Examining RED-S Knowledge & Current Practices in Athletic Trainers and Coaches of Adolescent Female Athletes

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Relative Energy Deficiency in Sport (RED-S) has been a popular topic of discussion relating to women's health in recent years. RED-S is a syndrome that occurs when athletes don't get enough fuel to support energy demands causing long- and short-term consequences on health and sport performance. Recently, researchers have investigated the knowledge levels of RED-S in athletics, however research has focused on collegiate levels rather than younger athletes. The purpose of this study was to examine the knowledge and confidence levels in stakeholders, as well as determine current practices and policies surrounding RED-S in athletics. This study utilized a cross-sectional, survey-based design. Forty-seven completed responses from coaches (n=15) and athletic trainers (ATs) (n=32) were analyzed. The responses of coaches and ATs were analyzed separately to determine differences in knowledge levels and education between occupations. The average age of the participants was 37.6 +/- 11.8 years, consisting of 28 females, 18 males, and 1 transgender male. The initial awareness of RED-S in survey participants encompassed 74.5% of participants having not heard of RED-S previously. The knowledge section of the survey consisted of 15 questions to test the current knowledge levels regarding RED-S. The average score for ATs was 11.4 +/- 1.6 and 11.2 +/- 2.5 for coaches, out of 15. Additionally, the confidence levels after each knowledge question resulted in an average confidence of 2.4 +/- 0.4 for ATs and 1.8 +/-0.5 for coaches, scored out of 4. All coaches and 6.3% of ATs said they are not aware of a RED-S educational program for athletes. Similarly, all coaches and 81.3% of ATs have not received

education of their own regarding RED-S. All coaches and 96.2% of ATs noted that their workplace does not have a policy regarding athletes suffering from one or more aspects of RED-S. Most participants indicated that they would like to learn more about RED-S. A limitation of this study was the small sample size, however, future research utilizing an increased sample size may produce different results. Overall, continued research regarding educational programs on RED-S is necessary to help minimize the occurrence of RED-S in female athletes.

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1.0 Introduction

High school girls' athletic participation increase from 295,000 in 1971 to 2.8 million in 2022-2003, seeing a positive change of over 840%.[1] It is widely acknowledged that regular participation in sports and physical activity has a positive effect on both physical and psychological health including improved self-esteem, body image, enhanced social interactions and higher bone mineral density.[2],[3] However, female athletes may have adverse health effects resulting from trying to reach a certain level of competition or achieving a particularly lean physique. This may result in an energy deficit putting them at risk for developing the Female Athlete Triad or RED-S.[4] The "Female Athlete Triad" emerged in the 1990s as researches understood more about how the female body adapts to sports training.[5] The Female Athlete Triad was initially described in 1993 and defined in 1997 by The American College of Sports Medicine (ACSM) as a syndrome of three disorders: disordered eating, amenorrhea, and osteoporosis.[6],[7] The ACSM held a consensus conference at this time focusing on this definition and strategizing on how to approach this emerging syndrome.[7] Educational materials and guidelines along with a position stand paper by the ACSM stating more research needs to be done and more individuals need to be educated on the topic were results of this consensus conference.[7] In 2007 it was discovered that the current triad components did not identify all women "at risk" and more appropriate criteria such as exercise-related menstrual alterations, disordered eating and osteopenia were suggested.[8] Burrows et al., found that 22% of the females in their study were considered at risk for health problems using the original criteria, but an additional 33% were at risk using broader terms such as menstrual irregularities and osteopenia.[9] Following this in 2007, three new components were

defined: low energy availability (LEA), menstrual dysfunction, and changes in bone mineral density.[10],[11],[6],[7] This definition gave the understanding of the spectrum ranging from an overall healthy athlete to the opposite end of the spectrum where menstrual dysfunction, low energy availability (EA), and osteoporosis occurs.[12] In the last 10 years, a broader concept of RED-S emerged.[5] In 2014 after the International Olympic Committee (IOC) meeting, the Female Athlete Triad was changed to RED-S, meeting the need for a holistic approach that is supported by scientific research.[13] RED-S refers to impaired physiological function affecting metabolic rate, menstrual function, bone health, immunity, protein synthesis, cardiovascular health resulting from relative energy deficiency.[12] Even more importantly, they now understood this syndrome does not only effect 'female athletes' but can occur in men as well. At this point, science moved forward to understand energy deficiency is the key to the disruption of several physiological functions including reproduction, bone health, growth and development, cardiovascular, GI, metabolic, physiological, leading to the consequences for performance and health of the athlete in general. [6]

The prevalence of RED-S is a concern, with recent studies estimating rates ranging from 22% to 58%, with a high percentage of endurance athletes (60%) experiencing menstrual disturbances.[4],[14] This is concerning due to the fact that if athletes develop LEA it can lead to RED-S which has severe consequences if not treated.[5] Specifically for an athlete it will not only effect their overall health but it can compromise training adaptations and performance capacity jeopardizing their future within the sport.[5] Without early intervention the athletes have an increased susceptibility to stress fractures, infertility, osteoporosis, impaired endothelial function, and suppressed immune function.[13] This is why it is critical that an athlete's support team recognized the behaviors that may indicated the evolution of RED-S.[5] The goal should be to help the athlete reach their full potential in the sport while also protecting their health.

Coaches typically have control over the athletes' training schedules and energetic demands which is why they are likely to be optimal individuals able to identify athletes at risk of long-term LEA.[15] Coaches have the potential to provide a constructive role in influencing the athletes' attitudes, belief, and knowledge of RED-S. However, research suggests that athletes, coaches, physicians, and other adults involved with female athletes lack a significant amount of knowledge on this topic.[16],[14] In a study conducted by Lodge et al., 69% of female cross-country athletes, 52% of coaches, and 51% of athletic trainers reported never receiving education on the Female Athlete Triad or RED-S from their athletic department.[17] Therefore, it isn't surprising that in another investigation of 123 high school coaches, only 24% had heard of the Triad/RED-S and only 14% were able to correctly identify all components.[17] Other studies show that those in the stakeholder role may have heard of the syndrome but were not fully educated on the topic. In a 2018 study, Kroshus et al., reported that respondents on an online survey showed 99% of collegiate Ats had heard of the triad, and 33% had heard of RED-S, but only 13.33% correctly identified energy imbalance or energy deficiency as a component of the triad.[18] These results may have to do with the fact that recent reports indicate that only 7% of the International Olympic Sport Federations endorse some form of educational material specifically related to RED-S. [13] These results are of concern because it may result in misinformation passed on to female athletes who may already be unaware of the consequence of inadequate energy intake.

1.1 Female Athlete Triad/RED-S

From the time the Female Athlete Triad was first defined in 1992 by ACSM to the most recent definition in 2022, the scope of the syndrome has been broadened. In the scope of this paper, we will be referring to the term 'RED-S' as it allows for a more comprehensive understanding of the syndrome. We will be referring to the previously stated definition, impaired physiological function affecting metabolic rate, menstrual function, bone health, immunity, protein synthesis, cardiovascular health resulting from relative energy deficiency.[12] The year 2007 was the first time we understood the relationship between energy availability (EA), menstrual function and bone health.[12] These scientific findings and clinical experience showed that the etiological factor causing the triad is an energy deficiency relative to the balance between energy intake (EI) and energy expenditure required to maintain homeostasis, health, and activities of daily living.[12] There is a cost that can come with these energy mismatches that can effect menstrual dysfunction, bone mineral density, and ultimately lead to poor performance. Among the causes of LEA, not getting enough EI can be caused by disordered eating (DE) where the prevalence of DE is about 20% and 13% among adult and adolescent female elite athletes, and 8% and 3% in adult and adolescent male elite athletes.[12],[19] Similar to the energy continuum, there is a disordered eating continuum starting with healthy eating behaviors and ending with clinical eating disorders, abnormal eating behaviors, etc.[12] LEA caused from disordered eating, too much energy expenditure, or not enough energy intake, etc. can cause an irregular menstrual cycle. Eumenorrhea is defined as a regular menstrual cycle occurring at intervals between 21 and 35 days.[20],[21] Any form of amenorrhea (primary or secondary) is the absence of menarche/menstrual cycle. Low EA, inadequate body fat stores, abnormal levels of hormones, and exercise stress can all effect an athlete's menstrual

cycle.[12] RED-S has adverse health consequences for bone, resulting from LEA alone or the occurrence of LEA and menstrual dysfunction.[12] Changes in bone structure can lead to an increased risk of stress fractures, some being high-risk stress fractures, and can have serious long-term consequences.[12] All of these factors together can affect athletic performance through functional impairments resulting from LEA.[12] In the following sections provides more detail about how all of this occurs and the damaging effects it may have on athletes, increasing awareness on why it so important to educate on this topic.

1.1.2 Low Energy Availability (LEA)

Energy availability (EA) is a human nutritional concept defined as the difference between daily energy intake (EI) – exercise energy expenditure (EEE) and expressed in relation to fat-free mass (FFM).[22] Low Energy Availability (LEA) can occur during intense training periods, competitions, or in sports with high energy expenditure or involving weight restrictions.[23] LEA can lead to increased detrimental health outcomes in athletes and has been termed as RED-S defined by a 2014 International Olympic Committee Medical Commission.[12] In healthy adults, a value of 45 kcal/kg FFM/day equates energy balance.[12] RED-S is the consequence of a frequently prevalent LEA in athletes, <30 kcal/kg FFM/day.[5] In female athletes, EA < 30 kcal/kg FFM/day is known as clinical LEA whereas EA between 30 and 45 kcal/kg FFM/day is subclinical.[4] LEA can occur for different amounts of time and can change the severity and consequences if it occurs for a long period of time. Stellingwerff et al., has suggested 1) short-term LEA = a few days to ~1 month, 2) medium-term LEA = ~1 month to <3 months, and 3) long-term LEA = >3 months.[24] A

study investigating EA in female and male athletes from a mix of sports reported clinical LEA in 58% of male endurance athletes (n = 22) compared with 51% of female endurance athletes (n=18).[14] A measurement of resting metabolic rate via indirect calorimetry may provide confirmation of suppressed metabolism secondary to LEA.[12] In a healthy athlete, the caloric intake is sufficient for sports energy needs and their bodies physiological functions. This creates an energy balance to allow for energy availability, bone metabolism, and normal menstrual cycle.[6] However, if an imbalance occurs from LEA it can lead to multisystemic dysregulation only allow for essential functions of the body to occur.[6] This imbalance can occur from a restrictive diet, eating disorders, or long periods of energy expenditure.[6] Due to the nature of LEA, we typically see this occur in a large number of high-performance athletes.[6] For some athletes, restrictive EI and excessive EEE behaviors occur following unfavorable childhood or young adult experiences such as bullying at school, diet culture, social pressure, negative comments and more. Individuals with these previous experiences may face severe anxiety, depression, and for some, suicidality thoughts after being asked to change their poor eating and exercise habits.[25] These results align with those found by Ackerman et al., noting a 2.4 times increased likelihood of psychological disorders in athletes with LEA compared to those with adequate EA.[25],[26] In addition, depending on the sport there can be other factors that may increase the likelihood of LEA in the athlete. These factors include dieting to enhance performance, personality factors, pressure to lose weight, frequent weight cycling, early start of sport-specific training, overtraining, recurrent and non-healing injuries, and inappropriate coaching behavior.[12] Optimal EA is crucial for health and performance however, periods of subclinical LEA may be necessary to reach desired physique goals for certain sports. Any effort from an athlete to reach a desired physique for performance needs to account for the physiological demands in order to avoid compromising health and

performance of the athlete.[13],[27] The ideal EA should support the basic functions that allow a healthy state and adequate performance.[6]

