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Impact of Training Volume on Female Athlete Triad Risk for Female Collegiate D1 Track and Field Athletes

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Impact of Training Volume on Female Athlete Triad Risk for Female Collegiate D1 Track and Field Athletes

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ABSTRACT

The Female Athlete Triad is the joint-presentation of three intertwined conditions (i.e., low energy availability (LEA), low bone mineral density (BMD), and menstrual dysfunction) that range in severity across affected individuals and have been known to affect the mental, emotional, and physical health of female athletes in a number of sports, especially those that are leanness-orientated and feature a high prevalence of disordered eating. The purpose of this study is to assess the potential relationship between increasing amounts of training volume and individual Triad risk factors in women's collegiate track and field. Online Qualtrics surveys were administered to NCAA D1 women's track and field programs throughout the spring and summer seasons of competition and conditioning, respectively. The six sections of the survey included questions regarding demographic information, sport information, collegiate injury history, Triad risk, sleep quality, perceived stress, and self-perceived depressive symptoms. 34 female athletes between the ages of 18 and 29 years were analyzed via Pearson Chi-Square tests. When separated into high and low percentile training groups for competition total training volume hours, it was found that significant differences existed for "*history of collegiate injury*" (p=0.022), "*desire to lose weight for 'sporting image'*" (p=0.042), and "*suffer from eating disorder*" (p=0.017). "*Low BMD or osteoporosis diagnosis*" (p=0.054) and "*ferritin supplement usage*" (p=0.051) were found to be approaching significance between the groups as well. Although some Triad risk factors were found to be increased in the higher training volume group, larger population pools and additional research is required to draw definite conclusions regarding the potential relationship between increases in training volume and elevated risks of developing the Triad in women's track and field athletes.

Keywords: Female Athlete Triad, Training volume, Low energy availability, Menstrual dysfunction, Bone mineral density, Disordered eating

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LIST OF ABBREVIATIONS

ACL	Anterior Cruciate Ligament
ACSM	American College of Sports Medicine
APA	American Psychological Association
BMD	Bone Mineral Density
BMI	Body Mass Index
CRH	Cotropin-Releasing Hormone
D1	Division 1
D2	Division 2
D3	Division 3
DSM-5	Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition
DXA	Dual-Energy X-Ray Absorptiometry
EA	Energy Availability
ED-NOS	Eating Disorder Not Otherwise Specified
FFM	Fat Free Mass
FSH	Follicle-Stimulating Hormone
GnRH	Gonadotropin-Releasing Hormone
ID	Identification
IOC	International Olympic Committee
Kcal	Kilocalorie
LEA	Low Energy Availability
LH	Luteinizing Hormone
NCAA	National Collegiate Athletic Association

OSFED	Other Specified Feeding or Eating Disorders
PHQ-9	Patient Health Questionnaire
PSS	Perceived Stress Scale
RDN	Registered Dietitian Nutritionists
RED-S	Relative Energy Deficiency in Sports
RF	Risk factor
RMR	Resting Metabolic Rate
SDS	ASSQ Sleep Difficulty Score
T3	Triiodothyronine
TDEE	Total Daily Energy Expenditure
Triad	Female Athlete Triad

CHAPTER I: Introduction

Sport participation has always been a trend throughout human history. From ancient Greece to the modern Americas, children and adults alike have participated in athletics. In 1972, the population of women in recorded athletics rapidly increased with the introduction of Title IX. Although sports were not the initial focus of Title IX, this amendment resulted in the growth of women's athletics into an entire subculture as it is known today (Edwards, 2010; Weiss Kelly et al., 2016). As the number of women who were able to experience the benefits of sports participation increased, so did the exposure to sport-related risks, both acute and chronic. Originally acknowledged in the 1990s by the American College of Sports Medicine (ACSM), the Female Athlete Triad is a collection of intertwining conditions characterized by their adverse effects on the human body (Gibbs et al., 2013; Nattiv et al., 2007; Skorseth et al., 2020; Weiss Kelly et al., 2016; Williams et al., 2019). Historically, the Triad, as it will be referred to hereafter, has been described as a clinical syndrome resulting from the combination of low energy availability, disordered eating, and amenorrhea (Gibbs et al., 2013; Nattiv et al., 2007; Skorseth et al., 2020; Weiss Kelly et al., 2016; Williams et al., 2019). As time has passed, however, it has become clear to researchers that the Triad is more complicated than previously thought. Specifically, the definition of the Triad has been expanded to include low energy availability (LEA) in conjunction with or independent of disordered eating, low bone mineral density (BMD), and menstrual dysfunctions (Gibbs et al., 2013; Nattiv et al., 2007; Skorseth et al., 2020; Weiss Kelly et al., 2016; Williams et al., 2019). Furthermore, it has been concluded that each individual component of the Triad occurs on a spectrum ranging from optimal health to a diseased state. Therefore, an athlete presenting with the Triad may not simultaneously exhibit all of the components at once (Gibbs et al., 2013; Nattiv et al., 2007; Weiss Kelly et al., 2016). This spectrum of specific risk factors is shown by Figure 1. This, along with its new classification under the broader scope of Relative Energy Deficiency in Sports (RED-s), has redefined our understanding of the Triad and has ushered in a new era of research focused on the long-term health of female athletes.

Figure 1. *The Female Athlete Triad*

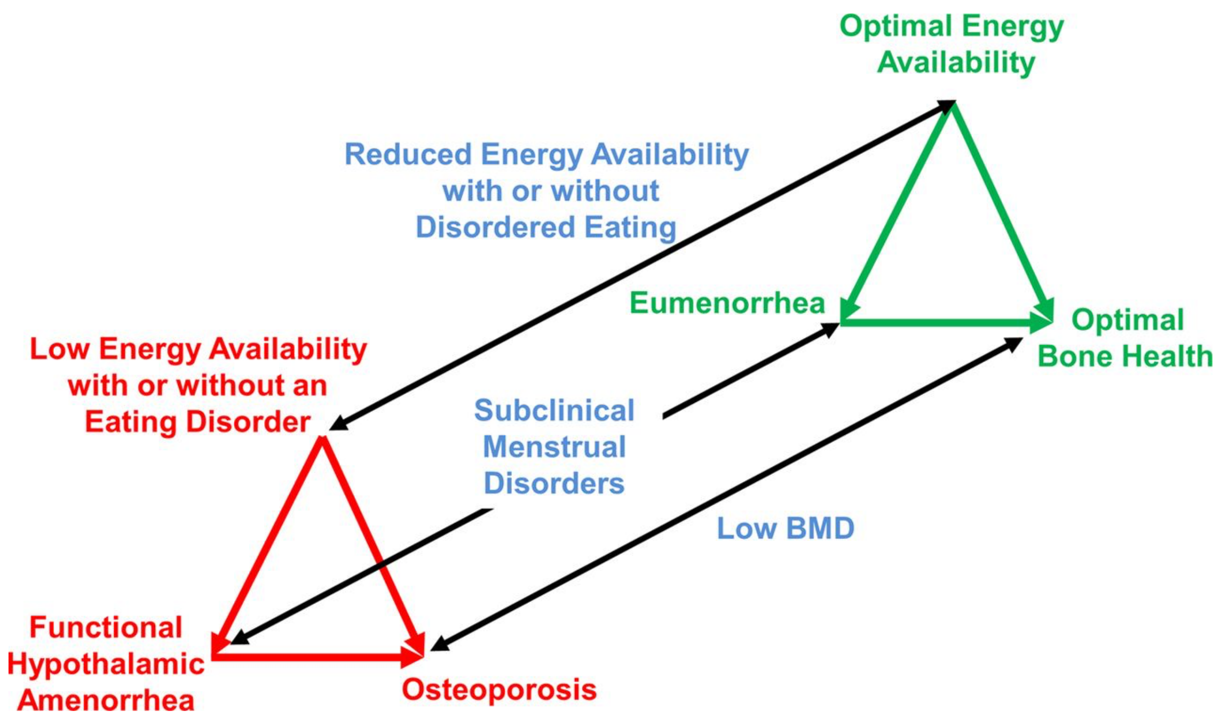


Figure 1. A depiction of the interrelated components of the female athlete triad. Adapted by permission from

Athletes are often categorized into either a lean or non-lean emphasis in sports. Lean sports are frequently defined as those that emphasize either the achievement or maintenance of a low body weight under the impression that it will improve personal performance, while non-lean sports are those described as sports in which a low body weight is not necessary for an athlete to be successful and/or competitive (Mancine et al., 2020). Sports can then be further broken down into six additional sub-classifications. Lean sports can be broken down into aesthetic, weight-dependent, and endurance sports, while non-lean sports can be categorized as ball game, power, and technical sports (Mancine et al., 2020). Running, a sport commonly associated with the Triad, is classified as an endurance sport (Rauh et al., 2014). Because of this association, running culture is rife with ideals regarding leaner body types in order to reach higher levels of competition and successful performance (Mancine et al., 2020). Although women of all ages and exercise levels are at risk for developing the Triad, research has shown female athletes participating in endurance sports emphasizing leanness are disproportionately affected (Skorseth et al., 2020). According to a study conducted by Beals and Hill in 2006, approximately 25% of an evaluated population of National Collegiate Athletic Association (NCAA) Division II athletes reported disordered eating, while 26% had menstrual dysfunction, and 10% had low bone mineral density scores (Beals & Hill, 2006; Skorseth et al., 2020). Among competitive female distance runners, the risk of developing any of the Triad components is increased by behaviors often associated with leanness-oriented sports, such as disordered eating and/or compulsive exercise patterns.

Due to its intricate nature and generally subtle presentation, the Triad is frequently unreported and/or misdiagnosed in female athletes, thus resulting in an amalgamation of acute and chronic consequences for the affected individual. The most common symptoms of the Triad include menstrual cycle dysfunction, low body mass index (BMD $<18.5 \text{ kg/m}^2$), iron deficiency and/or anemia, and low bone mineral density (BMD), which can easily lead to injuries (e.g., stress fractures) in the athlete or even early-onset osteoporosis (Nattiv et al., 2007; Skorseth et al., 2020). Oligomenorrhea, luteal suppression, anovulation, and general amenorrhea are included among the menstrual dysfunctions. Furthermore, the Triad may produce hormonal fluctuations, which may affect crucial body systems such as the cardiovascular, endocrine, gastrointestinal, and immune systems (Skorseth et al., 2020). Because these normal body functions are at risk of becoming disturbed, female athletes may also have trouble recovering from the Triad after they are diagnosed, resulting in altered mental states and compounding negative associations with either sport, body, or both.

Athletes who present with one Triad component are likely to or have already developed the remaining Triad components (Weiss Kelly et al., 2016). Therefore, it is common to encourage the optimization of energy availability in female athletes as a form of prevention for developing the Triad in high intensity sports (Nattiv et al., 2007). The ACSM has also recommended that practices surrounding harmful weight loss and body ideals be evaluated within sports to lessen the impact of negative nutrition habits on exercising females as another form of Triad prevention (Nattiv et al., 2007). Despite these efforts, however, screening for the Triad remains challenging. To address this limitation, the 2014 Female Athlete Triad Coalition developed a standardized set of twelve Triad screening questions (Weiss Kelly et al., 2016). These questions relate to dietary habits, bone health (i.e., BMD, osteoporosis), menstrual history (i.e., delayed menarche, oligomenorrhea, amenorrhea), and injury history (i.e., stress reactions and/or fractures), each of which are used to create a cumulative risk score. This risk score can then be used to determine if the athlete in question may return to sport participation if previously withheld or to determine the athlete's general risk for Triad development (De Souza et al., 2014; Nattiv et al., 2007; Skorseth et al., 2020). However, Triad screening protocols are typically only conducted at the beginning of a sport season alongside the general athlete physical examinations or in times in which an athlete must undergo return-to-play screenings following a severe illness or injury (Weiss Kelly et al., 2016). Thus, it can be difficult to keep track of an athlete's Triad risk in and out of a typical season.

Following a proper diagnosis of the Triad, the first aim of treatment should always be to improve the energy availability of the affected athlete by either increasing her energy intake or by reducing energy expenditure (Nattiv et al., 2007; Weiss Kelly et al., 2016). Research has shown that the improvement of energy availability to >30 kcal/kg FFM per day has resulted in restoration of normal menses. However, an energy availability of >45 kcal/kg FFM per day is optimal and should be achieved before treatment may end (Weiss Kelly et al., 2016). Other goals of treatment should include the restoration of a healthy body weight for the athlete, which is typically represented by a restoration of normal menses or a body mass index (BMI) $\geq$18.5 kg/m^2, as well as a minimum of 2000 kcal/day of energy intake (Weiss Kelly et al., 2016). Depending on the severity of the affected athlete's condition, the restoration of a normal menstrual cycle may be delayed by one year or longer following energy availability treatments (Weiss Kelly et al., 2016). If energy availability cannot be restored through nonpharmacological methods such as increasing caloric intake and decreasing energy expenditure, the Triad can also be treated through pharmacological therapies (Nattiv et al., 2007).

Despite considerable interest in both the public and research domains, few have directly examined the effects of training volume (i.e., mileage completed and/or hours trained per week) on Triad risk. Given the increased amounts of psychological and physical strain on modern female athletes, practitioners need to be made aware of the potential correlation between training volume and Triad risk to enable better risk stratification, especially as it is used in leanness-oriented sports such as women's track and field. Accordingly, the purpose of this study is to determine the influence of training volume on Triad risk for female collegiate track and field athletes. The influence of sleep quality, distress, and/or other stressors on Triad risk for female collegiate track and field athletes will also be determined as a secondary aim of this study. Demographics, training volume, and injury history will be evaluated alongside sleep quality and perceived stress and depressive levels collected by surveying of National Collegiate Athletic Association (NCAA) Division I schools located in the United States. We hypothesize that, as training volume increases for a female collegiate track and field athlete, Triad-associated risk factors will increase. By examining the potential relationship between training volume and Triad risk factors, this study hopes to increase awareness in women's athletics in an effort to lower injury rates and conditions associated with the Triad and to make competition safer for active participation in women's collegiate track and field.

Review of Literature

Relative Energy Deficiency in Sports (RED-S) and the Triad

In 2014, the International Olympic Committee (IOC) convened to review previous consensus statements regarding the Triad and subsequently published an updated version in which a new term was introduced for the syndrome (Mountjoy et al., 2014). Relative Energy Deficiency in Sports (RED-S) was introduced to the community in order to act as a broader, more comprehensive version of the Triad since studies had begun to show that the syndrome was tied to a relative energy deficiency in the body that would then result in impaired physiological functions beyond those introduced in the Triad (Mountjoy et al., 2014). For reference, the Triad focuses mainly on three conditions appearing in the body, while RED-S highlights more than ten health consequences and performance effects resulting from energy deficiencies (Mountjoy et al., 2014).

