes

Department of Nutrition, Exercise and Sports
Life Science
University of Copenhagen
Denmark
Contact: Anna Melin, aot@life.ku.dk

The low energy availability in females questionnaire (LEAF –Q), focuses on physiological symptoms of insufficient energy intake. The following pages contain questions regarding injuries, gastrointestinal and reproductive function. We appreciate you taking the time to fill out the LEAF-Q and the reply will be treated as confidential.

Name: ______________________________

Address: ______________________________

____

E-mail: ______________________________

Cell: ______________

Profession: ______________________________

Education: ______________________________

Age: ________(years)

Height: ________(cm) Weight: ________(kg)

Your highest weight with your present height: ________(kg)
(excluding pregnancy)

Your lowest weight with your present height: ________(kg)

Do you smoke? Yes ☐ No ☐

Do you use any medication (excluding oral contraceptives)? Yes ☐ No ☐

If yes, what kind of medication?______________________________

Your normal amount of training (average) – number of hours per week and what kind of exercise, such as running, swimming, bicycling, strength training, technique training etc.:

____

____

____

Comments or further information regarding exercise:______________________________

____

____

1. Injuries

Mark the response that most accurately describes your situation

A: Have you had absences from your training, or participation in competitions during the last year due to injuries?

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

A1: If yes, for how many days absence from training or participation in competition due to injuries have you had in the last year?

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

A2: If yes, what kind of injuries have you had in the last year? ______________________________

____

Comments or further information regarding injuries: ____________________________________

____

____

2. Gastro intestinal function

A: Do you feel gaseous or bloated in the abdomen, also when you do not have your period?

☐ Yes, several times a day ☐ Yes, several times a week

☐ Yes, once or twice a week or more seldom ☐ Rarely or never

B: Do you get cramps or stomach ache which cannot be related to your menstruation?

☐ Yes, several times a day ☐ Yes, several times a week

☐ Yes, once or twice a week or more seldom ☐ Rarely or never

C: How often do you have bowel movements on average?

☐ Several times a day ☐ Once a day ☐ Every second day

☐ Twice a week ☐ Once a week or more rarely

D: How would you describe your normal stool?

☐ Normal (soft) ☐ Diarrhoea-like (watery) ☐ Hard and dry

Comments regarding gastrointestinal function: ____________________

____

3. Menstrual function and use of contraceptives

3.1 Contraceptives

Mark the response that most accurately describes your situation

A: Do you use oral contraceptives?

☐ Yes ☐ No

A1: If yes, why do you use oral contraceptives?

☐ Contraception ☐ Reduction of menstruation pains ☐ Reduction of bleeding

☐ To regulate the menstrual cycle in relation to performances etc..

☐ Otherwise menstruation stops

☐ Other ________________________________

____

A2: If no, have you used oral contraceptives earlier?

☐ Yes ☐ No

A2:1 If yes, when and for how long? ______________________________

____

____

B: Do you use any other kind of hormonal contraceptives? (e.g. hormonal implant or coil)

☐ Yes ☐ No

B1: If yes, what kind?

☐ Hormonal patches ☐ Hormonal ring ☐ Hormonal coil ☐ Hormonal implant ☐ Other

____

3.2 Menstrual function **Mark the response that most accurately describes your situation**

A: How old were when you had your first period?

☐ 11 years or younger ☐ 12-14 years ☐ 15 years or older ☐ I don't remember

☐ I have never menstruated (If you have answered "I have never menstruated" there are no further questions to answer)

B: Did your first menstruation come naturally (by itself)?

☐ Yes ☐ No ☐ I don't remember

B1: If no, what kind of treatment was used to start your menstrual cycle?

☐ Hormonal treatment ☐ Weight gain

☐ Reduced amount of exercise ☐ Other

C: Do you have normal menstruation?

☐ Yes ☐ No **(go to question C6)** ☐ I don't know **(go to question C6)**

C1: If yes, when was your last period?

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

C2: If yes, are your periods regular? (Every 28th to 34th day)

☐ Yes, most of the time ☐ No, mostly not

C3: If yes, for how many days do you normally bleed?

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

C4: If yes, have you ever had problems with heavy menstrual bleeding?

☐ Yes ☐ No

C5: If yes, how many periods have you had during the last year?

☐ 12 or more ☐ 9-11 ☐ 6-8 ☐ 3-5 ☐ 0-2

3.2 Menstrual function

Mark the response that most accurately describes your situation

C6: If no or "I don't remember", when did you have your last period?

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

D: Have your periods ever stopped for 3 consecutive months or longer (besides pregnancy)?

- ☐ No, never
- ☐ Yes, it has happened before
- ☐ Yes, that's the situation now

E: Do you experience that your menstruation changes when you increase your exercise intensity, frequency or duration?