1.1.3 Eating Disorders

Disordered eating underpins many LEA cases often leading to severe chronic outcomes such as amenorrhea and osteoporosis.[5] Athletes can voluntarily participate in disordered eating behaviors for reasons related to their sport or their personal views of themselves.[5] Athletes can also unknowingly participate due to not finding time to eat due to busy schedules, high training demands without enough fuel, or general lack of nutritional knowledge.[5]The disordered eating (DE) continuum starts with appropriate eating and exercise behaviors to dieting, restrictive eating and abnormal eating behavior.[12],[28],[29] The continuum ends with clinical eating disorders (ED), abnormal eating behaviors, distorted body image, weight fluctuations and variable athletic performance.[12],[28] DE, or subclinical eating disorders, include a range of irregular eating behaviors, such as restriction, binging, taking laxatives, etc. but do not meet the diagnostic criteria for an eating disorder even though they include similar symptoms and can lead to LEA.[30],[31] Studies have shown the prevalence of DE among female collegiate athletes to be approximately 14-25%.[31] DE is believed to initiate clinical ED since they can have multiple symptoms that don't allow for one treatment option.[32] Clinical eating disorders, such as anorexia nervosa and bulimia nervosa meet specific diagnostic criteria in the *Diagnostic and Statistical Manual of Mental Disorders*, 5th edition (DSM-5) published by the American Psychiatric Association. Anorexia nervosa can be classified as a restricting type or binge-eating/purging type and involves restricting calorie intake resulting in a low body weight, an intense fear of gaining weight, and a distorted

view of body weight and shape.[33] In a study of 425 female collegiate athletes, 3.3% reported a clinical diagnosis of anorexia nervosa.[34] Diagnostic criteria for bulimia nervosa includes: binge eating, compensating for binging by purging, fasting, or excessively exercising; practicing these behaviors once a week for three months; and basing their self-esteem on weight and body shape.[35] The gold standard for the diagnosis of Eds is the Eating Disorder Examination Interview (EDE-16), where the interviewers are trained in the technique of what to investigate within the interview.[12]However, athletes tend to under-report disordered eating symptoms on questionnaires, it is ideal to look at symptoms like sudden weight changes, hair loss, irregular or missed menses, and stress fractures to get the full picture.[5] The pathogenesis of eating disorders is multifactorial with cultural, familial, individual, and genetic factors playing a role.[12],[28] Athletes may be influenced by societal or community pressure to strive for perfection, strong achievement orientation, competition, dieting at an early age, and pressure from coaches and sport regulations.[12],[28] Aesthetic sports have even more pressure from coaches that can be associated with the psychological pressure to diet. This rules into the belief that judges are influenced by the body composition of competing athletes.[28],[8] Sundgot-Borget et al., has identified personality factors, early start to sport-specific training, overtraining, and inappropriate coaching behavior as being linked to development of DE/ED.[12],[28] Some athletes with DE/ED practice extreme weight control methods such as fasting, vomiting, diuretic and laxative abuse.[12] With these practices comes consequences such as dehydration, electrolyte imbalances, gastrointestinal problems, and many more.[12] Typically EDs start to develop among adolescents at the age of about 14-17 years when the athletes begin to focus on a particular sport.[28],[8] Early attitudes on ideal body types and DE have been reported in high school runners.[4] A separate report from this population identified the belief that “being thinner leads to faster running performances” in over half of the girls and

two thirds of the boys.[36] Watching for weight manipulation among these young athletes in particularly important because it may delay pubertal development, growth, and bone accrual as well as increase this likelihood of developing ED/DEs.[10],[11],[13] Ideally weight manipulation for athletes younger than 18 should be avoided.[4]The prevalence of ED/DE also differs significantly among sports.[12] Weight-sensitive sports and sports with an emphasis on leanness have the highest prevalence of disordered eating and eating disorders.[37] Up to 94% of elite athletes in weight sensitive sports report dieting and use of extreme weight control methods to achieve a specific weight prior to competition.[28],[38] DE/ED is an important area to monitor for athletes, RED-S can have some ED/DE as an early clinical manifestation causing energy deficiency in the first place.[28] Being able to notice this early signs and symptoms can help us prevent the athlete from developing RED-S at a later stage.

1.1.4 Menstrual Function

Menstrual function can range from eumenorrhea (normal menses) to amenorrhea (absence of menses.[5],[12],[23] One of the most severe consequences of LEA in female athletes is the menstrual dysfunction that manifests, causing the most evident and severe forms like amenorrhea or oligomenorrhea.[5],[39] Cabre et al, have provided some key terms that can help us understand the scope of the menstrual cycle better.[5] (1) Eumenorrhea (normal menses) is defined as women who experience menstrual cycle lengths $\geq$ 21 days and $\leq$ 35 days, resulting in 9 or more consecutive periods per year, plus recent evidence of a LH surge, correct hormonal profile, and non EHC use in the past 3 months.[5],[12] (2) Oligomenorrhea is defined as women who experience fewer than 9 menstrual cycles per year or menstrual cycle length that is > 35 days.[5],[12] (3) Primary

amenorrhea (absence of menses) is defined as the failure of a girl to reach menarche by age 15 years when the development of secondary sexual characteristics is evident, or by age 14 when no secondary sexual characteristics are present.[5],[12],[23] Primary amenorrhea is observed to be the highest (22%) in cheerleading, diving, and gymnastics.[12],[34] (4) Secondary amenorrhea is defined as the absence of ≥ 3 consecutive menstrual periods in a non-pregnant woman who has a past normal menses history.[5],[12] Small studies found the prevalence of secondary amenorrhea to be as high as 69% in dancers and 65% in long-distance runners.[40] Similar studies have shown that menstrual irregularity is associated with low bone mineral density (BMD) in eliter female athletes older than 20 years of age, most likely as a result of secondary amenorrhea.[41] Another less discussed term is functional hypothalamic amenorrhea which refers to the absence of menses due to low energy availability.[10] In female track and field athletes, functional hypothalamic amenorrhea has been reported in 60% of elite middle and long distance athletes and 23% in elite sprinters.[45] LEA can cause menstrual irregularities due to change in hormone production ultimately leading to an anovulatory state where the athlete no longer has an ideal menstrual cycle.[5] Low energy availability causes the body to suppress reproductive function in order to prevent pregnancy.[40] Since the body has limited energy in these states, they must choose where it is essential for the energy to go. The body needs to disperse energy to areas where it is needed to stay alive, the reproductive system is not necessary to live. These menstrual disturbances can be determined by measuring hormone levels throughout the entire menstrual cycle.[42] Measurement of daily hormone concentrations among sedentary and exercising women found a 4.2% and 50% prevalence rate of subclinical menstrual disorders.[42] Subclinical menstrual disorders are just the start of what these athletes develop after years of high-intensity sports and the long-term menstrual disorders they develop are much more damaging. The prevalence of the menstrual disorders varies

widely depending on the female athlete's sport However, it is reported to be as high as 69% in weight-sensitive sports.[28] Another study found prevalence rates estimated to affect 20% of exercising females, 44% of ballet dancers, and 51% of female endurance runners.[43]Even with these high occurrence rates, it is known that female athletes underreport menstrual cycle disorders, with a prevalence of up to 40% in some studies.[39] Similarly, Miller et al., found that 22% of athletes in lean-build sports would not report amenorrhea.[44] Verhoef et al. conducted a study asking female athletes about the main reasons for not reporting amenorrhea. The top five reasons for not reported amenorrhea reported from the interviews were normalizing of amenorrhea within surroundings, the absence of menstruation is not perceived as a problem by athletes, shame and taboo, prioritizing performance, and denial.[39] Females tend to underreport when menstrual cycle irregularities are linked with an increased risk for cardiovascular (CV) disease, arterial thickness, creating anxiety, causing an emotional impact, and an altered perception of self-normalcy.[45],[46] Assessment of irregular menses should include an assessment of menstrual history including age of menarche, regularity of menses, use of medications, the presence of other health issues and a family menstrual history.[45] Hormonal contraceptives are often suggested for athletes with menstrual irregularity, however they may interfere with the ability to create a regular cycle and mask other symptoms that are causing the irregularity.[41] The outcome of the hormonal contraceptives can cause the athlete to misinterpret the withdrawal bleed as part of the menstrual cycle.[41] Returning an athlete to a eumenorrheic state after amenorrhea depends on improving their low energy availability and inducing weight gain.[40]

1.1.5 Bone Mineral Density

Bone mineral density (BMD) ranges from optimal bone density to osteoporosis.[10] BMD assessment should be considered when menstrual dysfunction, low BMI, or significant weight loss, in the presence of minor stress/post-traumatic fracture, or in the event of an eating disorder.[6] Bone mineral density, measured by dual energy x-ray absorptiometry (DXA), is grams of bone mineral content per area.[47] It is suggested that in athletes with low EA, disordered eating, ED, or amenorrhea of over 6 months, BMD should be measured by DXA.[12] The recommended interval to reassess BMD via DXA scan for athletes at risk, or who are being treated for low BMD is 12 months in adults and a minimum of 6 months in adolescents.[12] An athlete's BMD reflects their cumulative history of energy availability, menstrual status, and genetics combined with exposure to nutritional, behavioral, and environmental factors.[10] A low BMD score is between -1 and -1.9 with risk factors.[12],[10] As athletes in weight bearing sports should have 5-15% higher BMD than non-athletes, a BMD score < -1.0 SD warrants further attention. In the athlete population, low BMD is defined as a z-score between -1.0 and -2.0 SD, together with a history of nutritional deficiencies, hypoestrogenism, stress fracture or other secondary clinical risk factors for fracture.[10],[48],[49] A value below -2.0 is considered as osteoporosis with the presence of secondary clinical risk factors.[12],[10] These secondary clinical risk factors include chronic malnutrition, eating disorders, hypogonadism, glucocorticoid exposure, and previous fractures.[10] Osteoporosis is defined as "a skeletal disorder characterized by compromised bone strength predisposing a person to an increased risk of fracture."[10] The onset of amenorrhea doesn't immediately cause osteoporosis, but skeletal demineralization causes their BMD to move further down in that direction.[10] In amenorrheic athletes you'll see a decrease in BMD, volumetric bone density, and

strength associated with abnormal bone microarchitecture.[6] The bones of athletes with log-term, chronic amenorrhea don't benefit the same from the osteogenic effects of exercise.[50] Even in weight-bearing sports that would benefit BMD, negative changes are described mainly when associated with restrictive eating habits and low weight.[51],[52] Studies have reported disordered eating patterns in up to 62% of teenage amenorrheic athletes, and lower BMD in these athletes compared to those with a regular menstrual cycle and non-athletic controls.[9] Adolescent athletes with RED-S may encounter high-risk stress fractures that can have serious long term consequences and face bone loss that may be irreversible.[12],[53],[54] The consequences of long-term LEA are particularly severe for the adolescent athletes since the imbalance of bone remodeling hinders achievement of high peak bone mass.[28] Bone remodeling, the process of bone resorption and formation, occurs continuously throughout life.[47] According to Nichols et al., bone remodeling is affected by three factors: (1) hormonal status, (2) weight-bearing physical activity, (3) dietary intake (mostly calcium).[47] Bone development is negatively affected by LEA, causing a decrease in different elements that inhibit bone growth by decreasing growth and stimulation of osteoclasts and osteoblasts.[6] Decrease in bone formation and bone turnover are the main consequences of changes in bone metabolism.[6] Bennell et al., performed a 12 month longitudinal cohort study comparing bone mass and bone turnover in power athletes, endurance athletes, and non-athlete controls.[55] Compared with other disciplines or healthy controls, distance runners may have lower BMD at lumbar spine but higher BMD at weight-bearing sites. 53% of the endurance athletes revealed a history of oligo- and/or amenorrhea compared with only 21% of controls.[55] The history of menstrual cycle, ED, DE, and LEA can all negatively impact the BMD of an athlete.