Furthermore, evidence had been gathered that showed that men, not just women, could be potentially affected by RED-S (Mountjoy et al., 2014). Therefore, the new term was necessary to include all affected populations and impacted body systems. Due to the specificity of the population pool being studied in this paper (i.e., female collegiate runners), the Triad and its associated components will remain the sole focus of study. There are concerns that completely replacing the Triad with RED-S will dilute the much-needed attention on affected females because their population is the one in which the most serious complications can occur (Williams et al., 2019). Additionally, this study's main focus is on the intertwined appearance of low energy availability and menstrual dysfunctions as it relates to training volume and will be evaluated utilizing the Triad risk assessment from the Female Athlete Triad Coalition. Moreover, there is an inherent limitation in collecting data solely through anonymous online surveys that could potentially interfere with an adequate assessment of the many components of RED-S.

However, it would be amiss to ignore decisions made by the scientific community in regard to the expansion of the Triad into RED-S. Therefore, RED-S will be briefly overviewed in this section of the paper for comprehension purposes.

Defined as a clinical syndrome, RED-S is indicated when a relative energy deficiency in the body has resulted in impairments in basal metabolism, menstrual health, bone health, immune function, protein synthesis, and cardiovascular function (Mountjoy et al., 2014). These impairments are not limited to just those functions and may include decreases in athletic performance as well (Jagim et al., 2022; Mountjoy et al., 2014; Williams et al., 2019). Decreases in glycogen stores, endurance performance, training response, and coordination are possible with RED-S as well as increases in injury risk and potential impairments in judgment (Williams et al., 2019). There may also be decreases in concentration and an appearance of irritability and/or depression in the affected individual (Williams et al., 2019). Furthermore, affected individuals may experience changes in various body systems, such as the endocrine, cardiovascular, immune, and digestive systems (Skorseth et al., 2020).

While there are many health effects resulting from chronic relative energy deficiencies in the body, there are two of note to this study that are not otherwise listed among the typical Triad components. In the 2018 IOC consensus statement update for RED-S, Mountjoy et al. describe hematological and psychological health effects as part of the impact low energy availability may have in an individual affected by RED-S (Mountjoy et al., 2018). Furthermore, defects in both of these systems may also induce an energy deficiency in an otherwise healthy athlete (Mountjoy et al., 2018). As many athletes and coaches are aware, iron deficiency can be brutal in endurance sports such as track and field or cross country. There is evidence that an iron deficiency may contribute both directly and indirectly to the development of RED-S because appetite reductions due to a low iron supply can result in decreases in metabolic fuel availability within the body, thus limiting metabolic efficiency and causing increases in energy expenditure when the athlete is both exercising and resting (Mountjoy et al., 2018; Petkus et al., 2017). Brain health is also critical for prolonged performance and life outside of athletics. When psychological well-being is negatively impacted, performance and general well-being may be reduced. In a 2001 study examining psychological health and menstrual dysfunctions, Marcus et al. determined that adolescent females affected by functional hypothalamic amenorrhea tended to report increased occurrences of depressive symptoms, dysfunctional attitudes, and symptomatic disordered eating when compared to controls and females with less severe menstrual dysfunctions (Marcus et al., 2001). While these health effects might otherwise not be included in traditional Triad research, they will be partially investigated within this study alongside the expected Triad components due to the current prevalence of iron deficiencies and mental health concerns in the sports world.

Nutrition and Metabolism in Female Athletes

In athletics, nutrition is a subject of high importance yet is susceptible to being overlooked by athletes and coaches. Athletes require a certain amount of energy to function physiologically following exercise each day. This amount of energy is known as energy availability (EA) and is defined as the surplus of energy taken in via the diet after accounting for energy expended during exercise (De Souza et al., 2014; Nattiv et al., 2007; Weiss Kelly et al., 2016). Thermoregulation, homeostasis, metabolism, growth, and immunity are some of the bodily functions that utilize energy from this pool (Holtzman & Ackerman, 2021; Lambert et al., 2022). Because energy availability is based on dietary intake and energy expenditure during exercise, the specific amount varies per athlete due to factors such as an individual's basal metabolic rate and activity level. However, it is generally recommended that an energy availability of 45 kcal/kg of FFM/day is ideal for optimal performance of female athletes, as this promotes maintenance of body mass (Holtzman & Ackerman, 2021; Weiss Kelly et al., 2016). If a female athlete's goal is to gain weight and/or muscle, an EA of greater than 45 kcal/kg of FFM/day is adequate (Holtzman & Ackerman, 2021).

Low energy availability (LEA) occurs when dietary intake does not meet the physiological needs of the body following exercise. Among female athletes, this condition typically occurs when energy availability is less than the 30 kcal/kg of FFM/day threshold, thus disrupting metabolic functions and overall physiologic health (Holtzman & Ackerman, 2021; Jagim et al., 2022; Nattiv et al., 2007). Beyond EA numbers, low energy availability may be identified via a sudden decrease in body mass index (i.e., BMI < 17.5 kg/m2), disordered eating, and/or physiological signs which occur when the body has adapted to a chronic energy deficiency (e.g., low triiodothyronine [T3] or a reduced resting metabolic rate [RMR]) (De Souza et al., 2014). To that extent, an athlete may be considered at risk for LEA and/or chronic energy deficiency if her measured RMR is less than 90% of her predicted RMR, (De Souza et al., 2014).

Several factors may be at fault when an athlete is presenting with low energy availability and may be intentional or non-intentional. The main root of LEA is often attributed to inadequate energy intake of the athlete and/or a high energy expenditure of the athlete's training demands (Jagim et al., 2022). Dietary needs may be underestimated, which may be the result of confusion or misinformation in relation to nutritional strategies for health and performance (Jagim et al., 2022). In an endurance sport such as distance running, athletes require a high amount of carbohydrates to properly fuel their bodies. However, many modern diets being portrayed as healthy and accessible to the general population will often feature caloric restrictions, and in particular, carbohydrate restriction (Jagim et al., 2022). Because of this, many runners will attempt to limit their nutrient consumption without thought for the subsequent deficiencies and consequences. Many athletes are unaware of the macronutrient demands for their sport and therefore consume insufficient totals, thus leading to LEA (Lambert et al., 2022). Micronutrients are also of great importance in physiological functions, and micronutrient deficiencies can be antagonistic to the overall health and performance of the athlete. These can appear in conjunction with LEA due to many of the same reasons. Among female athletes, the most common are due to insufficient amounts of iron, calcium, Vitamin D, or a combination of the three (Holtzman & Ackerman, 2021). Iron deficiencies, in particular, can significantly contribute to Triad risk due to the body's reliance on iron for many important physiological functions (Skorseth et al., 2020).

Low energy availability can be a result of issues with food cost, food access, or lack of time (i.e., convenience of shopping). When athletes are tasked with balancing a difficult schedule between class and sport demands, living away from home, and traveling frequently, obtaining and preparing food to fit nutritional demands can be extremely challenging (Jagim et al., 2022). Campuses may not be properly equipped with cooking spaces, athletes may not have access to quality ingredients, and meals that are provided may not be nutrient-dense enough to satisfy energy demands, thus leading to increased consumption of nutrient-lacking ‘fast food’ and other convenient forms of energy (Jagim et al., 2022). Travel nutrition can also be tricky due to the busy schedules often associated with collegiate performance. While on the road, athletes may not have access to proper nutrition sources, thus further hampering energy availability (Lambert et al., 2022). When optimal fueling strategies are ignored, athletes generally fail to increase their energy intake adequately enough to meet the increased activity levels associated with sport training (Jagim et al., 2022). Although abnormal eating behaviors and/or disordered eating can result in low energy availability, inadvertent energy deficits due to the situations described above (i.e., underestimation of dietary needs, food cost/access, traveling, matching energy intake to energy usage) are more likely to occur. However, exercise levels still play a large role in LEA presentation. Biologically, the human body does not feel the same hunger cues when dietary restriction is directly compared to exercise expenditure. Thus, athletes will often be unaware of energy deficits produced by exercise alone (Nattiv et al., 2007). Therefore, even when energy intake is not being restricted and/or diminished, but exercise is ongoing, such as in an endurance sport like distance running, the athlete is still at risk of developing LEA.

While all athletes are at some risk of developing LEA, some sports place athletes at a greater risk. Sports which require increased volumes of training and exercise, such as endurance-based sports, require an increased total daily energy expenditure (TDEE), thus increasing the amount of energy intake needed to offset the athlete’s resultant energy expenditure (Jagim et al., 2022). Athletes may also choose to exercise for prolonged periods independent from their sport and risk LEA as well. Furthermore, athletes who participate in dietary restriction either purposely through dieting and limiting of certain 'bad' foods or inadvertently are at a high risk for developing LEA (Nattiv et al., 2007). Within the world of athletics, female athletes are at a higher prevalence of LEA than male athletes. Issues with body image, sport cultures, and societal pressures can be partially attributed to this trend (Jagim et al., 2022). In Ackerman et al.'s 2019 study, a survey of 1000 female collegiate-aged athletes of more than 40 sports estimated a LEA risk of 47.3% (Ackerman et al., 2019). Furthermore, Jagim et al. concluded in a 2022 narrative review that LEA prevalence was estimated to range from 41% in cross country runners in one study by Beermann et al. to 51% in track and field athletes in another study by Day et al. (Beermann et al., 2020; Day et al., 2015; Jagim et al., 2022).

Various consequences can arise when an athlete is presenting with low energy availability. In particular, reproductive and skeletal health are of a heightened concern when the Triad is involved. When LEA occurs, the body is often forced into an adaptive mode as it allocates energy from certain physiological mechanisms (e.g., thermoregulation, reproduction, and growth) to ensure survival of the athlete at the sacrifice of overall bodily health (Nattiv et al., 2007). Hormonal levels are impacted when these energy-sparing adaptations occur, which in turn impact menstrual health and bone health. When energy availability dips below the 30 kcal kg-1 FFM·day−1 threshold, metabolic hormones and female reproductive hormones are more likely to be suppressed (Heikura et al., 2018). Luteinizing hormone (LH) may be reduced after only 5 days below the threshold (Weiss Kelly et al., 2016). LH is one of several hormones whose functions directly impact menstrual regularity. When LH is disrupted, hypothalamic gonadotropin-releasing hormone (GnRH) is disrupted, which then disturbs the release of gonadotropin, thus resulting in a menstrual disturbance (e.g., oligomenorrhea, amenorrhea) in the affected athlete (Holtzman & Ackerman, 2021). Once menstrual activity is irregular and/or absent, estradiol becomes reduced, thus triggering negative effects in the athlete's bone health, such as increased osteoclast activity (Holtzman & Ackerman, 2021). Increased osteoclast activity can result in an overall loss in bone mineral density and increases the risk for bone-related injuries such as stress fractures and osteoporosis in female athletes. Therefore, it can be presumed that LEA likely has a causal relationship with exercise-associated menstrual and bone issues (De Souza et al., 2014). LEA and the body's adaptive response are also associated with fertility issues, a reduced resting metabolic rate, and an increased chance of failure in the immune system (Lambert et al., 2022). Failure to treat LEA may result in the inadequate recovery of the athlete, thus affecting the musculoskeletal system's function and development as well as the affected athlete's quality of sleep and cardiovascular health (De Souza et al., 2014; (Lambert et al., 2022).

Low energy availability is attributed to be one of the most significant influences related to a female athlete's risk for injury and/or illness (De Souza et al., 2014). Therefore, it is critical that LEA be treated immediately following its initial presentation if it has not already been prevented entirely. Among the treatment options, it has been suggested by Lambert et al. in their 2022 consensus statement to significantly increase services offered by sports registered dietitian nutritionists (RDNs) in order to better supplement athletes' general knowledge of nutrition in sports (Lambert et al., 2022). Evidently, college students with a better understanding of nutritional strategies consumed a larger amount of nutrient-dense and beneficial foods than individuals with little nutrition knowledge (Lambert et al., 2022). Additionally, athletes who received similar services showed increases in health and sport performance (e.g., increases in power output and BMD) when compared to their peers who had not undergone nutrition counseling (Lambert et al., 2022). Therefore, increasing nutrition education should result in substantial decreases in accidental LEA, while also bettering the athletes for life beyond sport.

As briefly mentioned above, disordered eating and malnutrition are some of the many potential causes of low energy availability. Although not always the source, body image plays a major role in many cases of disordered eating in athletics. Defined as the internalization of an individual's subjective viewpoint of their own body and physical appearance, body image is characterized as a personal interpretation and, in athletics, may be compartmentalized into a 'social' body and a 'sporting' body (Kong & Harris, 2015; Jagim et al., 2022). The 'social' body is often evaluated for its appearance and functionality in daily life, while the 'sporting' body is associated with its athletic ability, appearance, and functionality in a sporting context (De Bruin et al., 2011). This sporting body ideal can be dissociative and damaging to the athlete because it may increase body dissatisfaction if one facet of an individual's body image does not fit into its perceived environment. Body dissatisfaction is generally associated with an overall drive for thinness in order to achieve a higher rate of perceived athletic success (i.e., 'thin to win'). (Kong & Harris, 2015; De Bruin et al., 2011). Regardless of an athlete's appearance, ability, and/or health, body dissatisfaction can result in an athlete believing they are unfit or overweight, thus encouraging dietary restrictions, exercising in excess, and disordered eating patterns (Jagim et al., 2022). Societal expectations, influences from the media, and personal pressures from individuals themselves, their coaches, or their families and peers affect body image and perceptions of oneself. In Kong and Harris' 2014 study, it was estimated that over 60% of elite athletes experienced pressure from coaching staff to either obtain and/or maintain a leaner body type in order to increase performance in the athletic setting (Kong & Harris, 2015).

Disordered eating is a major cause of concern in athletics and within the Triad. Although it is possible for the Triad to occur in an athlete who presents without an eating disorder, any pattern of inhibited eating is still a major risk factor for the athlete. When considering disordered eating and eating disorders, an important distinction must be made. Disordered eating and clinical eating disorders exist on a spectrum ranging from optimized nutrition to disordered eating to clinical eating disorders (Jagim et al., 2022). Generally, disordered eating occurs before a clinical eating disorder, ranges in severity from poor nutritional habits to completely abnormal dietary patterns, and cannot meet the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) criteria (American Psychiatric Association [APA], 2022; Jagim et al., 2022). Clinical eating disorders are therefore considered to be significantly more problematic for the athlete as they are diagnosable by the DSM-5 and may be accompanied with associated psychiatric illnesses (Jagim et al., 2022; Nattiv et al., 2007). Anorexia nervosa and bulimia nervosa are considered to be clinical eating disorders (i.e., meet the DSM-5 criteria), while orthorexia nervosa is considered to be disordered eating (i.e., does not meet the DSM-5 criteria) (Jagim et al., 2022; Nattiv et al., 2007).