- ☐ Yes
- ☐ No

E1: If yes, how? (Check one or more options)

- ☐ I bleed less
- ☐ I bleed fewer days
- ☐ My menstruations stops
- ☐ I bleed more
- ☐ I bleed more days

(Supplemental Digital Content 2)

The LEAF-Q Scoring key

A total score ≥8 is to be considered at risk for the Triad

Department of Nutrition, Exercise and Sports
Life Science
University of Copenhagen
Denmark
Contact: Anna Melin, aot@life.ku.dk

1. A: **0** No, not at all, **1** Yes, once or twice, **2** Yes, three or four times, **3** Yes, five times or more

1. A1: **1** 1-7 days, **2** 8-14 days, **3** 15-21 days, **4** 22 days or more

2. A: **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

2. B: **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

2. C: **1** Several times a day, **0** Once a day, **2** Every second day, **3** Twice a week, **4** Once a week or more rarely

2. D: **0** Normal, **1** Diarrhoea-like, **2** Hard and dry

3.1 A1: **0** Contraception, **0** Reduction of menstruation pains, **0** Reduction of bleeding,

0 To regulate the menstrual cycle in relation to performances etc..., **1** Otherwise menstruation stops

3.2 A: **0** 11 years or younger, **0** 12-14 years, **1** 15 years or older, **0** I don't remember,

8 I have never menstruated

3.2 B: **0**Yes, **1** No, **1** I don't remember

3.2 B1: **1** Hormonal treatment, **1** Weight gain, **1** Reduced amount of exercise, **1** Other

3.2 C: **0** Yes, **2** No (go to question 3.2 C6), **1** I don't know (go to question 3.2 C6)

3.2 C1: **0** 0-4 weeks ago, **1** 1-2 months ago, **2** 3-4 months ago, **3** 5 months ago or more

3.2 C2: **0** Yes, most of the time, **1** No, mostly not

3.2 C3: **1** 1-2 days, **0** 3-4 days, **0** 5-6 days, **0** 7-8 days, **0** 9 days or more

3.2 C4: **0** Yes, **0** No

3.2 C5: **0** 12 or more, **1** 9-11, **2** 6-8, **3** 3-5, **4** 0-2

3.2 C6: **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

3.2 D: **0** No, never, **1** Yes, it has happened before, **2** Yes, that's the situation now

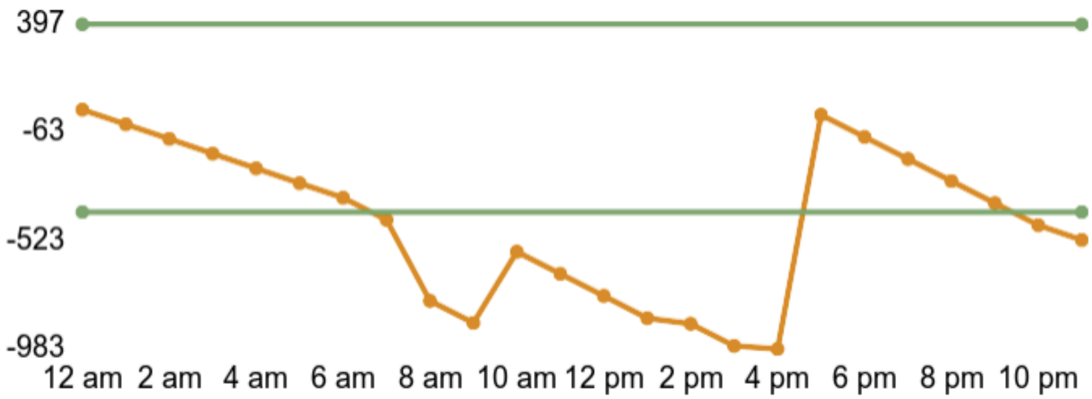
3.2 E: **1** Yes, **0** No

3.2 E1: **1** I bleed less, **1** I bleed fewer days, **2** My menstruations stops, **0** I bleed more, **0** I bleed more days

Appendix D

NUTRITIMING ENERGY BALANCE EXAMPLE

Energy Balance



Calories Out

Factor	Hours	Calories
1.0	8	502
1.5	15	1411
5.5	1	345
	Total	2258

24 Hour Calorie Balance

Starting Energy Balance		99
Calories In	1639	
Calories Out	2258	
24 Hour Energy Net	-618	
Ending Energy Balance		-519
KCal(in)/Kg - total	26.6	
KCal(in)/Kg - active	0.0	

Highs and Lows

Hours optimum (+- 400 KCal)	12
Hours surplus (> 400 KCal)	0
Hours deficit (< -400 KCal)	12
Ratio surplus to deficit	0.00
Hours anabolic (> 0 KCal)	2
Hours catabolic (< 0 KCal)	22
Ratio anabolic to catabolic	0.09
Highest energy	99
Lowest energy	-983