1.2 Identifying RED-S Prevalence

There have been a multitude of studies examining the prevalence of the Female Athlete Triad and/or RED-S, however there are many different definitions from various sources making it hard to identify the true prevalence. Prevalence of the triad based solely on high school athletes is estimated to range from 0% to 16% for all three components, 3% to 27% for two or more components, and 16% to 60% for one of the components.[56] They found similar results based in collegiate athletes where it was more likely for them to suffer from one or two components of the triad compared to all three.[57] The prevalence of MD and DE occurring together was the highest at 2.7%-50.0%.[56] These large variations in the prevalence estimates are the result of multiple different definitions of the components of the triad and differences in methodology of the various research studies.[56] Concerns exist relating to the methods of detection use in reports and the lack of appropriate definitions and criteria used for each triad component.[56] When comparing the presentation of all three triad conditions to estimates of individuals presenting one or two of the triad disorders, there are large discrepancies that exist. ACSM defined the disorder as an interrelationship among energy availability, menstrual function, and bone mineral density which is consistent with other studies and definitions.[10] Although in similar prevalence studies like one conducted by Reel, SooHoo, and Doetsch, the third component was described as musculoskeletal injuries.[57] A study conducted by Reel et al. included 451 NCAA Division I female collegiate athletes and found five athletes with all three components of the triad/RED-S.[57] However they did not study BMD. The researchers used the occurrence of stress fractures and muscle injuries to determine the third component of the triad, defined as musculoskeletal injuries.[57] Similarly, there are many studies that examine the prevalence of disordered eating and clinical eating disorders,

but only one examined the prevalence of low energy availability.[56],[58] Hoch et al., determined the prevalence of the Female Athlete Triad among high school female athletes compared to a non-athlete control group.[58] Results showed that both the athletes and controls, 78% and 65% respectively, met the criteria for one or more of the components of RED-S. They also found that 2/80 participants matched having all three components (LEA, MD, and low BMD) of the triad, one being an athlete and the other being a non-athlete control.[26] The LEA focus of their study showed that 36% of athletes had LEA and 6% of those athletes had EA less than 30 kcal/kg/LBM.[58] Another result from Hoch et al., showed that menstrual dysfunction was self-reported in 54% of the athletes compared to 21% of the sedentary controls.[58] There is concern when it comes to the self-report method of menstrual history because it only indicates that the MD is readily apparent to women by the absence and/or irregular intervals of menses.[56] De Souza et al., used daily urinary reproductive hormonal analyses resulting in approx. half of exercising women presenting with subclinical MD despite experiencing cycles of regular intermenstrual intervals and seemingly "normal" menstrual cycles.[42],[56] Subclinical MD has only been assessed in a few studies, but there is evidence suggesting that approximately half of exercising women experience subclinical MD.[56] As far as clinical MD concerns, the earliest prevalence estimated were seen predominantly in the most at risk populations such as runners and dancers.[56] Triad prevalence reports also include clinical eating disorders and/or DE as a component of the syndrome.[56] Previous findings show a higher proportion, up to 70% of clinical eating disorders and/or DE are present in elite female athletes compared with controls.[56] Eating disorders and DE have a large impact on BMD, however the prevalence of low BMD in female athletes is not as well documented. The occurrence of recent technological advancements in measurement tools and inconsistency in criteria used to identify low BMD has made it difficult to identify true

prevalence.[56] Although, it has been observed that the prevalence of low BMD in amenorrheic athletes ranged from 1.4% to 50.0% and estimates of osteoporosis is lower (0%-13.0%).[56] The prevalence of all three triad components previously discussed (DE, MD, and low BMD) have been identified to occur more often in lean-based sports. The prevalence in lean sport athletes ranged from 1.5% to 6.7% versus non-lean sport athletes where the prevalence ranged from 0% to 2.0%.[56] Lean sport athletes demonstrated a higher prevalence rate in both MD and low BMD alone as well compared to non-lean sport athletes.[21] However, DE was similar between groups where lean sport athletes ranged from 1.5% - 89.2% and non-lean sport athletes ranged from 0.0% - 89.2%.[56] A major area that prevalence studies lack is in younger populations of exercising women, where we need to research in order to bring awareness to the number of young girls at risk for RED-S.

1.2.1 Risks and Consequences of RED-S

At the time that the Female Athlete Triad was defined in the 1990s, all female adolescent athletes were considered at risk with only some adult female athletes.[7] The 1997 ACSM position at the time identified all physically active females as being at risk of the Female Athlete Triad.[59] In 2018 Mountjoy et al., created a RED-S model describing ten health outcomes and ten potential performance effects resulting from LEA in athletes.[13] The ten health outcomes include: Immunological, Menstrual Function, Bone health, Endocrine, Metabolic, Hematological, Growth and Development, Psychological, Cardiovascular, Gastrointestinal.[13] The health consequences were expanded from the concept of the Female Athlete Triad to broaden the range of outcomes and also the application to male athletes.[13] The ten potential performance consequences include:

Decreased endurance performance, Increased injury risk, Decreased training response, Impaired judgement, Decreased coordination, Decreased concentration, Irritability, Depression, Decreased glycogen stores, Decreased muscle strength.[13] It was acknowledged that non-athletes may experience the disorders of the triad, but athletes were considered to be at an increased risk.[7] Athletes in endurance or appearance sports who felt pressured to succeed in their sport and also to maintain a lean physique were also at an increased risk.[7] They identified risk factors as: sports that focus on a lean build, such as gymnastics and distance running, or sports that require revealing clothing, such as swimming and diving.[59]

Developing LEA and RED-S compromises training adaptations, performance capacity, and health in athletes.[5] Health concerns associated with longstanding LEA and RED-S include gastrointestinal, CV dysfunction, hypogonadotropic hypogonadism, psychological sequelae, and compromised bone health, all of which can lead to impaired training adaptations in the athlete, leading to increased risk of injury or illness, diminished adaptation to training, and sports performance being compromised.[5],[12] For example, Vanheest et al., showed diminished adaptation to training was demonstrated in elite female swimmers over a 12-week training program, reporting an 8.2% increase and 9.8% decrease in time trial performance by adequate EA and LEA groups, respectively.[60] Long-term LEA causes metabolic and physiological adaptations in order to reduce total energy expenditure to prevent further weight loss and allow the body to survive.[4] This causes the body to obtain a new energy balance steady state, where it is not working at its full energy potential.[4] In some cases, an athlete may be weight stable and not have an excessively low body mass or body fat levels yet to cause impaired physiological function due to LEA.[4] We have seen metabolic adaptations for LEA in both female and male middle- and long-distance athletes with decreased resting metabolic rate (RMR) compares to athletes with adequate

energy intake.[61],[62] As we discussed previously, inadequate body fat stores, exercise stress, and abnormal hormone levels may contribute to menstrual dysfunction in athletes.[63] Similarly, LEA has demonstrated impairments in female reproductive function in both short-term and long-term exposures.[63] The reduced sex hormones and associated reduced fertility resulting from LEA is seen in both male and female athletes.[4] The presence of menstrual dysfunction, EDs/DE, and low BMD can also all be related to a poor recovery from bone stress injuries.[64] They may also cause poor health recovery overall making getting sick more difficult to recover from than it should be. This was shown when LEA was reported as the strongest predictor of illness in Olympic athletes before the 2016 Rio Olympic Games with FHA athletes demonstrating higher frequencies of upper respiratory infection symptomology and suppressed immune function markers.[65],[66] Athletes should typically be healthier in these areas and this is where we see the true effects of LEA on the body overall.

The periodic health examination and the preparticipation physical evaluation (PPE) include relevant questions that may be helpful for early detection of RED-S.[12] The Low Energy Availability in Females Questionnaire (LEAF-Q) was developed as a brief questionnaire on physiological symptoms linked to energy deficiency.[12],[61] The LEAF-Q is a brief questionnaire focusing on self-reported physiological symptoms linked to persistent energy deficiency, with or without DE/ED, which can be routinely used to identify individuals at risk for RED-S.[12] Limitations of this questionnaire include the need for the questions to be varied according to athletic populations needed and the efficacy of self-reported questionnaires.[12] PPE forms are designed to screen for injuries, illnesses, or other factors that can increase an athlete's risk for injury or illness.[12] At a collegiate level, PPE forms are intended to identify female collegiate athletes at risk for RED-S, however, past studies have determined that PPE forms used by NCAA

Division I universities were found to be ineffective.[67] The Female Athlete Triad coalition recommends 12 questions to be on the PPE forms in order to screen for RED-S, but more than half of the universities in these studies used PPE forms with less than 50% of these recommendations.[67] Along with that PPE screening was required at all of these universities, but only 32% required annual screening.[67] Therefore, athletes may be returning to their sport at risk but have not been identified. The RED-S clinical assessment tool (RED-S CAT) can also be used to help clinicians screen for RED-S and the management of return to play decisions.[12] An athlete that is considered being at high-risk to return to sport participation may have anorexia nervosa or other serious eating disorder, have other psychological or psychological conditions related to LEA, extreme weight loss techniques leading to dehydration and other life-threatening conditions (not recommended to be cleared to return to play).[12] Reevaluation of an athlete's risk assessment is recommended in intervals of 1-3 months, depending on the scenario and the severity of the disorder.[12] Our first step towards helping athletes get better is education and engagement of athletes and coaches; increase our understanding of health and performance effects of RED-S.[12]

1.2.2 Prevention and Treatment of RED-S

Education is a crucial component to help prevent RED-S from affecting an athletes' life, yet this involves not only the athlete but also parents, coaches, athletic trainers, and physicians. Physicians should advocate for the incorporation of RED-S educational programs in sports governing bodies everywhere, as well as promote positive guideline changes in at-risk sports.[5] This helps ensure for early detection which is the best-case scenario to improve performance and prevent long-term health consequences.[12] Clinicians and coaching staff should screen all athletes

before the start of the season.[5] Screening for RED-S should start with a detailed personal history, including questions pertaining to physical activity, past and current injuries, eating and diet behaviors, and menstrual cycle history.[12] Screening for RED-S should occurring during the annual periodic health examination (PHE) and at other points during the year when an athlete presents with ED/DE, weight loss, lack of normal growth and development, menstrual dysfunction, recurrent injuries and illnesses, decreased performance or mood changes.[12] Monitoring individual athletes during periodic health examinations can help aid in identifying symptoms of overtraining syndrome and RED-S risk.[5] The preparticipation screening evaluation (PPE) is a commonly used tool that helps direct questions towards the development of RED-S and can be used during PHE for more detailed analysis.[4] The PPE can help screen and address LEA and mental health risk among athletes such as perfectionism, athletic identity, compulsive exercise, social or sport specific weight pressures, injuries or displaying ED/DE.[13],[68] Traditionally, the PPE developed by the ACSM has been utilized to identify disordered eating behaviors.[11],[69] For example, if an eating disorder inventory questionnaire is used where a drive for thinness score is high, it can be a marker for LEA.[4] The LEA in Females Questionnaire (LEAF-Q) can also be used to identify females at risk for long-term LEA with more serious consequences. The last assessment tool is known as the RED-S CAT, which is utilized for the evaluation of athletes or active individuals who are suspected of having LEA and acts as a guide for clinicians and coaches for return-to-play decisions.[12] The IOC has also developed a RED-S clinical assessment tool for return to play, however it has not been quite validated yet.[12]