As a clinical eating disorder, anorexia nervosa involves extreme forms of restrictive eating that is often characterized by feelings of inaccurate weight and body size and generally involves fears of weight gain (Nattiv et al., 2007). To be diagnosed with anorexia nervosa, the affected individual must be at least 15% below the weight that is expected for their age and height (Nattiv et al., 2007; Nielsen et al., 1998). Following a diagnosis, the mortality rate of an individual with anorexia nervosa increases by sixfold when compared to individuals who follow standard nutrition practices, thus underlining the severity of the condition (Nattiv et al., 2007). Classified as another type of clinical eating disorder, bulimia nervosa is characterized by cycles of binge-eating and/or overconsumption of food followed by compensatory behaviors, such as purging, fasting, or excessive exercise (Nattiv et al., 2007). Many individuals who experience bulimia nervosa struggle with compulsive exercise and become overly dependent on sport and athletic activity in order to make up for negative perceptions of body image and type. Occasionally, individuals will experience some but not all of the criteria necessary for an anorexia nervosa or bulimia nervosa diagnosis and are thus grouped under the eating disorder not otherwise specified (ED-NOS) classification (American Psychiatric Association, 2022; Nattiv et al., 2007). In more recent additions of the DSM, ED-NOS has been reclassified as other specified feeding or eating disorders (OSFED) (American Psychiatric Association, 2022; Practice Guideline, 2000). Although orthorexia nervosa is not classified as a clinical eating disorder, it remains a very serious consideration for athletes who may have a tendency to restrict their dietary intakes. Orthorexia nervosa involves a pathological fixation on eating foods deemed as healthy to a point in which eating becomes compulsive and anxiety-inducing for the athlete (Jagim et al., 2022). In more severe cases, eating patterns may become restrictive, thus resulting in malnourishment of the athlete and increases in the likelihood of nutrient deficiencies and low energy availability (Jagim et al., 2022).

When individuals with disordered eating habits and/or clinical eating disorders are involved with sport, severe consequences may result. The physical and mental health of the athlete is at risk and may incur lasting harm even after the condition itself is resolved (Lambert et al., 2022). Often, female athletes who practice disordered eating habits will limit their dietary intake while still maintaining high exercise levels, thus inadvertently causing chronic energy deficits and low energy availability (Cobb et al., 2003). Therefore, disordered eating can be linked with the consequences that typically result from LEA, such as menstrual dysfunctions from decreases in estrogen (e.g., oligomenorrhea, amenorrhea), overall disturbances in bodily metabolism, low bone mineral density, and increased rates of injury (Cobb et al., 2003; Jagim et al., 2022). In Cobb et al.'s 2003 study, it was determined that eumenorrheic female runners are likely to demonstrate low BMD due to their disordered eating patterns (Cobb et al., 2003). Among athletes, the prevalence of disordered eating and clinical eating disorders tends to be higher when compared to nonathletes (Kong & Harris, 2015). Furthermore, female athletes participating in sports which emphasize leanness and/or certain body types and weight, such as aesthetic sports, endurance sports, and weight-class sports, were more likely to experience disordered eating and clinical eating disorders than the general population (Nattiv et al., 2007). It was determined in Sundgot-Borgen and Torstveit's 2004 study that 25% of the elite female athlete sample population who participated in endurance, aesthetic, or weight-class sports reported experiencing a clinical eating disorder, while only 9% of the sampled general population reported the same (Sundgot-

Borgen & Torstveit, 2004; Nattiv et al., 2007). Because athletes experience pressures that may result in pathological behaviors for maintenance or weight loss, athletes of all levels of competition are therefore considered to be at a greater risk of disordered eating than their nonathlete counterparts (Joy et al., 2016; Lambert et al., 2022). Several factors likely contribute to the increased prevalence of disordered eating in athletics. Sporting type, level of competition, and psycho-social factors such as body image, body dissatisfaction, and athletic identity are all contributing factors (Turton et al., 2017). Characterized as the extent to which an individual personally identifies with their athletic and/or sporting role, the athletic identity is an internalized ideal similar to the 'sporting' body in which personal self-worth is tied with athletic ability (Brewer et al., 1993; Turton et al., 2017). Athletes with a high athletic identity may experience an increased vulnerability to disordered eating and eating disorder triggers, however, the athletic identity may only become negative once that athlete's ability is questioned or put at risk by an injury or setback (Turton et al., 2017). Along with disordered eating, high athletic identities may put individuals at a higher risk of compulsive exercise, such as when a distance runner continues to exercise out of fear of a reduced performance or to better feel the positive emotions often associated with post-exercise moods (Turton et al., 2017). Athletes who experience compulsive exercise, also known as exercise dependence or exercise addiction, tend to practice beyond normal levels of activity despite the increased risk of injury and other harmful effects due to a constant feeling of pressure to exercise and train (Jagim et al., 2022). Even when unable to exercise, athletes affected by this condition feel extreme guilt, thus further contributing to the feelings of pressure (Turton et al., 2017). Due to the high levels of exercise, these athletes will often experience low energy availability and all the consequences that accompany the condition (Jagim et al., 2022).

In the athletic world, female athletes are at a constant risk for illness and conditions associated with low energy availability. It is, therefore, of great importance that sports culture adapts to encourage optimal nutritional practices, increased energy intake, and the acceptance of bodies as they are in order to enhance performance and protect the overall physical and mental health of female athletes.

Menstrual Health in Female Athletes

As many might expect, hormones can play a large role in regulating the abilities and lifestyles of athletes. Female athletes, in particular, can face fluctuations in performance depending on their hormone levels and endocrine health. For this reason, female athletes may track their menstrual cycles to optimize training and performance in competition, while others may take hormonal contraceptives to minimize certain effects resulting from menstrual cycle irregularities (Carmichael et al., 2021; Sims et al., 2023). In a so-called normal menstrual cycle, female sex hormones (i.e., estrogen and progesterone) naturally fluctuate over a period of 21 to 35 days (Carmichael et al., 2021). These cycles are separated into two main phases (i.e., follicular and luteal) that are then divided into sub-phases (i.e., early, mid, and late) based on reproductive events within the female body such as menstruation and ovulation (Carmichael et al., 2021; Sims et al., 2023). Occurring typically between 4 and 6 days, menstruation begins the menstrual cycle and occurs at a time in which both estrogen and progesterone are stable and at low levels in the reproductive system (Carmichael et al., 2021). As estrogen begins to rise exponentially, the early, mid, and late follicular stages occur (Carmichael et al., 2021;

Sims et al., 2023). During the late follicular phase, high estrogen levels result in the elevated secretion of gonadotropin releasing hormone such that luteinizing hormone is also released. This surge in luteinizing hormone initiates ovulation, and the resultant rupturing of a mature follicle causes an egg to be secreted into the uterus (Carmichael et al., 2021). At ovulation, estrogen levels drop significantly while progesterone begins to increase and then peak during the mid luteal stage (Carmichael et al., 2021; Sims et al., 2023). Estrogen also reaches another peak, albeit smaller than the initial one, during the mid luteal stage (Carmichael et al., 2021; Sims et al., 2023). Once the late luteal stage has occurred, these female sex hormones have decreased back to baseline and proceed to restart the menstrual process in a cyclic pattern, given that fertilization has not occurred (Carmichael et al., 2021; Sims et al., 2023).

Given the inherent variability of hormone levels, menstrual cycles and phase timing are unique to each individual and may change over the course of an individual's reproductive timeline (Carmichael et al., 2021; Redman & Loucks, 2005). For eumenorrheic women, menstrual cycles are typically routine, last for the general 21-to-35-day cycle length and can be expected to stay roughly the same in terms of range and timing (Carmichael et al., 2021; Redman & Loucks, 2005). However, hormone fluctuations may become volatile and/or unpredictable for many women. These hormonal fluctuations can be variable, specific to individuals, and situational. As a result, there are a number of menstrual abnormalities and cycle types that can occur in females, and these generally exist along a continuum of progressing severity (De Souza et al., 2007; Redman & Loucks, 2005). In females who are naturally menstruating with a cycle length of 21 to 35 days (i.e., eumenorrheic), certain hormone fluctuations can result in luteal phase deficiency or anovulation (Carmichael et al., 2021; Sims et al., 2023). In an individual with luteal phase deficiency, the menstrual cycle either has a luteal phase of less than 11 days or low progesterone levels during the luteal phase (Weiss Kelly et al., 2016). Anovulation is diagnosed in an individual when ovulation no longer occurs due to impaired follicular development (Redman & Loucks, 2005). These types of menstrual disturbances are considered to be subclinical, asymptomatic, and can result in infertility in affected individuals (Redman & Loucks, 2005; Weiss Kelly et al., 2016). When a menstrual cycle has lasted for an interval longer than 35 or 40 days and results in infrequent periods, an individual will be diagnosed with oligomenorrhea (Nattiv et al., 2007; Redman & Loucks, 2005; Weiss Kelly et al., 2016; Sims et al., 2023). If a menstrual cycle is absent in an individual for over 90 days or three months, then amenorrhea has occurred (Nattiv et al., 2007). Amenorrhea may be further separated into primary, secondary, and functional hypothalamic amenorrhea. Primary amenorrhea is diagnosed in females who have not undergone a menstrual cycle by 15 years of age despite other signs that puberty has occurred and is otherwise known as the absence of menarche (Redman & Loucks, 2005; Weiss Kelly et al., 2016). Secondary amenorrhea is diagnosed in females who have undergone a menstrual cycle by 15 years of age (i.e., menarche) and have then experienced a lack of menstrual activity for a least three consecutive months (Redman & Loucks, 2005; Weiss Kelly et al., 2016). Functional hypothalamic amenorrhea is diagnosed in individuals if amenorrhea has occurred when the body is experiencing low energy availability such as in the Triad (Weiss Kelly et al., 2016). This specific type of amenorrhea is considered to be a "diagnosis of exclusion" because it is usually diagnosed in women when there is no other "identifiable organic cause” for amenorrhea such as with chronic energy deficits (Berz & McCambridge, 2016; Marcus et al., 2001). Functional hypothalamic amenorrhea has an estimated occurrence of 15-35% of reported cases of secondary amenorrhea and occurs often in female athletes such as those in endurance sports such as cross country (Berz & McCambridge, 2016; Marcus et al., 2001).

It is believed that functional hypothalamic amenorrhea results from the combined response of several physiological pathways attempting to counter incidences of low energy availability in the body (Coelho et al., 2021). When low energy availability occurs in the female body, cortisol and cotropin-releasing hormone (CRH) increase while leptin decreases (Coelho et al., 2021). Gonadotropin hormone-releasing hormone (GnRH) decreases in response along with reductions in the frequency of pulsations of follicle-stimulating hormone (FSH) and luteinizing hormone (LH), which then result in the development of menstrual abnormalities such as amenorrhea (Coelho et al., 2021). Similar to individuals with anovulation, females with amenorrhea do not ovulate and are thus temporarily infertile until their estrogen levels can be restored following treatment (Redman & Loucks, 2005). Menstrual cycle abnormalities such as these have a higher prevalence in athletes than females of the general population, with increased incidences in leanness-oriented sports (Legerlotz & Nobis, 2022; Redman & Loucks, 2005). Moreover, recent studies have reconfirmed that these menstrual dysfunctions have tended to appear in athletes of younger ages, athletes undergoing higher training volumes, and athletes of lower bodyweights (Redman & Loucks, 2005).

As covered in the previous section, chronic energy deficits such as low energy availability typically have a negative effect on menstrual health and reproductive functions in affected individuals. Evidence demonstrates that menstruation, although normally requiring only a small amount of overall energy in the body, is one of several physiological systems likely to be halted when an athlete has entered a mode of adaptive energy conversion due to energy imbalances (Cobb et al., 2003). In 2003, Cobb et al. conducted a study examining the potential relationships involved with disordered eating, menstrual irregularity, and bone mineral density in young, competitive female distance runners. Of the 91 participants, 26% were considered to be oligomenorrheic, and 10% met the criteria for amenorrhea within the past year (Cobb et al., 2003). Although these athletes were similar in terms of demographics and body composition to the athletes with eumenorrhea, they were reported to have 45% fewer menstrual cycles on average (Cobb et al., 2003). Furthermore, these athletes recorded 18% more mileage on average than their eumenorrheic counterparts thus lending evidence to the idea that greater energy imbalances and energy expenditures could contribute to higher incidences of menstrual dysfunctions (Cobb et al., 2003). However, since these athletes share a common range of body weight and leanness, low body fatness itself cannot be considered a causal risk factor for menstrual dysfunction in female athletes (Nattiv et al., 2007).

There are a number of consequences that can be associated with menstrual dysfunction in the female body. The most common appear to be the effects on bone health and musculoskeletal function due to abnormal levels of circulating estrogen, progesterone, and other female sex hormones. On average, athletes affected by oligomenorrhea or amenorrhea are more likely to have poorer bone health, as shown by lower bone mineral density scores when compared with their eumenorrheic counterparts (Cobb et al., 2003; Redman & Loucks, 2005). For example, when an athlete is affected by oligomenorrhea or amenorrhea, their bone microarchitecture could be negatively affected due to decreases in trabecular number and thickness of the cortical instead of the typical increases in tibial cross-sectional area expected with normal exercise (Holtzman & Ackerman, 2021). These trabecular bone mineral density decreases can be partially attributed to decreased stiffness and lower failure load during exercise (Holtzman & Ackerman, 2021). Bone deficits such as these are potentially irreversible and can result in higher incidences of stress fractures and other bone stress injuries (Berz & McCambridge, 2016; Cobb et al., 2003; Holtzman & Ackerman, 2021). These consequences can be long-term and could affect the athletes for life if untreated (Cobb et al., 2003). The cardiovascular system has also been shown to experience health effects related to oligo/amenorrhea. Athletes diagnosed with amenorrhea and oligomenorrhea may present with abnormal lipid profiles such as increased levels of cholesterol as well as endothelial dysfunctions, lower heart rates, and decreased systolic blood pressures (Berz & McCambridge, 2016; Coelho et al., 2021; Weiss Kelly et al., 2016). Hypoestrogenism in the setting of oligo/amenorrhea can also impair endothelium-dependent vasodilation, thus potentially resulting in a reduction in working muscle perfusion, impairments in skeletal muscle oxidative metabolism, and potential delays in recovery following exercise (Redman & Loucks, 2005). Additionally, studies have shown anxiety, depression, low self-esteem and reports of increased mortality as long-term consequences of Triad menstrual dysfunctions (Berz & McCambridge, 2016).