Management of RED-S and return-to-play decisions should be made by a multidisciplinary team of sports professionals using the appropriate models as guides.[5] A collaborative team approach is often needed for treatment including a sport medicine physician, a trained sports

dietitian, and a sport physiologist experienced in safe body composition management.[4] If ED/DE is a part of the symptomology, inclusion of a psychologist specialized in ED/DE in athletes would also be helpful and in some cases required.[4]Athletes who are presenting with severe EDs and medically unstable with cardiac arrythmia, electrolyte imbalance, or hypotension should receive intensive in-patient treatment.[4] The sports team dietitian should be involved with the interdisciplinary outpatient care for athletes with eating disorders.[5] Treatments can differ depending on what symptoms are displaying, whether it is one of them or all. Treatments for LEA is to increase the energy intake (EI), reduce exercise, or a combination of both.[12] Eating plans can consist of increasing current EI by ~300-600 kcal/day and addressing suboptimal practices related to managing energy expenditure, dietary composition and food-relate stress.[12] Treatment for LEA with menstrual dysfunction present is to induce weight gain, as it is the strongest predictor of recovery of normal menstrual function.[12] Oral contraceptives may mask and delay treatment of LEA, menstrual dysfunction and perpetuate bone loss.[12],[70] The utilization of the combined oral contraceptive pill for treatment is not recommended, in cases of low BMD it does not help reduce the risk of stress fractures or improve bone health in athletes.[70] Therefore, the treatment strategies for optimizing bone health actually parallel those used for anorexia treatment.[12] The athlete should be provided with programs of high-impact loading and resistance training for at least 2-3 days/week for athletes in non-weight bearing sports and/or those with decreased BMD.[12],[10] They should also include 1500 mg/day of calcium through dietary sources with supplementation if required.[12],[71] If there are presentations of a psychological sequelae the athlete should receive treatment by a mental health professional knowledgeable about the management of ED in athletes.[12] They can then be treated with cognitive behavioral therapy, dialectical behavior therapy or family-based therapy.[12] There may be a multitude of problems to be addressed

including depression, anxiety and other psychological problems.[12] Professional nutritional counseling can be useful to help track athletes focus on optimal energy and nutrient availability during training, competition, specific physical requirements and to prevent injury/illness.[72] In sports where physical appearance is important, times of intentional body modifications should ensure professional counseling with a time-limited nutritional treatment plan with safe and effective guidelines to establish adequate EA during weight modifications.[72] Having the ability to work with athletes one-on-one to promote necessary micro- and macronutrient consumption, timing of food/meals, supplement choices, and establishing positive dietary habits is also imperative.[72],[73]

1.3 Female Athlete Triad Knowledge

There are minimal existing studies focusing on knowledge of the Female Athlete Triad/RED-S, nor is there much research on female athletes' health in general. Most knowledge studies are focused on the collegiate level involving sports like cross-country, gymnastics, and dance. Lodge et al., assessed the knowledge of the triad/RED-S across 275 cross-country athletes, 55 collegiate cross-country coaches, and 30 Ats working with cross-country teams.[17] 69% of the female cross-country athletes indicated they had not received education on the triad and RED-S from their athletic departments.[17] These results are similar to 52% of coaches who also did not receive education on the triad/RED-S.[17] In a study conducted by Pantano et al., they survey 123

high school coaches, where only 24% had heard of the triad and 14% were able to correctly identify all components.[74] There were no significant differences between the gender and the coaches ability to name all three triad components.[47] Additionally, more than 85% of coaches said they would not know how to recognize or intervene if signs and symptoms were present.[74] This is striking due to the fact that these coaches were coaching for 6-10 years and coached female athletes 75-100% of the time.[74] Lodge et al, identified that 51% of ATs denoted not receiving education the triad/RES-S from their athletic department as well.[17] Kroshus et al., reported that 99% of collegiate athletic trainer respondents to an online survey had heard of the triad, and 33% had heard of RED-S.[18] However, only 13.33% correctly identified energy imbalance or energy deficiency as a component.[18] These findings demonstrate the inability of ATs to identify energy deficiency as a component even though it is the center of the RED-S model leading to several other health and performance consequences.[18] Tosi et al., conducted a study with 712 participants including 60% figure skaters, 28% dancers, 12% runners where only 12% of the participants had heard of the triad.[75] There was a higher proportion of runners compared to figure skaters and dancers who had high knowledge of the triad (16% v. 5-6%).[75] But, 60% of the athletes were identified as being at risk for RED-S, 25% skipped a period for 3 or more months and 34% had a history of stress fractures or shin splints.[75] The study found that overall less than 10% of survey participants had high knowledge of RED-S and risk for developing RED-S was prevalent in nearly 2/3 of the participants.[75]

Miller et al., conducted a similar study but focusing on female exercisers in general, rather than a specific sport population.[44] They focused on surveying 180 female exercisers and found that only 10% were able to name the three components of the triad/RED-S.[44] Nearly 45% of the females didn't think that amenorrhea would have any effect on bone health.[44] Also, 35% of the

female athletes considered having an irregular menstrual cycle “normal” for active females, this was shown more predominately in those who reported a history of menstrual dysfunction.[44] These results indicated that female exercisers do not understand the connection between the three components of the triad/RED-S.[44] These results show that we need education around this topic not only in sports settings, but in general health settings as well.

1.4 Educational Interventions

A survey of International Federations identified a lack of prevention programs on RED-S in 26 out of 28 Olympic International Federations.[13] This indicates that the need for education of sports leaders and elite team physicians in the health and performance consequences of RED-S in warranted.[13]

Krick et al., conducted an intervention investigating changes in RED-S knowledge among female high school athletes after participation in a number of brief 10 minute RED-S educational session.[75] These session included: (1) registered dietician defining the etiology and progression of the triad and providing nutritional strategies that may decrease its risk, (2) former collegiate athlete who shared personal experiences of overcoming triad-association problems, (3) a collegiate coach who shared insights into negative body image and pressure to achieve a specific bodyweight or appearance.[75] The results showed knowledge about consequences of RED-S (menstrual irregularity, stress fracture risk, low energy intake, and bone health) were identified in most participating athletes (>89%).[75] This suggest that educational videos may be an effective method

of improving athlete knowledge of the triad. Fahrenholtz et al., conducted a study amongst a high risk group for developing RED-S, female endurance athletes, where they attended a 16-week learning program known as FUEL.[76] This program focused on food and nutrition knowledge through weekly online lectures and individual athlete-centered nutritional counseling every other week.[76] The participants were 50 athletes with symptoms of RED-S and low risk of eating disorders, no use of hormonal contraceptives and no chronic diseases placed in a FUEL intervention (32 participants) or 16-week control period (18 participants).[76] There was strong evidence for improvements in sports nutrition knowledge and moderate to strong evidence in the rating concerning self-perceived nutrition knowledge in FUEL v. control.[76] The FUEL intervention group showed a 28% improvement in their sports nutrition knowledge during the 16-week intervention period.[76] Comparing the results of this study to 32 studies reviewed by Tam and colleagues, the 28% improvement from FUEL was higher than the mean increase of 16% from similar studies.[77] Their studies included primarily took place in a face-to-face group setting, were short-term (<300 mins of contact time), had a variety of session frequencies and duration frequencies (usually <1 hour).[77] The FUEL study used online content, with a longer duration of the intervention, higher overall contact time (558 mins) and the online approach worked better for higher tier athletes that have time challenges due to high training load and classes.[76] However, the analyses of a seven-day food record and sports nutrition habits, suggested weak evidence for improvements in FUEL v. control.[76] There were several other factors besides education affecting the athletes food intake included social and economic factors.[76] Nutrition knowledge is not a sufficient factor for changing behavior, providing behavioral strategies to promote dietary behavior change in athletes may help.[76] There may be additional barriers for female endurance athletes with symptoms of RED-S when trying to improve their dietary behavior.[76] These may

include focusing on maintaining a lower body mass, limited time to eat due to a busy training schedule, and suppression of an appetite after training.[76] A longer intervention in the FUEL study could have enabled further motivation for change and supported more athletes during the action phase of the study.

Mountjoy et al., identified many recommendations for athletes, healthcare professionals, and sports organizations to help prevent and reduce the prevalence of RED-S.[12] Athlete entourage recommendations can prevent RED-S through implementation of the following strategies such as educational programs on RED-S, healthy eating, nutrition, EA, risk of dieting, and how these affect health and performance, putting less emphasis on weight, more emphasis on nutrition and health to enhance performance, developing realistic and health-promoting goals related to weight and body composition, and encouragement and support of effective treatment; avoidance of critical comments about an athlete's weight and body composition.[12] Healthcare professionals recommendations to help decrease the health implications of RED-S through identification of multidisciplinary athlete support team including sports physician, nutritionist, psychologist, physiotherapist, and physiologist, education of the medical team in the detection and treatment of RED-S, and use of the RED-S risk assessment model.[12] Sports organization recommendations for International Federations, National Olympic Committee and National Sport Federations can help prevent RED-S by implementing preventative educational programs, rule modifications/changes to address weight-sensitive issues in sport, policies for coaches on managing healthy eating habits and proper weight and body composition management.[12] Providing education on RED-S to every coach, AT, parent, teacher, and athlete is the start of reducing the amount of women that have their health and sports performance impacted in a negative way.

1.5 Problem Statement

Most studies that have examined the knowledge of RED-S and related factors focus on athletes, coaches, athletic trainers, etc. at the collegiate level. However, by the time these females reach the collegiate level, they and some of their friends most likely already developed RED-S not only acutely, but long term. Young athletes are particularly vulnerable to developing RED-S due to going through their normal growth and development on top of a high training load. This is why it is important that there is some amount of knowledge among stakeholders to educate the young athletes. This study examined what the knowledge level is among coaches and athletic trainers that are involved in the lives and training performance of young female athletes. If the people who are educating the athletes don't know what RED-S is, we can't expect them to be able to teach it. We need to find out their knowledge level so we can find a way to intervene with these athletes and provide a purely positive experience in their sport.

1.6 Study Purpose

The purpose of this study was to gather and analyze results from a survey on the current knowledge of RED-S among stakeholders who are involved with young female athletes' well-being.

1.7 Specific Aims

Specific Aim 1: Identify demographics and awareness levels of RED-S among stakeholders, being that it is a condition their female athletes may develop.

Specific Aim 2: Identify and evaluate the current knowledge and confidence levels of stakeholders on RED-S related factors through a Qualtrics survey questionnaire consisting of 15 knowledge questions followed by a confidence rating scale.

Specific Aim 3: Identify the current educational training provided to stakeholders through the education section of the Qualtrics online survey questionnaire. Additionally, identify any policies and procedures in place for identifying and helping athletes with RED-S.