Alongside studies involving menstrual disturbances, research is also being conducted in regard to hormone fluctuations and injury risk in eumenorrheic female athletes. There is considerable evidence surrounding potential correlations between certain menstrual cycle phases and increased rates of injuries in women, specifically musculoskeletal injuries such as anterior cruciate ligament (ACL) ruptures in the knee (Legerlotz & Nobis, 2022). In 2011, Walden et al. conducted a literature review to determine the validity of acknowledging the prevalence of ACL ruptures as sex-related and found that, for female football/soccer players, the injury risk of an ACL rupture is 2-3 times higher than their male counterparts (Waldén et al., 2011). This investigation is one of many that has contributed to the idea that ruptures of the ACL may be related to the menstrual cycle phase an athlete may be in at the time of injury. Accordingly, research has shown that while ACL rupture risk may be lower during the luteal phase, it may be higher when a female athlete is close to ovulation, specifically during the preovulatory phase (Legerlotz & Nobis, 2022). Furthermore, there are assumptions that high estrogen levels in this preovulatory phase may result in raised injury rates because of an increase in potential mechanical weakness of the ligaments within the knee joint (Legerlotz & Nobis, 2022). Estrogen fluctuations may also result in increased knee joint laxity and decreased postural stability, all of which could lead to an increase in falls or other similar situations that then contribute to these high injury rates (Legerlotz & Nobis, 2022). Neurophysiological changes due to hormone fluctuation during the menstrual cycle have also been documented. Around ovulation, women may feel elevations in motivation to train and/or compete (Cook et al., 2018; Legerlotz & Nobis, 2022). While this may appear to be of a benefit for female athletes and their overall performance, increases in motivation can also result in changes in movement patterns or intensity which may ultimately result in injury (Cook et al., 2018; Legerlotz & Nobis, 2022). Risk-taking behaviors have also been shown to increase alongside motivation around ovulation, thus further increasing this injury risk for eumenorrheic female athletes (Cook & Crewther, 2019; Legerlotz & Nobis, 2022).

General recommendations for coping with fluctuating hormone levels from the menstrual cycle during training and performance involve nutrition, hydration, and/or supplement advice. Nutritional needs can vary due to these hormonal fluctuations and should be taken into consideration when exercising (Holtzman & Ackerman, 2021). While some of these may vary from sport to sport, the main conclusion is that all female athletes must focus primarily on maintaining a level of energy availability that is sufficient to meet the overall demands of their training (Sims et al., 2023). As mentioned in earlier sections, the general recommendation for optimal performance is an energy availability of at least 45 kcal kg-1 FFM·day−1 (Holtzman & Ackerman, 2021; Weiss Kelly et al., 2016). This value should be met regardless of the athlete's hormone status or menstrual cycle phase. However, certain phases of the menstrual cycle may result in different energy demands in the female body because energy homeostasis can be significantly affected by hormones, particularly estrogen and progesterone (Sims et al., 2023). For example, estrogen has been shown to reduce food intake when levels are high (Sims et al., 2023). During the late follicular phase, energy intake may be low, and resting metabolic rate (RMR) is typically reduced due to the increased concentrations of estrogen and decreased concentrations of progesterone circulating in the body (Sims et al., 2023). When both estrogen and progesterone levels hit peaks, such as during the mid luteal phase, RMR is generally increased, and energy intake is high (Sims et al., 2023). Therefore, it is recommended that eumenorrheic athletes increase their overall energy intake during the luteal phase to match the corresponding increase in RMR (Sims et al., 2023).

Additionally, female athletes are often recommended to take dietary and sports supplements while training to improve performance and overall health. In a 2004 study on supplement use by collegiate female athletes, Herbold et al. found that 65.4% of participants took supplements at least once a month (Herbold et al., 2004; Sims et al., 2023). Within that sample, 36% reported taking a multivitamin and iron supplement, and 60.1% identified "good health" as the main reason behind supplementation (Herbold et al., 2004). Despite increased awareness and recent research on iron deficiency, anemia is still a major problem in female athletics and is known to diminish athletic performance due to the limitations placed upon the body when oxygen transport is reduced by this condition (Parks et al., 2017). Compared to their male counterparts, female athletes are five to seven times more likely to experience iron deficiency anemia and/or iron deficiency (DellaValle & Haas, 2011; Sims et al., 2023). Additionally, higher incidences of iron deficiency have been linked to endurance sports, especially those that feature increased occurrences of suboptimal calorie consumption and/or disordered eating such as leanness-oriented sports like cross country (Clénin et al., 2015; Parks et al., 2017). These increased prevalence rates are likely linked to the effect the menstrual cycle has on iron regulation as well as other sex differences, impaired absorption rates, inadequate dietary intakes, and exacerbated iron losses due to exercise (Holtzman & Ackerman, 2021; Sims et al., 2023).

Musculoskeletal Adaptations and Bone Health in Female Athletes

Often cited as the 'silent component' of the Triad, poor bone health in female athletes generally develops following the development of low energy availability and suppressed levels of estrogen characteristic of various menstrual-centric conditions (Mallinson & De Souza, 2014). These determinants may occur together or separately depending on the situation of the athlete and her individual health circumstances and have been determined to have both independent and synergistic effects on an athlete's bone health through various studies (Mallinson & De Souza, 2014). However, bone health is compromised more significantly and at a higher rate when low energy availability has already resulted in a menstrual dysfunction, thus exaggerating any suppression of bone formation and upregulation of bone mineral reabsorption that may occur due to detrimental energy- and estrogen-related health factors (Mallinson & De Souza, 2014).

Low bone mineral density (BMD) is typically diagnosed through T-scores and Z-scores following bone microarchitecture and/or dual-energy x-ray absorptiometry (DXA) tests. According to ACSM's position stand on the Triad, low bone mineral density is defined as a BMD Z-score between -1.0 and -2.0 (Nattiv et al., 2007). When an athlete's BMD Z-score is equal to or lower than -2.0 for her age, race, and sex-matched controls, and also demonstrates secondary risk factors for bone fracture such as undernutrition, hypoestrogenism, and/or prior fractures, then osteoporosis may also be diagnosed (Nattiv et al., 2007). For athletes, a Z-score lower than -1.0 is considered to be lower than expected for that particular group and is indicative of a low BMD even when appearing in the absence of any previous bone fractures or other related injuries (Weiss Kelly et al., 2016). A low body mass index (i.e., <18.5 kg/m2), recurrent stress fractures, an oligomenorrhea or amenorrhea diagnosis within the past six months, and a history involving eating disorders, disordered eating, and/or low energy available are risk factors which should promote a BMD evaluation in athletes, especially those with an active stress fracture (Weiss Kelly et al., 2016). BMD evaluations should also be considered if an athlete is currently prescribed any medications associated with adverse bone health effects or if a bone fracture has occurred in any of the following sites: proximal femur, tibial plateau, and calcaneus (Weiss Kelly et al., 2016). Furthermore, training factors and delayed menarche may also have direct influences on both the athlete's menstrual cycle and BMD (Cobb et al., 2003).

It should be emphasized that low weight, especially in endurance-centric sports such as cross country and track and field, can appear as an independent risk factor for low BMD (Cobb et al., 2003; Mountjoy et al., 2018). A lack of multidimensional loadbearing on certain bone sites also increases risk significantly. Non-impact or low-impact sports such as running are at an increased risk for reduced BMD and related bone health complications. While cross country may involve varying running surfaces, the sports motion involved with distance running is primarily sagittal-only and is generally lower impact than movements associated with soccer and other sports involving player-to-player contact. In their 2018 study regarding sport and Triad risk factors, Tenforde et al. evaluated the influence of sports participation on resultant BMD across 16 collegiate sports via DXA scans measuring Z-scores for the total body and the lumber spine (Tenforde et al., 2018). Cross country athletes were reported to be among the lowest average BMD z-scores populations alongside swimming and rowing (Tenforde et al., 2018). It was confirmed through this study that Triad risk factors may serve independently alongside sport factors and that these athletes participating in low-impact sports are at an increased risk for reduced BMD (Tenforde et al., 2018). It has also been suggested through numerous cross-sectional studies that endurance runners are more likely to develop lower BMDs on average than their sprinter counterparts (Weiss Kelly et al., 2016). A recommendation for these low-impact sports is to increase the load on critical bone sites in multiple dimensions in order to increase bone stiffness and overall fracture-resistance to decrease incidences of low BMD and related injuries, especially among runners in endurance-dominant sports (Tenforde et al., 2018).

Musculoskeletal adaptations resulting from the Triad are often hard to identify due to the subtle development of symptoms. Therefore, consequences associated with low BMD can be severe and impact affected athletes long-term, even beyond the period in which they may have recovered from other Triad-related conditions. Osteoporosis is frequently associated with the Triad and has been characterized as a skeletal disorder in which compromised bone strength has predisposed an individual to an increased risk for bone fractures (Nattiv et al., 2007). While less severe than an osteoporosis diagnosis, stress fractures and bone stress injuries are a frequent occurrence when an athlete has presented with low BMD. Although not as long-term as osteoporosis, these acute consequences are enough to sideline athletes and can potentially reduce training and competition outcomes to an extent significant enough to affect an athlete’s overall success and sports career.

Remaining Questions

The purpose of this study is to answer the following questions: To what extent are Triad related risk factors related to training volume, and how do these factors change among event groups when Triad risk is determined across the entirety of a track and field team?

To our knowledge, few studies have attempted to directly measure training volume as it relates to Triad risk factors such as menstrual dysfunction, stress fractures, and low energy availability. Furthermore, few studies have observed these variables as they differ among the different sporting groups within track and friend (i.e., distance runners, sprinters, throwers, and jumpers) as well as the individual variation within these groups based on event classification, season schedules, competition standards, and personal training plans. This study also aims to evaluate any cognitive factors relating to Triad risk such as depression, sleep quality, and perceived stress.

Any potential correlations between these factors and Triad risk are critical and need to be shared among athletes, coaches, and practitioners in order to decrease risk as it pertains to an athlete's health and collegiate career. Furthermore, any potential correlations need to be identified in order to enable better risk stratification and screening protocols to better protect athletes, especially athletes in leanness-oriented sports such as women's track and field. Furthermore, understanding the relationships between any of these factors could improve the collective understanding of the Triad, thus theoretically lowering injury rates and associated conditions and increasing competition level and medical safety for active participants in women's track and field and other at-risk sports.

CHAPTER II: Methods

Study Design and Participants

In order to assess training volume, Triad risk, and a number of secondary factors, this study incorporated a cross section design in which participants were recruited anonymously through an online survey. The online survey was distributed to participants at two different data collection periods corresponding to the spring and summer seasons of competition and training for women's track and field athletes. The surveys were administered through Qualtrics and were distributed electronically to the compliance offices of NCAA D1 universities in which a women's track and field program was listed across the United States. This ensured the anonymity of participants to the investigators. A total of 319 universities across the nine NCAA regions were contacted in the process of distributing the online survey.

Participants for this study were female adults between the ages of 19 and 30. In order to be included, participants had to be 18 years or older, capable of providing informed consent, of any race or ethnicity, and a collegiate women's track and field athlete. The only exclusion criteria were if a participant was younger than 18 years of age or was pregnant due to potential influences of hormones and other pregnancy-related conditions on the other study variables.

Survey Structure and Data Collection

Each survey consisted of six sections. Section 1 contained the introduction to the study as well as the standard online informed consent document. Sections 2 and 3 contained questions regarding basic demographic information (i.e., age, height, weight, race and ethnicity, region of homeland, and region of school), basic sport designation information (i.e., university classification; event(s); year classification; typical weekly milage, training hours, and cross-training amounts; for season(s) of competition and season(s) of conditioning) and injury history at the collegiate level. For injury history, the type of injury (i.e., acute or chronic), classification of injury (i.e., musculoskeletal, soft tissue, orthopedic, other), result of injury (i.e., "redshirt" season), and if treatment was received from participant's university were obtained. The information from this section was used to designate the athletes into their specific track subpopulation, and to assess the percentage of injuries resulting from their collegiate training. Body mass index (BMI) was also calculated from the information obtained in this section.

Section 4 contained questions addressing Triad risk and was inspired by the Female Athlete Triad Coalition's recommended Triad screening questions (Weiss Kelly et al., 2016). All twelve questions were incorporated into this section and are outlined in the appendices. In general, these questions regarded statements about body image, food intake, menstrual activity, bone health, and energy levels. The data collection from this section was then used to assess and determine Triad risk among the participants. Because direct reports (i.e., Z-scores) of low BMD were unable to be collected via online surveys, cumulative risk was unable to be fully addressed using the Triad Cumulative Risk Assessment as designed by De Souza et al. in the 2014 Triad Coalition Consensus Statement (De Souza et al., 2014). However, individual factors of Triad risk such as self-reports of LEA, low BMI, delayed menarche, oligomenorrhea and/or amenorrhea, and stress reaction/fracture from the questions in this section were used to assess the Triad risk of participants, and it was these variables that were then compared to training volume, quality of sleep, perceived stress, and perceived depressive symptoms.

Supplemental questions involving iron and ferritin supplementation were also included in this section as well as self-perceptions of energy levels and fatigue.

Section 5 contained questions adapted from the ASSQ Sleep Difficulty Score (SDS) to determine the quality of participant's sleeping habits (Bender et al., 2018). A categorization of 'none' was assigned if participants scored between 0 to 4 points. 'Mild' was assigned to a score of 5 to 7 points. 'Moderate' was assigned to a score of 8 to 10 points. Any participants with a score of 11 to 17 were assigned to the 'severe' group and were considered to have a severe clinical sleep problem.

Section 6 contained questions adapted from the Perceived Stress Scale (PSS) and the Patient Health Questionnaire (PHQ-9) (Cohen et al., 1983; Kroenke et al., 2001). These questions were used to assess the level of perceived stress experienced by participants as well as their self-evaluated depression severity. The PSS asked ten questions involving perceived stress within the last month and incorporated a Likert scale style of answering in which 'never' was 0 points, 'almost never' was 1 point, 'sometimes' was 2 points, 'fairly often' was 3 points, and 'very often' was 4 points. Participants scoring between 0 to 13 points were considered low perceived stress. Participants scoring between 14 to 26 points were considered moderate perceived stress. Participants scoring between 27 to 40 points were considered high perceived stress. The PHQ-9 asked ten questions in which the first nine involved problem statements regarding how bothered participants had been by certain things within the last 2 weeks and the last regarded how difficult the aforementioned problem statements had made daily living for the participants in order to determine the affect these problems might be having on the participant's overall level of function. Scoring for this section was also based on a Likert scale style of answering in which ‘not at all’ was 0 points, ‘several days’ was 1 point, ‘more than half the days’ was 2 points, and ‘nearly every day’ was 3 points. For the use of this study, the resultant PHQ-9 severity scores were assigned to participants, and they were then ranked by degree or severity ranging from no symptoms to symptoms of severe major depression. No symptoms were determined by a severity score between 0 to 4 points. Minimal symptoms were determined by a severity score between 5 to 9 points. Minor depression, dysthymia, or mild major depression was determined by a severity score between 10 to 14 points. Moderately severe major depression was determined by a severity score between 15 to 19 points. Severe major depression was determined by a severity score of 20 points or greater.

Statistical Analysis

First, descriptive statistics (frequencies and means) were used to describe the participant sample, including age, body size, and sport participation. Within the sports participation section of the survey, participants were asked to provide estimates of average training volume for the following variables: competition cross training hours, competition resistance weight training hours, competition training hours, competition training mileage, conditioning cross training hours, conditioning resistance weight training hours, conditioning training hours, and conditioning training mileage. ‘Competition’ was used to refer to the seasons in which the participants were actively competing in their sport, while ‘conditioning’ was used to refer to the seasons in which the participants were not actively competing in their sport and were instead training in preparation for the competition seasons (e.g., a sprinter, jumper, or thrower would consider Winter and Spring to be competition seasons and Summer and Fall to be conditioning seasons, whereas a distance runner would consider Fall, Winter, and Spring to be competition seasons and Summer to be a conditioning season for the average NCAA D1 university). These training volume variables were then summed into two separate total training volume hours respective of their season classification (i.e., the competition training variables were summed into the competition total training volume hours and the conditioning training variables were summed into the conditioning total training volume hours). Due to a lack of consistency when providing training mileage across the study sample, the competition training mileage and conditioning training mileage were excluded from the total training volume hour variables.

In order to determine the overall Triad risk for participants, the total number of known individual Triad risk factors collected in Section 4 of the online survey were counted. *T*-tests were used to compare total in-season training volume (in mileage) between individuals reporting high (>50th percentile) vs. low (<50th percentile) Triad risk factor counts. Next, Pearson Chi-Square tests were performed to determine if specific Triad risk factors were more prevalent in individuals reporting high (>50th percentile) vs. low (<50th percentile) in-season training volumes expressed as total training hours. This same approach was used to determine if sleep quality, stress, and depressive symptoms were more prevalent in the high vs. low training volume groups.

CHAPTER III: Results

Demographics and Descriptives

A total of 66 data entries were recorded through the Qualtrics software during the spring and summer data collection periods. Of these 66 entries, 34 participants met all criteria and were analyzed for demographics and various descriptives through IBM SPSS software. These results are shown in Table 1. The descriptives for this study involved assessments of age, height (cm), weight (lbs), and BMI (kg/m^2). The mean age of the study pool was 21 ± 2 years, with a minimum age of 18 years and a maximum age of 29 years. The mean height was 164.2 ± 7.4 cm, with a minimum height of 152 cm and a maximum height of 178 cm among the study participants. The mean weight was 128.7 ± 16.1 lbs., with a minimum weight of 100 lbs and a maximum weight of 165 lbs among the study participants. BMI was calculated using the height and weight entries and was found to have a mean of 21.6 ± 2.2 kg/m^2 with a minimum BMI of 17.9 kg/m^2 and a maximum BMI of 26.1 kg/m^2.

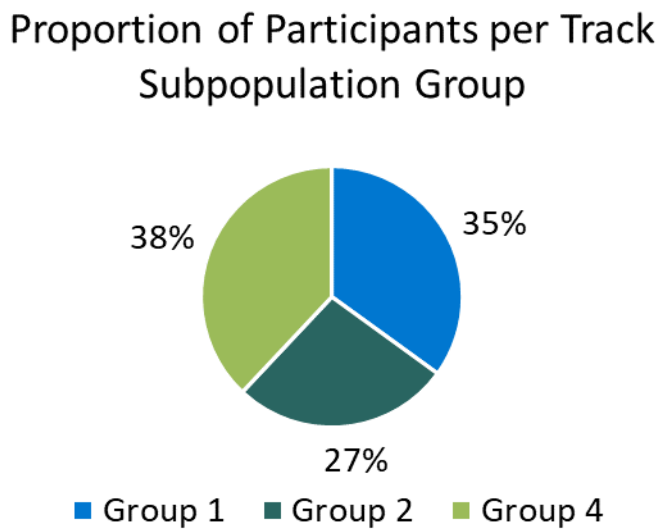
Table 1. Comparisons of Demographics and Descriptives Between Track Subpopulation Groups and Total Sample Population.

	Total Sample Population	Track Subpopulation Group 1	Track Subpopulation Group 2	Track Subpopulation Group 4	Sig. Between Groups
Number of participants	34	12	9	13	
Age	21 ± 2	21 ± 2	20 ± 1	21 ± 3	0.630
Height (cm)	164.2 ± 7.4	162.7 ± 9.1	166.0 ± 4.0	164.3 ± 7.7	0.614
Weight (lbs)	125.1 ± 26.1	119.0 ± 12.6	133.8 ± 15.1	124.8 ± 38.4	0.450
BMI (kg/m^2)	21.0 ± 4.1	20.4 ± 1.7	22.0 ± 1.8	20.8 ± 6.3	0.674
Triad RF count	5.2 ± 2.7	5.6 ± 2.5	4.1 ± 2.4	5.5 ± 3.2	0.404
Competition total training volume hours	16.3 ± 7.1	18.2 ± 7.5	12.0 ± 5.3	17.8 ± 7.1	0.131
Conditioning total training volume hours	16.3 ± 7.2	16.5 ± 8.5	12.7 ± 6.9	18.6 ± 5.5	0.266
SDS score	6.2 ± 2.9	5.3 ± 3.3	5.8 ± 2.9	7.3 ± 2.4	0.208
PSS score	17.4 ± 6.8	14.3 ± 7.1	17.5 ± 7.1	20.2 ± 5.3	0.096
PHQ-9 score	6.2 ± 5.3	6.3 ± 5.2	4.5 ± 5.9	7.3 ± 5.0	0.508

Dataset was analyzed through an IBM SPSS software and included "*number of participants,*" "*age,*" "*height (cm),*" "*weight (lbs)*," "*BMI (kg/m*^{2}*),*" "*Triad RF count,*" "*competition total training volume hours,*" "*conditioning total training volume hours,*" "*SDS score,*" "*PSS score,*" and "*PHQ-9 score.*" Significance was also found between groups via an ANOVA.

In order to better compare the descriptives and other variables between the different athlete types, the participants were broken down into four track subpopulations and categorized using numerical IDs based on the responses given during the sport information section of the survey. All participants who selected 'distance runners' were categorized into the track subpopulation group 1. All participants who selected either 'sprinters' or 'jumpers' were categorized into the track subpopulation group 2. All participants who selected 'throwers' were categorized into the track subpopulation group 3. Because only one participant for the thrower category was included in the final analysis sample, track subpopulation group 3 was excluded from the datasets for this section of the study. If a participant selected more than one category (i.e., selected 'distance runners, throwers, jumpers, sprinters,' 'distance runners, throwers,' or 'distance runners, sprinters'), they were labeled as multievent and categorized into the track subpopulation group 4. Out of the 34 participants, 12 (35%) were categorized into Group 1, 9 (27%) were categorized into Group 2, and 13 (38%) were categorized into Group 4 as shown in Figure 2. The mean demographics and descriptives for these groups are shown in Table 1 alongside the calculated significance of the variables between the groups.

Figure 2. *Proportion of participants per track subpopulation group.*



Group 1 was representative for those who selected "*distance runners.*" Group 2 was representative for those who selected either "*sprinters*" or "*jumpers.*" Group 4 was representative of those who selected more than one subpopulation group and was termed as "*multievent.*"

Participants were also asked questions regarding their history of injury at the collegiate level. Of the 34 participants, 28 (82.4%) selected yes to having received an injury while training and/or competing in college.

For the competition total training volume hours variable, a total of 28 participants were included resulting in a mean value of 16.3 ± 7.1 hours with a minimum value of 2 hours and maximum value of 33 hours. For the conditioning total training volume hours variable, a total of 27 participants were included resulting in a mean value of 16.3 ± 7.2 hours with a minimum value of 4 hours and a maximum value of 33 hours. Additionally, the participants were then sorted into either high or low training groups at the 50^{th} percentile (i.e., those below the 50^{th} percentile for the total training volume hours were sorted into the lower training group and those above the 50^{th} percentile for the total training volume hours were sorted into the higher training group).

Triad risk factor count, which will henceforth be referred to as Triad RF count, was calculated using the responses from the twelve questions adapted from the Female Athlete Triad Coalition's recommended Triad screening questions as well as from two questions regarding energy levels during daily life and during exercise (Weiss Kelly et al., 2016). An affirmative response corresponded to a point in the Triad RF count for eleven of these questions. A negative response was required for the question regarding monthly menstrual cycles to add a point in the Triad RF count. Finally, the two questions regarding energy levels were answered on a 5-point Likert scale from strongly disagree to strongly agree. Responses equaling to semi agree or strongly agree were counted as a point in the Triad RF count. The mean Triad RF count for the total sample population and each of the track subpopulation groups is shown in Table 1. A total of 34 participants were included in this section of the analysis. The mean score for the Triad RF count was 5.2 ± 2.7 points with a minimum count of 0 points and a maximum count of 11 points. These scores were then used to sort the participants into percentile groups (i.e., above or below the 50th percentile). Participants scoring 6 points or lower in the Triad RF count were sorted into the low-risk Triad group and participants scoring 7 points or higher in the Triad RF count were sorted into the high risk Triad group. These results are shown in Table 2.

Table 2. Comparisons of Triad RF Count Percentile Groups Between Track Subpopulation Groups and Total Sample Population.

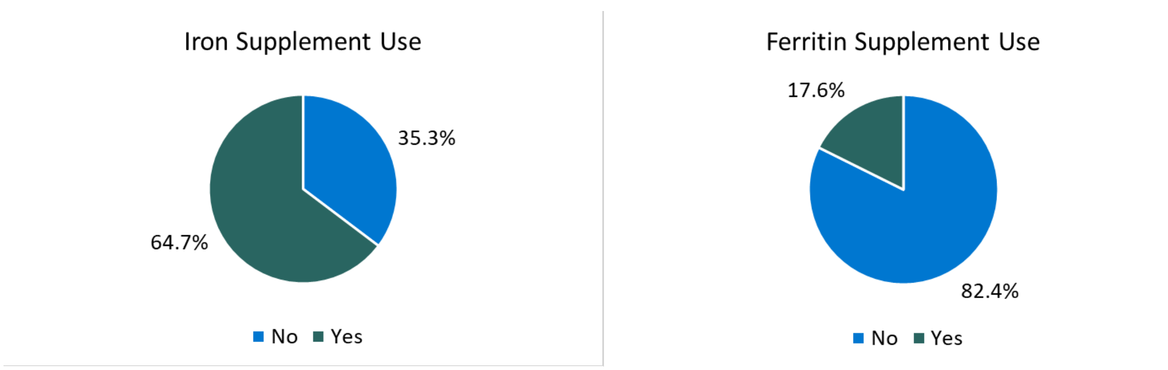
	Total Sample Population	Track Subpopulation Group 1	Track Subpopulation Group 2	Track Subpopulation Group 4	Sig. Between Groups
Mean Triad RF count	5.2 ± 2.7	5.6 ± 2.5	4.1 ± 2.4	5.5 ± 3.2	0.404
High risk Triad group	7.6 ± 1.6	7.3 ± 1.9	8.0 ± 1.4	7.6 ± 1.6	0.881

(>50th percentile)					
Low risk Triad group (<50th percentile)	3.1 ± 1.4	3.8 ± 1.6	3.0 ± 0.8	2.2 ± 1.6	0.172

Dataset was analyzed through an IBM SPSS software and included "*mean Triad RF count,*" "*high risk Triad group*" (>50th percentile was 7 points or greater), and "*low risk Triad group*" (<50th percentile was 6 points or lower). These variables were then compared between the total sample population and the track subpopulation groups. Significance values ($p \geq 0.172$) were found between groups via a split-samples analysis.

Participants were asked whether they used iron supplements and/or ferritin supplements as well. Out of the 34 participants, 22 (64.7%) selected yes to iron supplement usage and 6 (17.6%) selected yes to ferritin supplement usage. The proportions of these frequencies are shown in Figure 3.

Figure 3. *Percentage of participants who selected yes to iron supplement use and ferritin supplement use.*



Both iron supplement use and ferritin supplement use were analyzed through an IBM SPSS software to find the percentage of participants engaging in either behavior. 64.7% of participants selected yes for iron supplement use and 17.6% of participants selected yes for ferritin supplement use.

Similar to the Triad RF count, overall values for SDS, PSS, and PHQ-9 were calculated and the participants were sorted into their corresponding groups. The mean overall score for the SDS section of the survey was 6.21 ± 2.9 points with a minimum score of 2 points and a maximum score of 11 points among the participants. The mean overall score for the PSS section of the survey was 17.4 ± 6.8 points with a minimum score of 2 points and a maximum score of 30 points among the participants. The mean overall score for the PHQ-9 section of the survey was 6.2 ± 5.3 points with a minimum score of 0 points and a maximum score of 18 points. The comparisons of these mean values between the total sample population and the track subpopulation groups can be found in Table 1.

T-tests and Pearson Chi-Square tests

Using the descriptives described above, independent sample *t*-tests were performed to check for significant differences between Triad RF counts across high vs. low training volume groups and differences in training volume across high vs. low Triad RF count groups. When directly analyzing the Triad RF counts against any of the training volume variables (i.e., competition total training volume hours, competition cross training hours, competition resistance weight training hours, competition training hours, competition training mileage, conditioning total training volume hours, conditioning cross training hours, conditioning resistance weight training hours, conditioning training hours, and conditioning training mileage) when broken down into below and above the 50th percentiles, no significant differences were found (all $p \geq 0.24$). However, when individual Triad risk factor frequencies were compared between the high vs. low training volume groups via Pearson Chi-Square tests, certain Triad risk factors were more likely to be present in the higher training group for competition total training volume hours (Table 3). Statistically significant differences were observed for frequencies of the following Triad risk factors: "*history of collegiate injury*" (p=0.022), "*desire to lose weight for 'sporting image'*" (p=0.042), and "*suffer from eating disorder*" (p=0.017).

Additionally, "*low BMD or osteoporosis diagnosis*" (*p*=0.054) and "*ferritin supplement usage*" (*p*=0.051) approached significance in these Pearson Chi-Square tests as shown in Table 3 and Figure 4. Other Triad risk factors of interest included incidence of "*stress fracture or stress reaction,*" "*iron supplement usage,*" "*fatigue during daily activities,*" and "*fatigue during exercise.*" As shown in Table 3 and Figure 4, the results involving these variables were non-significant ($p \geq 0.084$).