1.8 Study Significance

This research is significant because it will help parents, educators, and coaches understand the importance of how lifestyle and wellness factors influence their players, daughters, and students. Education around this subject can help the topic become more well-known and increase the well-being of these young girls and allow them to help others around them. There are a lot of consequences to not having your health intact as an athlete and not being aware can decrease an athlete's performance. It is vital that an athlete's support team recognizes the behaviors and actions that increase the risk of LEA development and the symptomology of RED-S evolution.[1] Spreading

knowledge about this subject may decrease the risk of females developing RED-S and in turn be able to educate those around them including teammates, coaches, parents and even peers. [32]

2.0 Methodology

2.1 Research Design

This study utilized a survey-based cross sectional study design to gather information regarding RED-S knowledge in athletic trainers and coaches of female athletes. An online survey was sent to Western Pennsylvania Interscholastic Athletic League (WPIAL) and Pennsylvania Interscholastic Athletic Association (PIAA) committees involving girls' athletics for ages 12-18. The survey includes a demographics section used to determine if the participant is an athletic trainer or coach along with identifying additional roles such us parent, specialized/personal trainer, or teacher to a female athlete. Survey questions focus on RED-S knowledge in terms of energy deficiency, eating disorders, bone health, menstrual cycles, etc. related to female athletes. The survey also includes an education section to determine their education received and the education and treatment provided to the athletes.

2.2 Subject Recruitment

To recruit subjects, an email was sent to WPIAL and PIAA committees involving girls' athletics. These committee members are available to be accessed through the WPIAL and PIAA websites containing both rosters and committees for each female sport throughout different Pennsylvania districts. In addition, the PIAA website provides non-sport specific committees for parents' advisory committees, girls' athletics, junior high/middle schools, and athletic directors.

Participants will be contacted via email and asked to complete a short survey. Participation in the survey is completely optional and participants are free to opt out of the study at any point. The survey includes an acknowledgement to participate in the study and an assurance granting complete anonymity to the participants. Subjects were given detailed instructions of how to fill out the survey prior to completion. This study was reviewed by the Institutional Review Board (IRB) at the University of Pittsburgh and considered exempt.

2.3 Subject Characteristics

2.3.1 Inclusion Criteria

Individuals were included in the study if they were a coach or athletic trainer that is involved with the health and well-being of any female athlete(s) ages 12 to 18, 7th grade or older, and involved in any sport in the state of Pennsylvania.

2.3.2 Exclusion Criteria

Individuals were excluded from the study if their role does not fit within the realm of being involved with the health and well-being of a female athlete(s) outside of the 12 to 18 age range.

2.4 Instrumentation

This study utilized a survey the includes questions obtained from similar questionnaires and modified to fit the population. The survey was also piloted to test for reliability and validity before use.

2.4.1 Qualtrics Online Survey System

The Qualtrics Survey Software, a software system utilized by the University of Pittsburgh, was utilized to create and administer survey questions. The software has shown high security results, as it has numerous certifications to comply with regulations. The anonymity of the participants in this survey was maintained using the Qualtrics software. Participants must obtain the role of either a coach or athletic trainer, or the survey would end after the first question. They were then able to choose additional roles such as personal trainer, parent, or teacher for additional analysis of results. Survey data collection occurred from Wednesday December 6th until Wednesday January 10th during the 2023-2024 academic year.

2.4.2 RED-S Knowledge Questionnaire (RKQ)

The measurement instrument in this study is a RED-S Knowledge Questionnaire (RKQ) developed by the author. The content of the RKQ is based on information obtained from an exhaustive review of literature. The RKQ includes a demographic section, a knowledge section, and an education section (which is not included in the scoring of the knowledge section). The

demographic section of the RKQ relates to background information such as age, relationship to the athlete, sport involvement, coaching experience, etc. The knowledge section includes questions pertaining to signs and symptoms, triad components, treatment, and other related questions. The remainder of the RKQ includes a section regarding the screening and treatment process for athletes and the education the participant receives regarding RED-S.

2.5 Procedures

An email was received by any individual on the WPIAL or PIAA sport specific or non-sport specific committee lists involving female athletics. Additional individuals not listed on the direct site but are known by the author to have relation to female athletes received an email. The email invitation included a brief description of the study purpose and the inclusion criteria. Once the subjects acknowledged their intent to participate in the study, they could then click the included link to go to the online survey. Then, the subjects filled out the first section assessing demographics: Age, Gender, Relation to female athlete, Highest degree completed, have they heard of "RED-S", and specific questions for coaches only including the sport they are currently coaching, the total of years coaching, and total of years coaching female athletes. Following that, the knowledge section assessed their knowledge and confidence regarding RED-S, nutrition, energy deficiency, menstrual cycle, and more. The last section provided to all participants asked questions regarding education received and given, treatment for athletes, and resources.

All survey responses remained anonymous and no information about their district or organization will be accounted for. The data was collected and recorded in the Qualtrics software

which allows for more filtered and organized responses. The survey consisted of 42 questions total and took approximately 10-12 minutes to complete.

2.6 Data Reduction

All responses were reviewed in the Qualtrics Survey Software. Any responses that contained identifiable subject factors such as subject name or name of school were excluded, as they would not allow for complete anonymity. Analysis was done for each question that was answered. Based on demographic response of their relation to the athlete(s), data was extracted and analyzed separately for additional understanding.

2.7 Data Analysis

Data was collected via Qualtrics Core XM Online Survey System (Qualtrics XM, Provo, UT, USA). Data was exported and analyzed using SPSS Statistics Version 27 (IBM Corporation, Armonk NY, USA). For the knowledge questions a total knowledge score was determined by adding one point for each correct answer based out of a total. Total confidence score for part b answers were determined from a confidence scale ranging from 0 (no confidence) to 4 (completely sure) for each knowledge item and averaged for overall confidence levels. Participants received one point for answering correctly on a knowledge-based question and zero points for answering incorrectly. The total possible knowledge score for a participant to receive was 15 points.

Descriptive statistics such as mean and standard deviation were used to identify central tendency and variability of demographics. Frequency distributions were used to report participant responses to the screening process question and the available resources.

3.0 Results

The data collection period for this study lasted five weeks from Wednesday, December 6 to Wednesday, January 10. The survey results consisted of 58 survey responses from Athletic Trainers and Coaches, however only 47 fully completed responses were used for data analysis. The results of those survey responses are listed in the following sections.

3.1 Qualtrics Survey Data

3.1.1 Survey Participants

Out of the Forty-seven total completed responses to this survey, 32 were athletic trainers and 15 were coaches. In addition to their role as an AT or Coach, 6 also held the role of a parent and 3 others as a personal/specialized trainer. The average age of the participants was 37.6 +/- 11.8 years.

3.1.1.1 Gender Representation in Athletic Trainers and Coaches

The gender of the participants were 28 females, 18 males, and 1 transgender male. The athletic trainer respondents were predominantly females (69%), and the coach respondents were primarily males (60%). **Error! Reference source not found.** below represents each gender a ccording to their role(s) for female athletes. Most of the survey respondents had received either a Bachelor's (36%) or master's degree (57%).

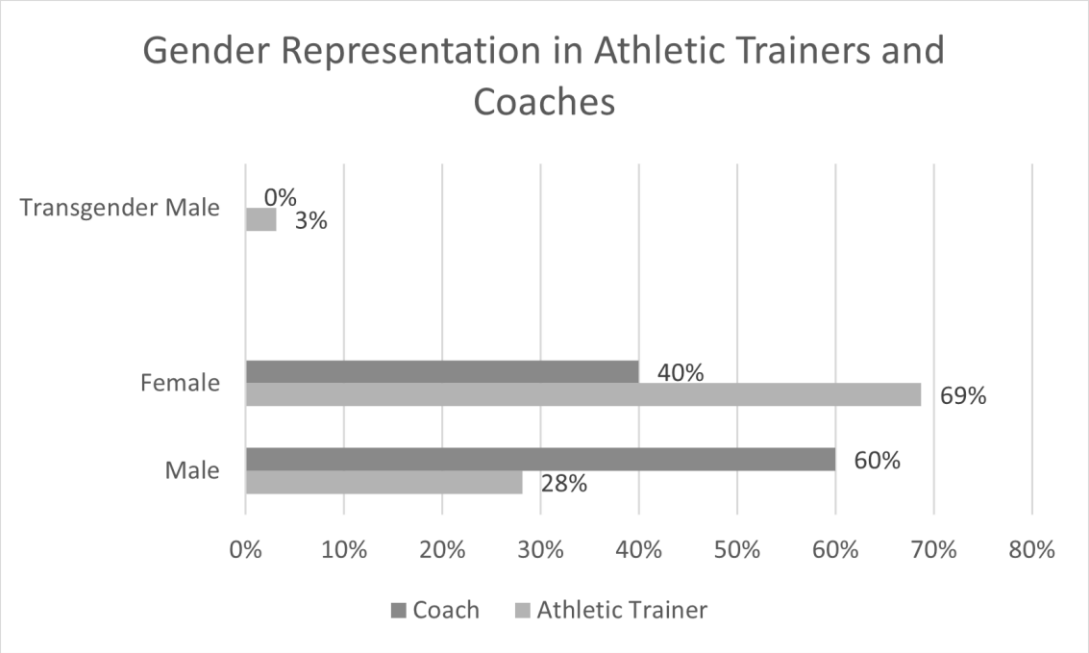

Figure 1 Gender Represented in Athletic Trainers and Coaches (%)

3.1.1.2 Highest Degree of Education in Athletic Trainers and Coaches

Error! Reference source not found. below shows the highest degree of education r eceived according to their role(s) to the female athlete(s). Regarding the nature of the degree received, 52% of the respondents received a degree related to Athletic Training, Sports Medicine, Sports Psychology, etc. Other respondents received degrees in fields related to Education, Mathematics, Psychology, and Computer Science.

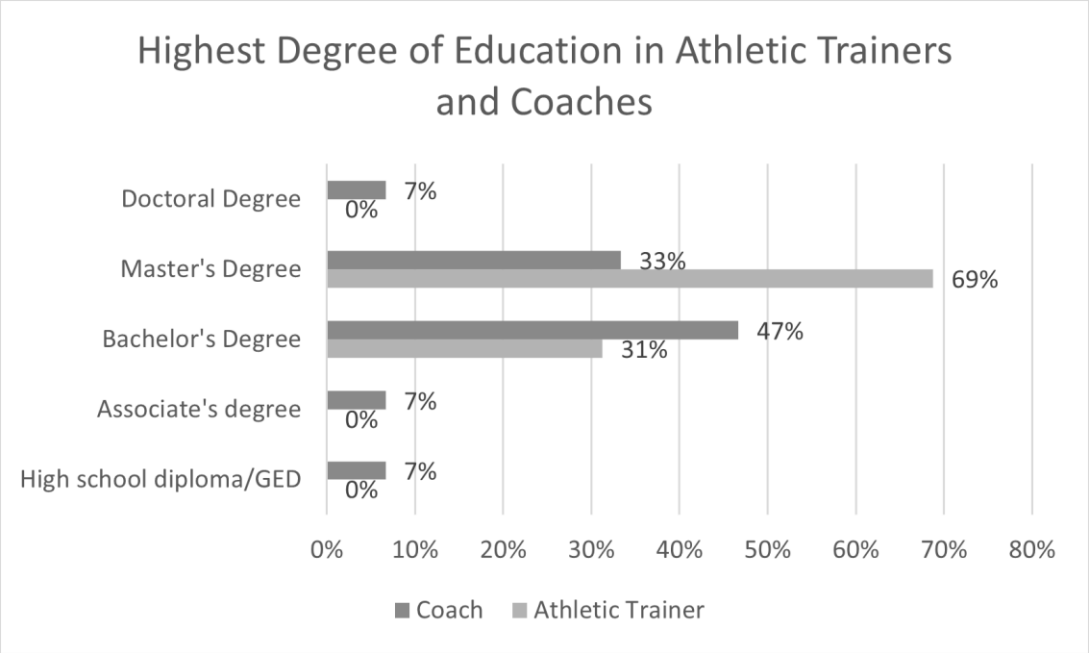

Figure 2 Highest Degree of Education Received in Athletic Trainers and Coaches

3.1.1.3 Sports Overseen by Athletic Trainers and Coaches

The most reported female sports being coached or provided healthcare were Basketball (30), Soccer (27), and Track & Field Throwing Events (26). All responses regarding sporting assignments and training for their current female sport(s) are depicted below in **Error! Reference source not found.**, respectively. The average total number of years respondents had coached or provided healthcare for female athletes was 13.1 +/- 10.5 years.

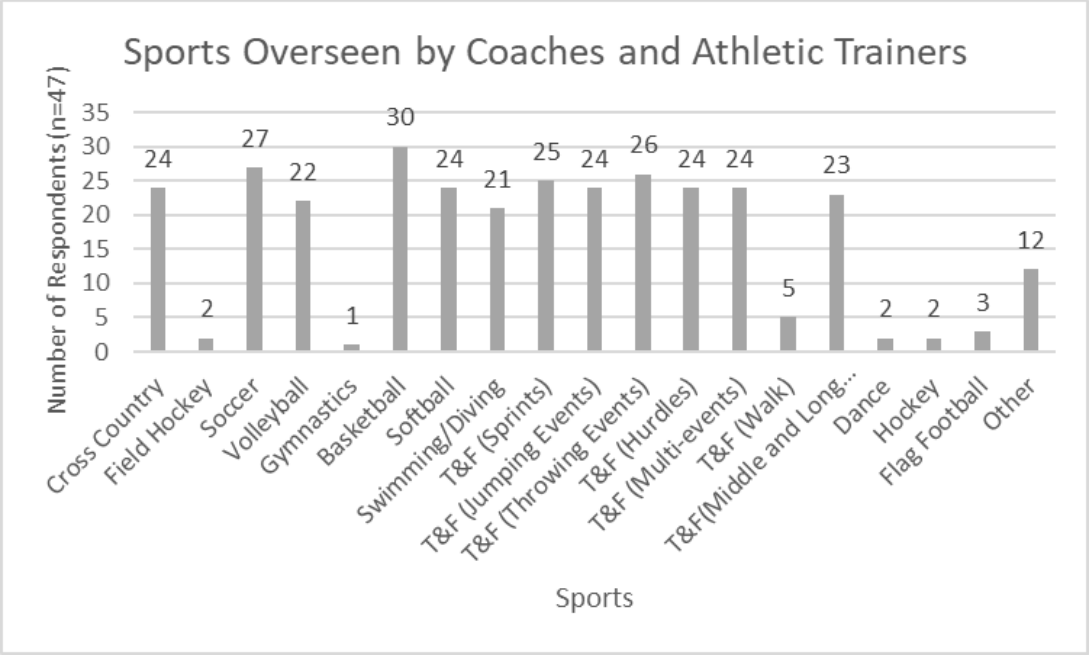

Figure 3 Current Sports Overseen by Coaches and Athletic Trainers

***Respondents were able to select more than one sport when answering this question to represent all current female sports they oversee.**

***T&F represents Track and Field Events**

3.1.1.4 Level of Sport Overseen by Athletic Trainers and Coaches

The level of sport most coaches and athletic trainers coach or provide healthcare for is the high school level, at 60% and 81%, respectively. Figure 4 shows which level(s) of sports the ATs and Coaches currently oversee.

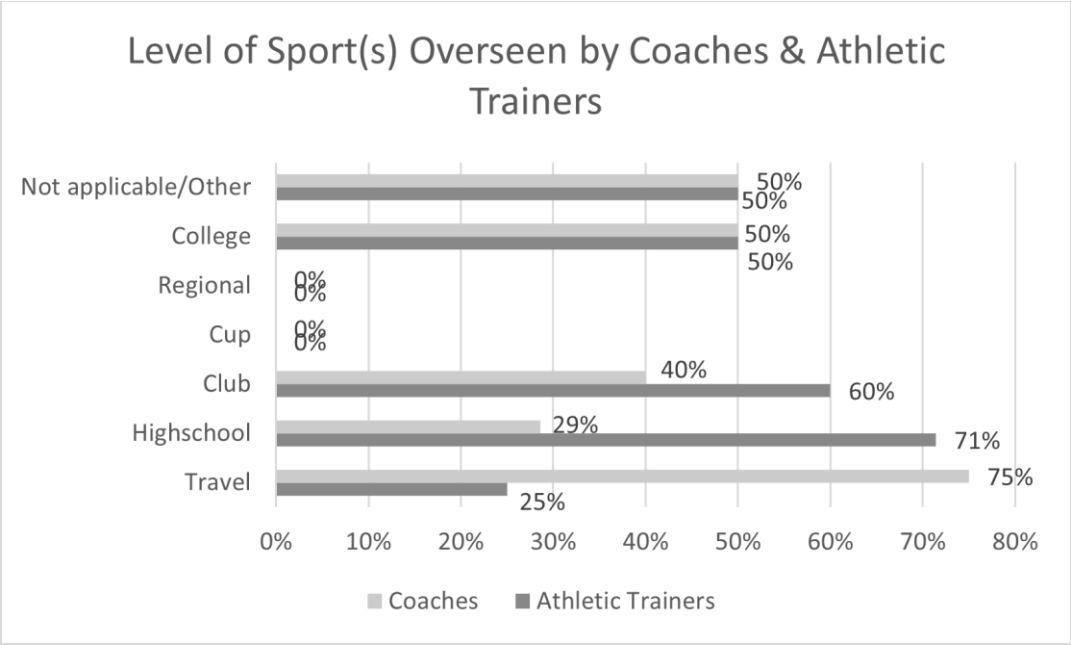

Figure 4 Level of Sport(s) Overseen by Coaches and Athletic Trainers

3.1.2 RED-S Awareness

Before moving onto the knowledge portion participants were asked if they had ever heard of Relative Energy Deficiency in Sport (RED-S), 74.5% of the respondents answered “no” to having heard of RED-S previously. All the coaches (100%) responded “no” to this question, whereas 63% of the athletic trainers responded “no”. Figure 5 below shows a better breakdown of those who were aware of RED-S before they took the knowledge portion of the survey.

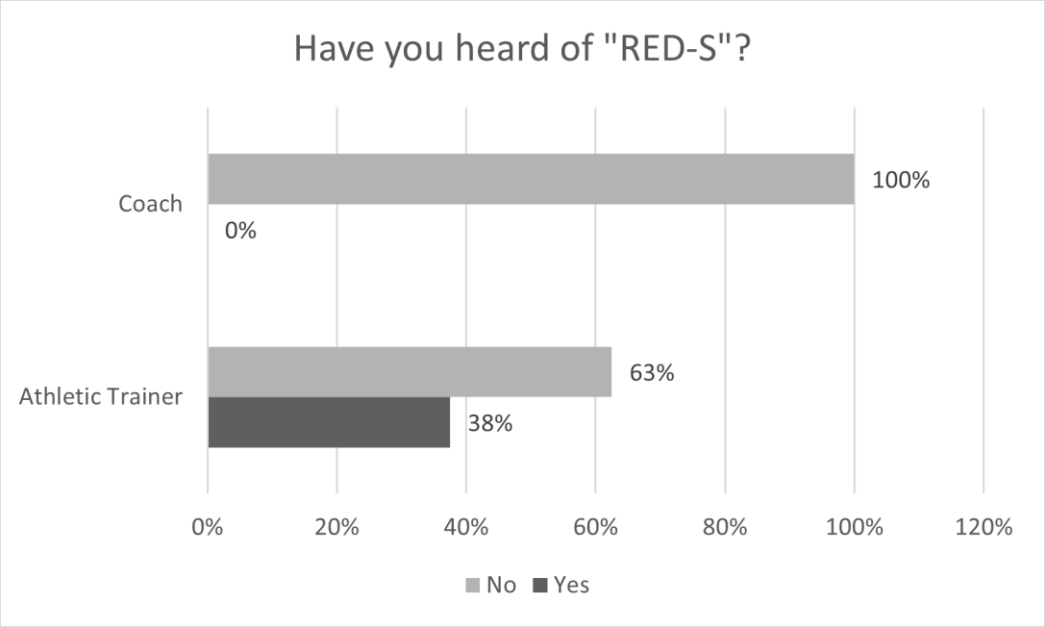

Figure 5 Awareness of RED-S in Coaches and Athletic Trainers

3.1.3 Knowledge and Confidence Results

In the Knowledge section of the survey, participants were asked 15 knowledge questions about RED-S components, symptoms, consequences, and other health related questions regarding menstrual irregularity, eating disorders, etc. Table 1 below shows the scoring by question for each the Athletic Trainer and Coaches along with the average total score per group in the knowledge section of the survey. The answer to each question is included following each question in the row. The total average knowledge score for the Athletic Trainers was 11.4+/-1.6/15 (76%) and for the coaches was 11.2+/-2.5/15 (75%). Following each knowledge question, the respondents were also asked to rank their level of confidence in choosing the correct answer in the previous question. The columns next to the knowledge scores represent the average confidence score following each question. Comparison across the rows shows differences in confidence per question between ATs and Coaches. At the bottom of the average confidence score columns is the average confidence score for all ATs compared with all coaches. The average confidence scores for the ATs were 2.4+/-0.4 and for the coaches was 1.8+/-0.5. The difference in knowledge scores between athletic trainers and coaches was 0.2, however the difference in confidence scores was 0.6.

Table 1 Knowledge and Confidence Scores For Athletic Trainers and Coaches

Question	Athletic Trainers Correct	ATs Avg. Confidence	Coaches Correct	Coaches Avg. Confidence
	N= 32		N =15	
What are the three components of RED-S? **Correct Answer:** Amenorrhea, Disordered Eating, Osteoporosis, and Physiological Effects	14 (43.7%)	2.2	6 (40%)	1.5
How long can the consequences of RED-S affect a female athlete? **Correct Answer:** For the rest of her life	31 (96.8%)	2.6	13 (86.6%)	1.6
Signs and Symptoms of RED-S can include all the following EXCEPT which one? **Correct Answer:** Hyperactivity	22 (68.7%)	2.2	12 (80%)	1.7
Which of the following is a performance consequence of RED-S? **Correct Answer:** Impaired judgement	22 (68.7%)	2	12 (80%)	1.4
Which is the MAIN cause of RED-S? **Correct Answer:** Low Energy Availability	15 (46.8%)	2.2	7 (46.6%)	1.5
All of the following are features of RED-S EXCEPT which one? **Correct Answer:** Only Affects Women	19 (59.3%)	1.8	12 (80%)	1.8
Can low energy availability be present without a change in weight? **Correct Answer:** Yes	32 (100%)	2.8	13 (86.6%)	2.1
What is considered menstrual irregularity for any girl? **Correct Answer:** All of the above	30 (93.7%)	2.8	13 (86.6%)	2.5
True or False: Hormonal Contraception is recommended in athletes with RED-S to resume menses. **Correct Answer**: False	12 (37.5%)	1.7	9 (60%)	1.2
True or False: Oligomenorrhea (6 or few menstrual cycles per year) is not a major health concern as long as the athlete is menstruating in the off-season. **Correct Answer:** False	27 (84.3%)	2.4	13 (86.6%)	1.9
True or False: Menstrual cycle disturbances, of any kind, are a normal part of training and there is nothing wrong with a female athlete losing her period. **Correct Answer:** False	31 (96.8%)	2.6	11 (73.3%)	1.7
True or False: Athletes must present all aspects of RED-S in order to be diagnosed with this condition. **Correct Answer:** False	25 (78.1%)	2.2	13 (86.6%)	1.7
True or False: Because of the high impact of running on bone health, bone loss does not occur in many running athletes. **Correct Answer:** False	29 (90.6%)	2.5	12 (80%)	1.9
True or False: Repeated stress fractures should serve as a warning with regard to low bone mineral density. **Correct Answer:** True	32 (100%)	2.9	14 (93.3%)	2.1
True or False: Stressing an ideal weight helps an athlete understand how she can perform best in her sport. **Correct Answer:** False	25 (78.1%)	2.9	12 (80%)	2.2
Average Score	**11.4 +/- 1.6/15***	**2.4 +/- 0.4**	**11.2 +/- 2.5/15***	**1.8 +/- 0.5**

***Knowledge Scores are based on a score out of 15**

3.1.4 Workplace and Education Results

In the last block of the survey participants were asked questions pertaining to their workplace policies, resources, and continuing education for their coach or athletic training role. If they held a role in multiple programs or institutions, they were asked to respond pertaining to their primary workplace. The following sections go into detail on results for each individual question, comparing differences in responses between athletic trainers and coaches.