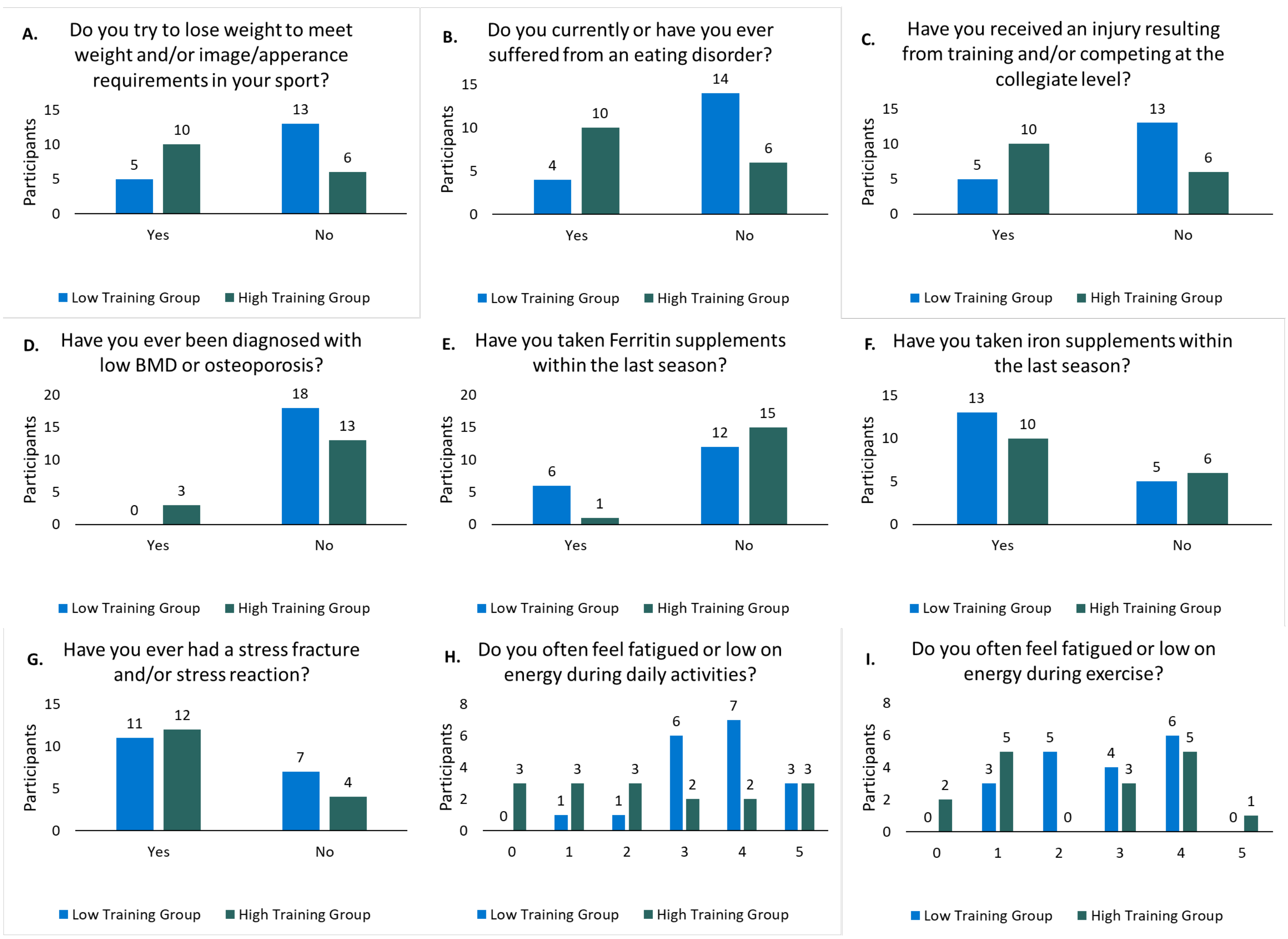
Table 3. Pearson chi-square tests comparing competition total training hours to several variables of interest.

Variable of Interest	Participant Response	Low Training Group (<50th percentile)	High Training Group (>50th percentile)	Asymptomatic Significance (2-sided)
History of collegiate injury	1	13	16	0.022
	2	5	0	
	Total	18	16	
Lose weight for sport image	1	5	10	0.042
	2	13	6	
	Total	18	16	
Suffer from eating disorder	1	4	10	0.017
	2	14	6	
	Total	18	16	
Stress fracture or stress reaction	1	11	12	0.388
	2	7	4	
	Total	18	16	
Low BMD or osteoporosis diagnosis	1	0	3	0.054
	2	18	13	
	Total	18	16	
Iron supplement use	1	13	10	0.545
	2	5	6	
	Total	18	16	
Ferritin supplement use	1	6	1	0.051
	2	12	15	
	Total	18	16	
Stress fracture or stress reaction	1	11	12	0.388
	2	7	4	
	Total	18	16	
Fatigue during daily activities*	0	0	3	0.084
	1	1	3	
	2	1	3	
	3	6	2	
	4	7	2	
	5	3	3	
	Total	18	16	
Fatigue during exercise*	0	0	2	0.124
	1	3	5	
	2	5	0	
	3	4	3	
	4	6	5	

5	0	1
Total	18	16

Dataset was analyzed through an IBM SPSS software via Pearson chi-square tests in which competition total training hours were compared to variables including "*history of collegiate injury,*" "*lose weight for sport image,*" "*suffer from eating disorder,*" "*low BMD or osteoporosis diagnosis,*" "*iron supplement use,*" "*ferritin supplement use,*" "*stress fracture or stress reaction,*" "*fatigue during daily activities,*" and "*fatigue during exercise.*" The participant responses were graded as 1 equaling a "*yes*" and 2 equaling a "*no*" on the survey questions. Participants were separated into a high training group (>50th percentile for competition total training hours) and a low training group (<50th percentile for competition total training hours) and evaluated on each risk factor. Asymptomatic significance (2-sided) was found for history of collegiate injury, lose weight for sport image, and suffer from eating disorder. Low BMD or osteoporosis diagnosis and ferritin supplement use were found to be approaching significance.
* Graded on a Likert scale from 0 (i.e., strongly disagree) to 5 (i.e., strongly agree).

Figure 4. *Pearson chi-square tests comparing competition total training hours to several variables of interest.*



Graphical depiction of the dataset shown in **Table 3** in which competition total training volume hours were compared to the variables above via Pearson chi-square tests. The variables of interest are marked by the panel ID's and are as follows: A. "*lose weight for sport image*", B. "*suffer from eating disorder*", C. "*history of collegiate injury*", D. "*low BMD or osteoporosis diagnosis*", E. "*ferritin supplement use*", F. "*iron supplement use*", G. "*stress fracture or stress reaction*", H. "*fatigue during daily activities*", and I. "*fatigue during exercise*".

CHAPTER IV: Discussion

As outlined in the Results section, several Triad risk factors were found to have statistically significant differences when the high training group was compared to the low training group for competition total training volume hours. These Triad risk factors were "history of collegiate injury" (p=0.022), "desire to lose weight for 'sporting image'" (p=0.042), and "suffer from eating disorder" (p=0.017). Additionally, two other Triad risk factors were found to be approaching statistical significance during the same analyses. These Triad risk factors were "low BMD or osteoporosis diagnosis" (p=0.054) and "ferritin supplement usage" (p=0.051). Given that statistical significance was found for several of these Triad risk factors in the higher training group, we can determine that, as training volume increases for a female collegiate track and field athlete, certain Triad risk factors are also likely to be more prevalent. Therefore, our hypothesis was partially supported by this data. However, certain limitations in the present study likely prevented further observations of statistical significance involving Triad risk and training volume. These limitations will be addressed throughout the discussion as explanations are offered for the various occurrences of the different Triad risk factors among the different groups.

Body Dissatisfaction, Disordered Eating, and LEA

Of the three intertwining components of the Triad, low energy availability (LEA) has been marked as one of the most, if not the most, influential elements of the syndrome. Whether or not LEA results from disordered eating, it has been shown to play a causal role in the development of various menstrual disturbances and has also been linked with impairments in bone health and other body systems, such as the cardiovascular system

(De Souza et al., 2014; Weiss Kelly et al., 2016). Body dissatisfaction is a well-known component of disordered eating and one of the common causes of LEA in female athletes. As discussed in the introduction section, body dissatisfaction can occur due to a number of reasons and often presents in female athletes as a disconnect between their ‘social’ bodies and their ‘sporting’ bodies. The Triad risk factor “desire to lose weight for sporting image” was found to be statistically significant (p=0.042) in the high training volume group when analyzed for competition total training volume hours. The female athletes in the high training group (i.e., >50th percentile for competition total training volume hours) are not only spending more time on the track, at the gym, and in practice but are also more worried about the appearance of their so-called ‘sporting’ bodies and whether they were the correct weight or had the ideal body composition for their track subpopulation group than their lower volume counterparts. Additionally, the Triad risk factor “suffer from eating disorder” was also shown to be statistically significant (p=0.017) in the high training group. Both of these variables point to a high risk for the development of LEA, especially in a leanness-oriented sport such as track and field.

The question associated with the “suffer from eating disorder” Triad risk factor asked whether the athlete had either experienced or was experiencing an eating disorder. As a result, there is a high potential for athletes to reply in the negative despite having disordered eating patterns because they either may not meet the full diagnostic criteria to be diagnosed with an official eating disorder or have not been screened to be diagnosed with an official eating disorder by a physician. This is somewhat mediated by the other accompanying questions (e.g., Do you limit or carefully control the foods you eat?) in the disordered eating section of the Triad screening questions, but various factors such as faulty recall, fear of stigma or social oddity, and/or biased perceptions of personal eating habits may undermine the accuracy of self-reporting through these survey questions. In a 2009 study by Greenleaf et al., it was found that 25.5% of D1 female athletes in 17 sports across 3 universities were positive for subclinical symptoms (i.e., demonstrating disordered eating patterns) while only 2% of these 204 athletes were fully diagnosable for an eating disorder (Greenleaf et al., 2009). Therefore, the occurrence of this risk factor may be even higher than shown in this study due to the high prevalence of disordered eating patterns that are not fully diagnosable among athletes (Lambert et al., 2022). Any athlete with a form of disordered eating or body dissatisfaction is at risk of developing the Triad regardless of whether the condition is diagnosed as an eating disorder or not. These behaviors appear to be very prevalent among this population for all volume and event types and are especially high among the high training group when sorted into percentiles as they have been in Table 3 and Figure 4.

“Fatigue during daily activities” and “fatigue during exercise” were assessed as Triad risk factors as well. Although neither of these Triad risk factors showed a significant difference between the training groups, it should be noted that a relatively high number of participants self-reported experiencing fatigue or feelings of low energy. Specifically, 9 athletes (26.5%) selected somewhat agree and 6 athletes (17.6%) selected strongly agree on the provided Likert scale for “fatigue during daily activities”. For “fatigue during exercise,” 11 athletes (32.4%) selected somewhat agree and 1 athlete selected strongly agree. Due to the low number of participants in the sample pool, significance was unable to be drawn from these numbers. However, an upward trend does appear to be evident among the athletes for low energy as shown in Table 3 and Figure 4, thus further supporting the high prevalence of energy-related conditions among female athletes.

Injury History and Low BMD

Although exercise has been documented to produce positive osteogenic impacts on bone health for women, situations in which LEA is present, such as in a high intensity, high volume track and field athlete, can result in substantial impairments to bone health (Gibbs et al., 2014). Described to be the 'silent component' of the Triad, identifying low bone mineral density (BMD) and other associated bone health dysfunctions is critical for ensuring the long-term health of female athletes (Mallinson & De Souza, 2014). In the present study, three participants in the high training group responded in affirmative to the "low BMD or osteoporosis diagnosis" Triad risk factor. The resulting statistical difference between the training groups for this Triad risk factor was found to be approaching significant for the high training group ($p=0.054$). General "history of collegiate injury" was also recorded within the general sports information section of the survey and unsurprisingly given the level of competition and training of the sample population was found that 72% (13 of 18) of participants in the low training group and 100% (16 of 16) participants in the high training group experienced a collegiate injury while training or competing for their university. Furthermore, when the high and low training groups were directly compared, a statistically significant difference ($p=0.022$) was found between the groups. Given this data it can be assumed that while the majority of female track and field athletes competing at the collegiate level are likely to sustain an injury at some point in their career, the higher the training volume of the athlete, the more likely that athlete is to receive that injury and may potentially experience more than one injury during their career.

Several other Triad risk factors were analyzed alongside these as well and while they were not found to be significant ($p>0.084$), these other variables still provide an interesting depiction of the sample population. The incidence of "stress fracture or stress reaction" is of special importance due to the relatively high prevalence rates in female collegiate track and field athletes. In the present study, 75% (12 of 16) of the participants in the low training group and 61% (11 of 18) of the participants in the high training group experienced either a stress fracture or a stress reaction as shown in Table 3 and Figure 4. These elevated rates of injury are reflective of other studies in the field. Nattiv et al. found that 16% of the collegiate track and field and cross-country athletes in their 5-year prospective analysis sustained some form of bone stress injury (Nattiv et al., 2013). It should be noted as well that the incidence and/or risk of developing bone stress injuries such as these increase substantially with Triad components. For a female athlete with one Triad component, the risk of experiencing a stress fracture or stress reaction is at least three times higher than the risk of a counterpart with no Triad components (Edama et al., 2021; Mallinson & De Souza, 2014). If a female athlete is presenting with two or more Triad components, her risk is estimated to be nearly five times higher (Edama et al., 2021; Mallinson & De Souza, 2014). Barrack et al.'s work supported these bone stress injury risk rates in their 2014 prospective multisite study on exercising females (Barrack et al., 2014). It was found that female athletes with certain Triad risk factors (i.e., low BMD [Z-score: -1.00], >12 hours of exercise per week, and/or low BMI [<21.0 kg.m2]) were 2.4 to 2.9 times more likely to develop a bone stress injury when compared to non-

Triad presenting counterparts (Barrack et al., 2014). Therefore, incidences of injuries, especially those that are related to bone stress such as stress fractures or stress reactions, appear to be very predictive of a female athlete's risk of Triad development. In a similar vein, physicians and coaches should note that the presentation of any of the three Triad components in a female athlete can significantly increase the risk of developing these injuries as well.

Menstrual History, Dysfunction, and Supplementation

Although simple measures of menstrual history (i.e., age of menarche, regularity of menstrual cycles, and consistency of menstrual cycles) were asked of participants, there were no significant findings in this present study. However, "ferritin supplement usage" was found to be approaching significance (p=0.051) for statistical difference between the training groups, and "iron supplement usage" was high (64.7%) for the total sample population. Interestingly, more athletes in the low training group were taking ferritin supplements, thus suggesting that these athletes may be on lower training schedules due to a potential iron deficiency. Even if this is not the exact case for the ferritin supplements, most athletes in both training groups regularly consumed iron supplements. These high prevalence rates for iron supplements in the present study are indicative of the high prevalence rates of iron deficiency and anemia in sports such as track and field that have been demonstrated in other studies. In a 2017 retrospective review of laboratory results spanning over 15 years, 30.9% of female athletes from 25 D1 sports teams had iron deficiency without anemia, and 2.2% had iron-deficiency anemia (Parks et al., 2017). Within this population of diagnosed female athletes, only 1 out of each 20 was identified prior to the start of training at their preparticipation examinations

(Parks et al., 2017). Because iron deficiency and anemia are not overtly obvious conditions, some programs have begun incorporating preventative measures by instructing athletes to consume mineral supplements such as iron regularly. This is likely due to the elevated hazards of iron deficiency and anemia commonly found in these types of populations (e.g., endurance sports and/or sports linked with elevated occurrences of disordered eating) as iron deficiency has been identified as both a direct and indirect contributor to the energy deficiencies associated with the Triad, thus further emphasizing the importance of mineral supplements and monitoring hemoglobin and ferritin levels of female athletes (Clénin et al., 2015; Skorseth et al., 2020).

Limitations

The most significant limitation of the present study lies in the general limitations associated with subject recall and self-reporting measures characteristic of online surveys. Consistent with this limitation, a number of individuals failed to either complete the survey itself or did not pass the selection variable due to inappropriate formatting and errors in the provided responses (e.g., providing a weight value of "5"). Likewise, for many athletes, the answers related to training volume were likely estimates of current or previous training volumes rather than actual recorded data. It should be noted some individuals may have responded to in-season training questions (i.e., questions related to competition training volumes) during an out-of-season period, increasing the duration of recall. Considering the typical seasons of competition, this limitation likely influenced the summer data collection period primarily. Certain perceptional and societal ideals may have also affected answers for certain sections of the survey, such as with the disordered eating questions featured during the Triad section of the survey. Specifically, despite maintaining anonymity, we cannot rule out the possibility that some athletes were resistant to divulging potential issues with their personal eating habits.

The other major limitation of the present study involves the inability to directly collect physical data for variables such as BMD and LEA. Because the survey used here was distributed completely online with no direct contact with participants, values such as Z-scores or actual measurements of energy intake and energy expenditure could not be collected. The Triad Cumulative Risk Assessment established by De Souza et al. in the 2014 Triad Coalition Consensus Statement is the one of the main methods in which the Triad is screened for incoming female athletes and involves physical reports of Z-scores for BMD (De Souza et al., 2014). While this assessment method is a gold standard for screening female athletes for Triad risk at preparticipation evaluations, it was unable to be used due to the online format of the study surveys and the anonymity of the study participants. Because of this, the ability to generalize these findings to studies reporting cumulative Triad risk is somewhat limited.

Expansions/Future Directions

When considering possible expansions and future directions for this line of research, the most logical first step would be to work on expanding the target population beyond NCAA D1 female track and field athletes. Several of the variables in this study that were either similar or showed insignificant differences between the percentile training groups may be explained by all athletes meeting a minimal "dose" of training volume, likely associated with collegiate-level competition. For example, a majority of the athletes in this study were positive for experiencing a collegiate injury as shown in the Results section. Depending on the level of training and competition (e.g., D2, D3, intramural or recreational), other athletes of a similar demographic may not experience injuries at such a high prevalence rate. By recruiting more athletes in different categories of collegiate athletics, potential trends between Triad risk factors and training volume for endurance-centric sports could become more defined and may show more difference between the different percentile training groups. Including athletes outside of the college population could also significantly contribute to the analyses in this type of study, as well as looking at similar sports, such as swimming and cycling to see how these trends are compared over differing scenarios.

Another logical step would be to move beyond the basic online surveys utilized in the present study. As briefly mentioned in the Limitations subsection above, physical measures of BMD and LEA were unable to be directly collected. By incorporating physical aspects within data collection, variables such as BMD and LEA could be better assessed. With the current online survey method, direct measurements of participant Z-scores were unable to be gathered for the low BMD variable. Instead, participants were required to rely on self-reporting and subject recall for the questions associated with this Triad component. However, many athletes are likely to not have been screened or diagnosed with a BMD-related condition during routine evaluations for reasons such as cost and accessibility. Generally, an athlete may only be screened for a condition such as low BMD or osteoporosis if the athlete is presenting with a previous history of bone stress injuries or if the athlete is already presenting with components of the Triad. Relying on self-reporting for LEA is also challenged by the general difficulties of estimating an individual's energy availability without physical measurements. According to Capling et al. in their systematic review on the validity of dietary assessments currently used in athletics, athletes generally underreport measures of energy intake by an average of 19% (Capling et al., 2017). Therefore, it is likely that the questions used in this study to determine LEA risk underestimated the actual rate of LEA in the study's total sample population.

CHAPTER V: Conclusion

Due to the preestablished hazards and long-term consequences of the Triad in female athletes participating in sports emphasizing leanness, the primary purpose of this study was to determine the influence of training volume on Triad risk for female collegiate track and field athletes. It was hypothesized that, as training volume was increased, individual factors of Triad risk would also increase in this relatively high-risk population. The collected data partially supported this hypothesis. Several Triad risk factors (i.e., "history of collegiate injury," "desire to lose weight for 'sporting image,'" and "suffer from eating disorder") were found to be increased in the higher training volume group when competition total training volume hours were evaluated across the percentile groups. However, larger population pools and additional research are required to draw more definite conclusions regarding the potential relationship between increases in training volume and elevated risks of developing the Triad in female track and field athletes. Even without a definite conclusion on whether increasing training volume levels is linked with elevated risks of developing the Triad, practitioners and coaches should be aware of the numerous causes and consequences associated with the Triad and strive to embrace the various data-supported recommendations regarding the prevention and treatment of this potentially career-ending syndrome.

REFERENCES

Ackerman, K. E., Holtzman, B., Cooper, K. M., Flynn, E. F., Bruinvels, G., Tenforde, A. S., Popp, K. L., Simpkin, A. J., & Parziale, A. L. (2019). Low energy availability surrogates correlate with health and performance consequences of Relative Energy Deficiency in Sport. *British Journal of Sports Medicine*, *53*(10), 628–633. https://doi.org/10.1136/bjsports-2017-098958

American Psychiatric Association. (2022). *Diagnostic and Statistical Manual of Mental Disorders* (5th ed., text rev.). https://doi.org/10.1176/appi.books.9780890425787

Barrack, M. T., Gibbs, J. C., De Souza, M. J., Williams, N. I., Nichols, J. F., Rauh, M. J., & Nattiv, A. (2014). Higher incidence of bone stress injuries with increasing female athlete triad-related risk factors: a prospective multisite study of exercising girls and women. *The American Journal of Sports Medicine*, *42*(4), 949–958. https://doi.org/10.1177/0363546513520295

Beals, K. A., & Hill, A. K. (2006). The prevalence of disordered eating, menstrual dysfunction, and low bone mineral density among US collegiate athletes. *International Journal of Sport Nutrition and Exercise metabolism*, *16*(1), 1–23. https://doi.org/10.1123/ijsnem.16.1.1

Beermann, B. L., Lee, D. G., Almstedt, H. C., & McCormack, W. P. (2020). Nutritional Intake and Energy Availability of Collegiate Distance Runners. *Journal of the American College of Nutrition*, *39*(8), 747–755. https://doi.org/10.1080/07315724.2020.1735570

Bender, A. M., Lawson, D., Wethner, P., & Samuels, C. H. (2018). The Clinical Validation of the Athlete Sleep Screening Questionnaire: an Instrument to

Identify Athletes that Need Further Sleep Assessment. *Sports Medicine Open, 4*(23). https://doi.org/10.1186/s40798-018-0140-5

Berz, K., & McCambridge, T. (2016). Amenorrhea in the Female Athlete: What to Do and When to Worry. *Pediatric Annals*, *45*(3), e97–e102. https://doi.org/10.3928/00904481-20160210-03

Brewer, B., Van Raalte, J., & Linder, D. (1993). Athletic identity: Hercules' muscles or Achilles heel? *International Journal of Sport Psychology, 24*(2), 237-254.

Capling, L., Beck, K. L., Gifford, J. A., Slater, G., Flood, V. M., & O'Connor, H. (2017). Validity of Dietary Assessment in Athletes: A Systematic Review. *Nutrients*, *9*(12), 1313. https://doi.org/10.3390/nu9121313

Carmichael, M. A., Thomson, R. L., Moran, L. J., & Wycherley, T. P. (2021). The Impact of Menstrual Cycle Phase on Athletes' Performance: A Narrative Review. *International Journal of Environmental Research and Public Health*, *18*(4), 1667. https://doi.org/10.3390/ijerph18041667

Clénin, G., Cordes, M., Huber, A., Schumacher, Y. O., Noack, P., Scales, J., & Kriemler, S. (2015). Iron deficiency in sports - definition, influence on performance and therapy. *Swiss Medical Weekly*, *145*, w14196. https://doi.org/10.4414/smw.2015.14196

Cobb, K. L., Bachrach, L. K., Greendale, G., Marcus, R., Neer, R. M., Nieves, J., Sowers, M. F., Brown, B. W., Jr, Gopalakrishnan, G., Luetters, C., Tanner, H. K., Ward, B., & Kelsey, J. L. (2003). Disordered eating, menstrual irregularity, and bone mineral density in female runners. *Medicine and Science in Sports and Exercise*, *35*(5), 711–719. https://doi.org/10.1249/01.MSS.0000064935.68277.E7

Coelho, A. R., Cardoso, G., Brito, M. E., Gomes, I. N., & Cascais, M. J. (2021). The Female Athlete Triad/Relative Energy Deficiency in Sports (RED-S). A tríade da atleta feminina/déficit energético relativo no esporte (RED-S). *Revista Brasileira de Ginecologia e Obstetricia : Revista da Federacao Brasileira das Sociedades de Ginecologia e Obstetricia*, *43*(5), 395–402. https://doi.org/10.1055/s-0041-1730289

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior*, *24*(4), 385–396.

Cook, C. J., & Crewther, B. T. (2019). Within- and between-person variation in morning testosterone is associated with economic risk-related decisions in athletic women across the menstrual cycle. *Hormones and Behavior*, *112*, 77–80. https://doi.org/10.1016/j.yhbeh.2019.04.007

Cook, C. J., Kilduff, L. P., & Crewther, B. T. (2018). Basal and stress-induced salivary testosterone variation across the menstrual cycle and linkage to motivation and muscle power. *Scandinavian Journal of Medicine & Science in Sports*, *28*(4), 1345–1353. https://doi.org/10.1111/sms.13041

Day, J., Wengreen, H., Heath, E., & Brown. K. (2015). Prevalence of Low Energy Availability in Collegiate Female Runners and Implementation of Nutrition Education Intervention. *Sports Nutrition and Therapy, 1*(1). http://dx.doi.org/10.4172/%202473-6449.1000101

de Bruin, A. P., Oudejans, R. R., Bakker, F. C., & Woertman, L. (2011). Contextual body image and athletes' disordered eating: the contribution of athletic body image to disordered eating in high performance women athletes. *European Eating*

Disorders Review : The Journal of the Eating Disorders Association, *19*(3), 201–215. https://doi.org/10.1002/erv.1112

De Souza, M. J., Lee, D. K., VanHeest, J. L., Scheid, J. L., West, S. L., & Williams, N. I. (2007). Severity of energy-related menstrual disturbances increases in proportion to indices of energy conservation in exercising women. *Fertility and Sterility*, *88*(4), 971–975. https://doi.org/10.1016/j.fertnstert.2006.11.171

De Souza, M. J., Nattiv, A., Joy, E., Misra, M., Williams, N. I., Mallinson, R. J., Gibbs, J. C., Olmsted, M., Goolsby, M., Matheson, G., & Expert Panel (2014). 2014 Female Athlete Triad Coalition Consensus Statement on Treatment and Return to Play of the Female Athlete Triad: 1st International Conference held in San Francisco, California, May 2012 and 2nd International Conference held in Indianapolis, Indiana, May 2013. *British Journal of Sports Medicine*, *48*(4), 289. https://doi.org/10.1136/bjsports-2013-093218

DellaValle, D. M., & Haas, J. D. (2011). Impact of iron depletion without anemia on performance in trained endurance athletes at the beginning of a training season: a study of female collegiate rowers. *International Journal of Sport Nutrition and Exercise Metabolism*, *21*(6), 501–506. https://doi.org/10.1123/ijsnem.21.6.501

Edama, M., Inaba, H., Hoshino, F., Natsui, S., Maruyama, S., & Omori, G. (2021). The relationship between the female athlete triad and injury rates in collegiate female athletes. *PeerJ*, *9*, e11092. https://doi.org/10.7717/peerj.11092

Edwards, A. (2010). Why Sport? The Development of Sport as a Policy Issue in Title IX of the Education Amendments of 1972. *Journal of Policy History, 22*(3), 300-336. doi:10.1017/S0898030610000126

Gibbs, J. C., Nattiv, A., Barrack, M. T., Williams, N. I., Rauh, M. J., Nichols, J. F., & De Souza, M. J. (2014). Low bone density risk is higher in exercising women with multiple triad risk factors. *Medicine and Science in Sports and Exercise*, *46*(1), 167–176. https://doi.org/10.1249/MSS.0b013e3182a03b8b

Gibbs, J. C., Williams, N. I., & De Souza, M. J. (2013). Prevalence of individual and combined components of the female athlete triad. *Medicine and Science in Sports and Exercise*, *45*(5), 985–996. https://doi.org/10.1249/MSS.0b013e31827e1bdc

Greenleaf, C., Petrie, T. A., Carter, J., & Reel, J. J. (2009). Female collegiate athletes: prevalence of eating disorders and disordered eating behaviors. *Journal of American College Health : J of ACH*, *57*(5), 489–495. https://doi.org/10.3200/JACH.57.5.489-496

Heikura, I. A., Uusitalo, A. L. T., Stellingwerff, T., Bergland, D., Mero, A. A., & Burke, L. M. (2018). Low Energy Availability Is Difficult to Assess but Outcomes Have Large Impact on Bone Injury Rates in Elite Distance Athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *28*(4), 403–411. https://doi.org/10.1123/ijsnem.2017-0313

Herbold, N. H., Visconti, B. K., Frates, S., & Bandini, L. (2004). Traditional and nontraditional supplement use by collegiate female varsity athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *14*(5), 586–593. https://doi.org/10.1123/ijsnem.14.5.586

Holtzman, B., & Ackerman, K. E. (2021). Recommendations and Nutritional Considerations for Female Athletes: Health and Performance. *Sports Medicine*

(Auckland, N.Z.), *51*(Suppl 1), 43–57. https://doi.org/10.1007/s40279-021-01508-8