3.1.4.1 Workplace Policies and Resources

In order to understand what policies were in place for ATs or coaches involved with young female athletes, they were asked "Does your workplace currently have a policy in place that specifies what to do when you suspect that a female athlete may be suffering from one or more aspects of RED-S?" 96.2% of the ATs and all 100% of coaches responded no, there is not a policy in place. Following that, respondents were asked "Are you aware of any resources available to you/your female athlete(s) regarding RED-S through your current institution". Once again, 100% of the coaches responded no, they are not aware of any resources available. Additionally, 90.6% of ATs responded that they are not aware of any resources.

3.1.4.2 Educational Programming and Continuing Education

The educational programming and continuing education questions were used to identify resources that are available to coaches and athletes to learn more about RED-S in the workplace as well as if they were currently participating in continuing education to learn about new issues arising regarding female athletes. To identify if there was a direct program from departments for athletes' participants were asked, "Has your athletic department/program provided educational programming for the athletes that may be affected by RED-S?". The entirety of the coaches (100%) responded no; they have not provided an educational program. Results showed that 93.7% of ATs indicated that there is not an educational program provided. To evaluate if there was currently programming available for stakeholders, respondents were asked "Have you received training/educational programming through your current institution/employer regarding RED-S?" Once again, 100% of the coaches responded no, they have not received training/educational programming. While 81.3% of the ATs have not received training/educational programming regarding RED-S. In the follow-up question, participants were asked "If you answered yes to the previous question, which component(s) have you received training/educational programming on?". Responses from 18.7% of ATs that received training showed that 100% received training on both osteoporosis and disordered eating but only 80% received any training on the amenorrhea feature. Respondents were then asked about their own continuing education in general and continuing education regarding RED-S education. Firstly, respondents were asked, "Indicate the type of GENERAL continuing education you take part in at least once a year (check all that apply

in general): *the next question will ask about continuing education directly related to the Triad/RED-S; this is GENERAL continuing education only*". In this section, all ATs responded that they take part in some type of general continuing education. Mostly all coaches responded that they take part in general continuing education, except 20% who responded that they do not participate in continuing education. Figure 6 below shows all responses and the varying types of continuing education they participate in with professional journals, conferences, and finding information online being some of the most popular. Participants were then asked, "Indicate the type of continuing education you take part in at least once a year DIRECTLY RELATED to the Triad/RED-S (check all that apply specific to the Triad/RED-S)". Where now, 80% of coaches and 53% of ATs responded with not participating in continuing education related to RED-S. Figure 7 below shows the breakdown of where they do receive the continue education of RED-S, if they do, majority coming from professional conferences and finding information online.

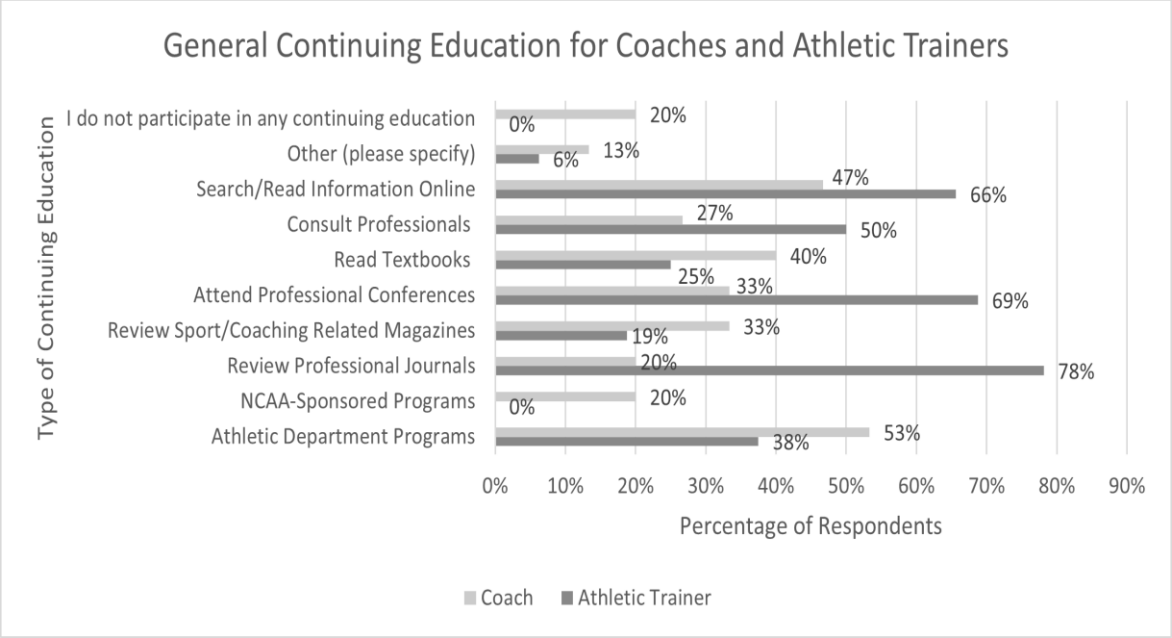

Figure 6 General Continuing Education of Athletic Trainers and Coaches

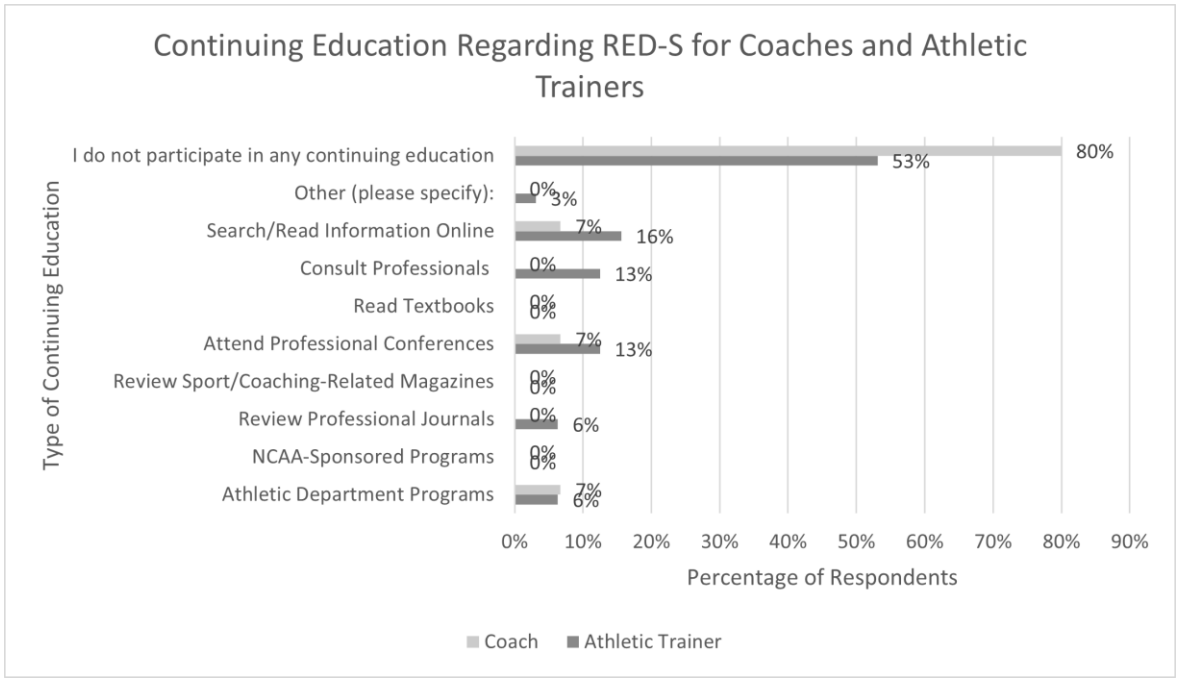

Figure 7 Continuing Education Regarding to RED-S for Athletic Trainers and Coaches

3.1.4.3 Providing Health Care to Athletes with RED-S

The remainder of the questions were asked to gain insight on stakeholders' confidence and belief in themselves and their coworkers around recognizing and treating RED-S. The first figure below, Figure 8, represents the question that asked respondents "Would you know how to recognize the signs and symptoms of RED-S?". Out of all the ATs, 40.6% responded that they would not know how to recognize signs and symptoms while 93.3% of coaches responded the same. The next question in Figure 9 focused on the comfortability of referring athletes to get help. Participants were asked, "Would you be comfortable referring your female athletes to a resource to get help with any RED-S symptoms?". The responses showed that 71.9% of ATs would refer their athletes to help. Whereas, with the coaches, 60% of them would not refer their athletes to a resource to get help. The next question focused on the comfortability of the coach's diagnosis, asking "Would you feel confident identifying RED-S in your female athletes?". The responses for this question are shown in Figure 10 reveal that only 28.1% of ATs and 6.7% of coaches would be confident in identifying RED-S. Lastly, they were asked a question regarding their belief in their coworkers' ability to identify, "Do you believe your coaches, athletic director, athletic trainers, and other coaching staff have a good understanding of RED-S?". The responses showed that 90.6% of ATs and 73.3% of coaches think their peers do not have a good understanding, shown in Figure 11 below.