Jagim, A. R., Fields, J., Magee, M. K., Kerksick, C. M., & Jones, M. T. (2022). Contributing Factors to Low Energy Availability in Female Athletes: A Narrative Review of Energy Availability, Training Demands, Nutrition Barriers, Body Image, and Disordered Eating. *Nutrients*, *14*(5), 986. https://doi.org/10.3390/nu14050986

Joy, E., Kussman, A., & Nattiv, A. (2016). 2016 update on eating disorders in athletes: A comprehensive narrative review with a focus on clinical assessment and management. *British Journal of Sports Medicine*, *50*(3), 154–162. https://doi.org/10.1136/bjsports-2015-095735

Kong, P., & Harris, L. M. (2015). The sporting body: body image and eating disorder symptomatology among female athletes from leanness focused and nonleanness focused sports. *The Journal of Psychology*, *149*(1-2), 141–160. https://doi.org/10.1080/00223980.2013.846291

Kroenke, K., Spitzer, R. L., & Williams, J. B. (2001). The PHQ-9: validity of a brief depression severity measure. *Journal of General Internal Medicine*, *16*(9), 606–613. https://doi.org/10.1046/j.1525-1497.2001.016009606.x

Lambert, V., Carbuhn, A., Culp, A., Ketterly, J., Twombley, B., & White, D. (2022). Interassociation Consensus Statement on Sports Nutrition Models for the Provision of Nutrition Services From Registered Dietitian Nutritionists in Collegiate Athletics. *Journal of Athletic Training*, *57*(8), 717–732. https://doi.org/10.4085/1062-6050-0157.22

Legerlotz, K., & Nobis, T. (2022). Insights in the Effect of Fluctuating Female Hormones on Injury Risk-Challenge and Chance. *Frontiers in Physiology*, *13*, 827726. https://doi.org/10.3389/fphys.2022.827726

Mallinson, R. J., & De Souza, M. J. (2014). Current perspectives on the etiology and manifestation of the "silent" component of the Female Athlete Triad. *International Journal of Women's Health*, *6*, 451–467. https://doi.org/10.2147/IJWH.S38603

Mancine, R. P., Gusfa, D. W., Moshrefi, A., & Kennedy, S. F. (2020). Prevalence of disordered eating in athletes categorized by emphasis on leanness and activity type - a systematic review. *Journal of Eating Disorders*, *8*, 47. https://doi.org/10.1186/s40337-020-00323-2

Marcus, M. D., Loucks, T. L., & Berga, S. L. (2001). Psychological correlates of functional hypothalamic amenorrhea. *Fertility and Sterility*, *76*(2), 310–316. https://doi.org/10.1016/s0015-0282(01)01921-5

Mountjoy, M., Sundgot-Borgen, J. K., Burke, L. M., Ackerman, K. E., Blauwet, C., Constantini, N., Lebrun, C., Lundy, B., Melin, A. K., Meyer, N. L., Sherman, R. T., Tenforde, A. S., Klungland Torstveit, M., & Budgett, R. (2018). IOC consensus statement on relative energy deficiency in sport (RED-S): 2018 update. *British Journal of Sports Medicine*, *52*(11), 687–697. https://doi.org/10.1136/bjsports-2018-099193

Mountjoy, M., Sundgot-Borgen, J., Burke, L., Carter, S., Constantini, N., Lebrun, C., Meyer, N., Sherman, R., Steffen, K., Budgett, R., & Ljungqvist, A. (2014). The IOC consensus statement: beyond the Female Athlete Triad--Relative Energy

Deficiency in Sport (RED-S). *British Journal of Sports Medicine*, *48*(7), 491–497. https://doi.org/10.1136/bjsports-2014-093502

Nattiv, A., Loucks, A. B., Manore, M. M., Sanborn, C. F., Sundgot-Borgen, J., Warren, M. P., & American College of Sports Medicine (2007). American College of Sports Medicine position stand. The female athlete triad. *Medicine and Science in Sports and Exercise*, *39*(10), 1867–1882. https://doi.org/10.1249/mss.0b013e318149f111

Nielsen, S., Møller-Madsen, S., Isager, T., Jørgensen, J., Pagsberg, K., & Theander, S. (1998). Standardized mortality in eating disorders--a quantitative summary of previously published and new evidence. *Journal of Psychosomatic Research*, *44*(3-4), 413–434. https://doi.org/10.1016/s0022-3999(97)00267-5

Parks, R. B., Hetzel, S. J., & Brooks, M. A. (2017). Iron Deficiency and Anemia among Collegiate Athletes: A Retrospective Chart Review. *Medicine and Science in Sports and Exercise*, *49*(8), 1711–1715. https://doi.org/10.1249/MSS.0000000000001259

Petkus, D. L., Murray-Kolb, L. E., & De Souza, M. J. (2017). The Unexplored Crossroads of the Female Athlete Triad and Iron Deficiency: A Narrative Review. *Sports Medicine (Auckland, N.Z.)*, *47*(9), 1721–1737. https://doi.org/10.1007/s40279-017-0706-2

Practice guideline for the treatment of patients with eating disorders (revision). American Psychiatric Association Work Group on Eating Disorders. (2000). *The American Journal of Psychiatry*, *157*(1 Suppl), 1–39.

Rauh, M. J., Barrack, M., & Nichols, J. F. (2014). Associations between the female athlete triad and injury among high school runners. *International Journal of Sports Physical Therapy, 9*(7), 948–958.

Redman, L. M., & Loucks, A. B. (2005). Menstrual disorders in athletes. *Sports medicine (Auckland, N.Z.)*, *35*(9), 747–755. https://doi.org/10.2165/00007256-200535090-00002

Sims, S. T., Kerksick, C. M., Smith-Ryan, A. E., Janse de Jonge, X. A. K., Hirsch, K. R., Arent, S. M., Hewlings, S. J., Kleiner, S. M., Bustillo, E., Tartar, J. L., Starratt, V. G., Kreider, R. B., Greenwalt, C., Rentería, L. I., Ormsbee, M. J., VanDusseldorp, T. A., Campbell, B. I., Kalman, D. S., & Antonio, J. (2023). International society of sports nutrition position stand: nutritional concerns of the female athlete. *Journal of the International Society of Sports Nutrition*, *20*(1), 2204066. https://doi.org/10.1080/15502783.2023.2204066

Skorseth, P., Segovia, N., Hastings, K., & Kraus, E. (2020). Prevalence of Female Athlete Triad Risk Factors and Iron Supplementation Among High School Distance Runners: Results From a Triad Risk Screening Tool. *Orthopaedic Journal of Sports Medicine*, *8*(10), 2325967120959725. https://doi.org/10.1177/2325967120959725

Sundgot-Borgen, J., & Torstveit, M. K. (2004). Prevalence of eating disorders in elite athletes is higher than in the general population. *Clinical Journal of Sport Medicine : Official Journal of the Canadian Academy of Sport Medicine*, *14*(1), 25–32. https://doi.org/10.1097/00042752-200401000-00005

Tenforde, A. S., Carlson, J. L., Sainani, K. L., Chang, A. O., Kim, J. H., Golden, N. H., & Fredericson, M. (2018). Sport and Triad Risk Factors Influence Bone Mineral Density in Collegiate Athletes. *Medicine and Science in Sports and Exercise*, *50*(12), 2536–2543. https://doi.org/10.1249/MSS.0000000000001711

Turton, R., Goodwin, H., & Meyer, C. (2017). Athletic identity, compulsive exercise and eating psychopathology in long-distance runners. *Eating Behaviors*, *26*, 129–132. https://doi.org/10.1016/j.eatbeh.2017.03.001

Waldén, M., Hägglund, M., Werner, J., & Ekstrand, J. (2011). The epidemiology of anterior cruciate ligament injury in football (soccer): a review of the literature from a gender-related perspective. *Knee Surgery, Sports Traumatology, Arthroscopy : Official Journal of the ESSKA*, *19*(1), 3–10. https://doi.org/10.1007/s00167-010-1172-7

Weiss Kelly, A. K., Hecht, S., & COUNCIL ON SPORTS MEDICINE AND FITNESS (2016). The Female Athlete Triad. *Pediatrics*, *138*(2), e20160922. https://doi.org/10.1542/peds.2016-0922

Williams, N. I., Koltun, K. J., Strock, N. C. A., & De Souza, M. J. (2019). Female Athlete Triad and Relative Energy Deficiency in Sport: A Focus on Scientific Rigor. *Exercise and Sport Sciences Reviews*, *47*(4), 197–205. https://doi.org/10.1249/JES.0000000000000200

APPENDIX A: SURVEY DOCUMENTS

Item A1. The Female Athlete Triad Coalition's Recommended Screening Questions for the Female Athlete Triad

Questions
1. Do you worry about your weight or body composition?
2. Do you limit or carefully control the foods that you eat?
3. Do you try to lose weight to meet weight or image/appearance requirements in your sport?
4. Does your weight affect the way you feel about yourself?
5. Do you worry that you have lost control over how much you eat?
6. Do you make yourself vomit or use diuretics or laxatives after you eat?
7. Do you currently or have you ever suffered from an eating disorder?
8. Do you ever eat in secret?
9. What age was your first menstrual period?
10. Do you have monthly menstrual cycles?
11. How many menstrual cycles have you had in the last year?
12. Have you ever had a stress fracture?

Source: Weiss Kelly, A. K., Hecht, S., & COUNCIL ON SPORTS MEDICINE AND FITNESS (2016). The Female Athlete Triad. *Pediatrics*, *138*(2), e20160922. https://doi.org/10.1542/peds.2016-0922

Item A2. ASSQ Sleep Difficulty Score (SDS) Survey Questions

Questions
1. During the recent past, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.) a. 5 to 6 hours (4) b. 6 to 7 hours (3)

c. 7 to 8 hours (2)
d. 8 to 9 hours (1)
e. more than 9 hours (0)

3. How satisfied/dissatisfied are you with the quality of your sleep?

a. very satisfied (0)
b. somewhat satisfied (1)
c. neither satisfied nor dissatisfied (2)
d. somewhat dissatisfied (3)
e. very dissatisfied (4)

4. During the recent past, how long has it usually taken you to fall asleep each night?

a. 15 minutes or less (0)
b. 16 – 30 minutes (1)
c. 31 – 60 minutes (2)
d. longer than 60 minutes (3)

5. How often do you have trouble staying asleep?

a. none (0)
b. once or twice per week (1)
c. three or four times per week (2)
d. five to seven days per week (3)

6. During the recent past, how often have you taken medicine to help you sleep (prescribed or over-the-counter)?

a. none (0)
b. once or twice per week (1)
c. three or four times per week (2)
d. five to seven times per week (3)

Scoring Key

Add the scores from ASSQ items 1, 3, 4, 5, and 6 to get the total score. The score corresponds to the following clinical sleep problem category:

None: 0-4 Mild: 5-7 Moderate: 8-10 Severe: 11-17

Source: Bender, A. M., Lawson, D., Wethner, P., & Samuels, C. H. (2018). The Clinical Validation of the Athlete Sleep Screening Questionnaire: an Instrument to Identify Athletes that Need Further Sleep Assessment. *Sports Medicine Open, 4*(23). https://doi.org/10.1186/s40798-018-0140-5

Item A3. Perceived Stress Scale (PSS) Survey Questions

Questions
1. In the last month, how often have you been upset because of something that happened unexpectedly? 2. In the last month, how often have you felt that you were unable to control the important things in your life? 3. In the last month, how often have you felt nervous and stressed? 4. In the last month, how often have you felt confident about your ability to handle your personal problems? 5. In the last month, how often have you felt that things were going your way? 6. In the last month, how often have you found that you could not cope with all the things that you had to do? 7. In the last month, how often have you been able to control irritations in your life? 8. In the last month, how often have you felt that you were on top of things? 9. In the last month, how often have you been angered because of things that happened that were outside of your control? 10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?
Scoring Key
For each question, chose from the following options: Never: 0 Almost never: 1 Sometimes: 2 Fairly often: 3 Very often: 4 To calculate the PSS score, reverse the scores for questions 4, 5, 7, and 8 as shown below: 0 = 4 1 = 3 2 = 2 3 = 1 4 = 0 Add the scores from each item to get a total score. The score corresponds to the following perceived stress level:

Low perceived stress: 0-13 Moderate perceived stress: 14-26 High perceived stress: 27-40

Source: Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of health and social behavior*, *24*(4), 385–396.

Item A4. Patient Health Questionnare-9 (PHQ-9) Survey Questions

Questions
Over the last 2 weeks, how often have you been bothered by any of the following problems? 1. Little interest or pleasure in doing things 2. Feeling down, depressed, or hopeless 3. Trouble falling or staying asleep, or sleeping too much 4. Feeling tired or having little energy 5. Poor appetite or overeating 6. Feeling bad about yourself — or that you are a failure or have let yourself or your family down 7. Trouble concentrating on things, such as reading the newspaper or watching television 8. Moving or speaking so slowly that other people could have noticed? Or the opposite — being so fidgety or restless that you have been moving around a lot more than usual 9. Thoughts that you would be better off dead or of hurting yourself in some way If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people? Not difficult at all Somewhat difficult Very difficult Extremely difficult
Scoring Key
For each question, chose from the following options: Not at all: 0 Several days: 1 More than half the days: 2 Nearly every day: 3

Add the scores from each item to get a total score. The score corresponds to the following level of depression severity: Minimal: 1-4 Mild: 5-9 Moderate: 10-14 Moderately severe: 15-19 Severe: 20-27

Source: Kroenke, K., Spitzer, R. L., & Williams, J. B. (2001). The PHQ-9: validity of a brief depression severity measure. *Journal of general internal medicine*, *16*(9), 606–613. https://doi.org/10.1046/j.1525-1497.2001.016009606.x

APPENDIX B: IRB APPROVAL LETTER

Office *of* Research Integrity

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NOTICE OF INSTITUTIONAL REVIEW BOARD ACTION

The project below has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services regulations (45 CFR Part 46), and University Policy to ensure:

- The risks to subjects are minimized and reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.

- Any unanticipated, serious, or continuing problems encountered involving risks to subjects must be reported immediately. Problems should be reported to ORI via the Incident submission on InfoEd IRB.
- The period of approval is twelve months. An application for renewal must be submitted for projects exceeding twelve months.

PROTOCOL NUMBER: 22-1474

PROJECT TITLE: Impact of Training Volume on Female Athlete Triad Risk Score for Female Collegiate Track and Field Athletes

SCHOOL/PROGRAM: Kinesiology

RESEARCHERS: PI: Sarah Parnell

Investigators: Parnell, Sarah~Stavres, Jonathon~Graybeal, Austin~Renna, Megan~Behringer, Kylee~

IRB COMMITTEE ACTION: Approved

CATEGORY: Expedited Category

PERIOD OF APPROVAL: 09-Feb-2023 to 08-Feb-2024

Donald Sacco, Ph.D.

Institutional Review Board Chairperson