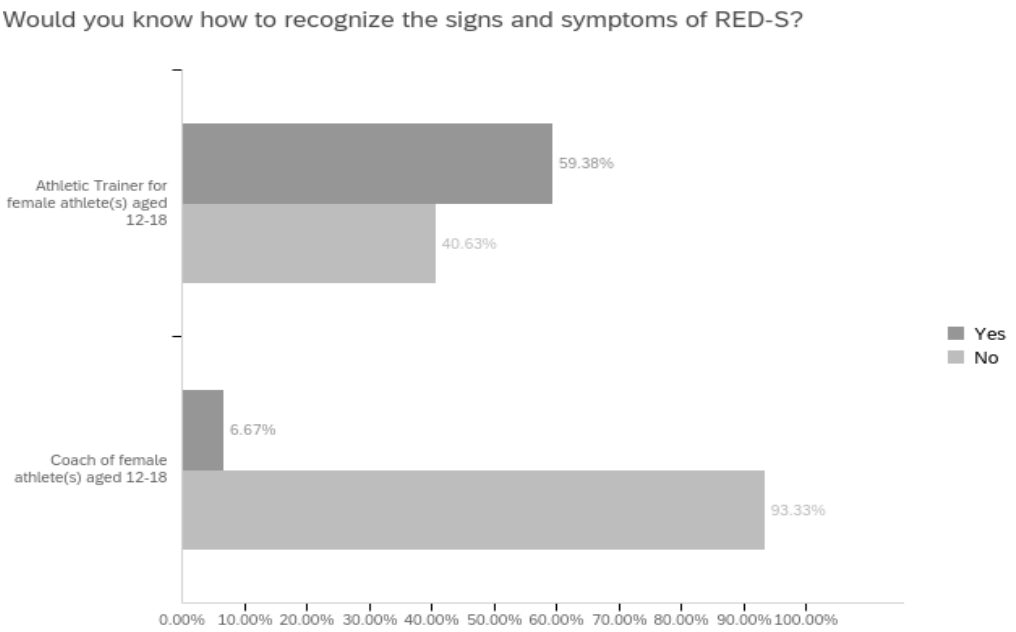

Figure 8 Athletic Trainers and Coaches Recognition of Signs and Symptoms of RED-S

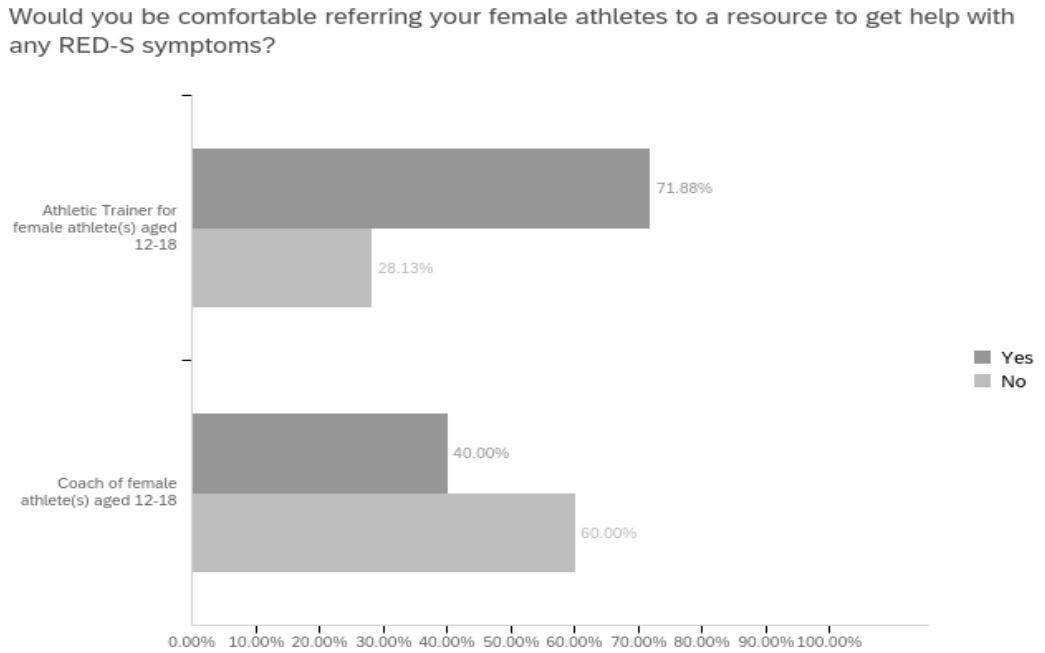

Figure 9 Comfortability of Athletic Trainers and Coaches Referring Athletes with RED-S to Resources

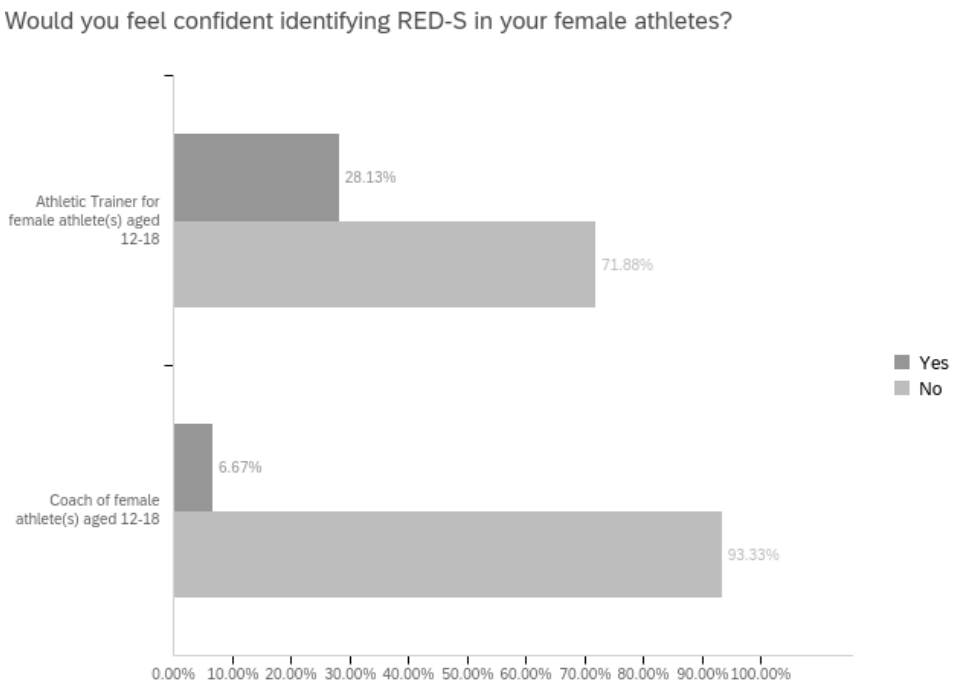

Figure 10 Athletic Trainers and Coaches Confidence Identifying RED-S in Female Athletes

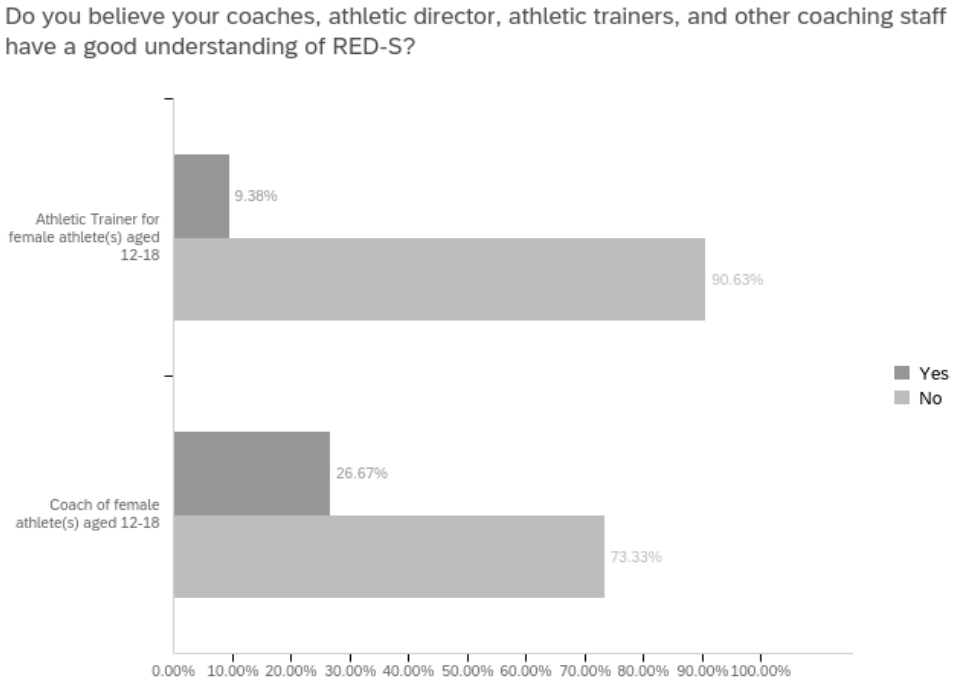

Figure 11 Athletic Trainers and Coaches Belief in Coworkers and Peers In Understanding RED-S

3.1.5 Interest in Learning More About RED-S

The next questions were asked to gauge the interest in the participants on learning more about RED-S to help their female athletes in the future. Participants were asked "If your workplace provided educational training for you with respect to RED-S, would you attend or take the course?" shown below in Figure 12. The results concluded that 96.8% of ATs and 86.7% of coaches said yes, they would attend or take the course to receive RED-S education. Respondents were then asked, "If educational training with regards to RED-S was required by your workplace, would you prefer the training be online or in-person?" Results revealed that 81.3% of ATs preferred for training to be online while the other 18.8% would have rather it be in-person. While 66.7% of the coaches preferred to have training online and the remaining 33.3% preferred in-person training. Figure 13 below shows a better visualization of who prefers online v. in-person training on RED-S. At the end of the survey, participants were asked if they would like to learn more about RED-S as a closing out question. Out of all the respondents only 13.33% said they would not like to learn more, those respondents were all coaches, as shown in Figure 14. After the survey exit slide, participants were provided a link to the RED-S website if they decided they wanted to learn more.

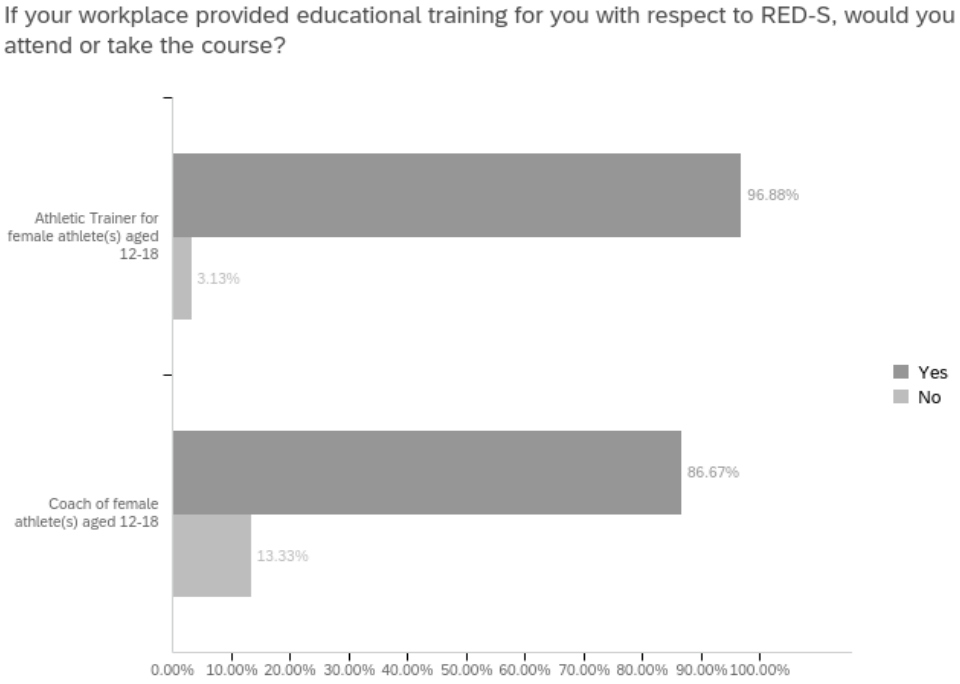

Figure 12 Athletic Trainers and Coaches Interest in Attending Workplace Educational Training

Figure 13 Online or In-Person Educational Training Preference

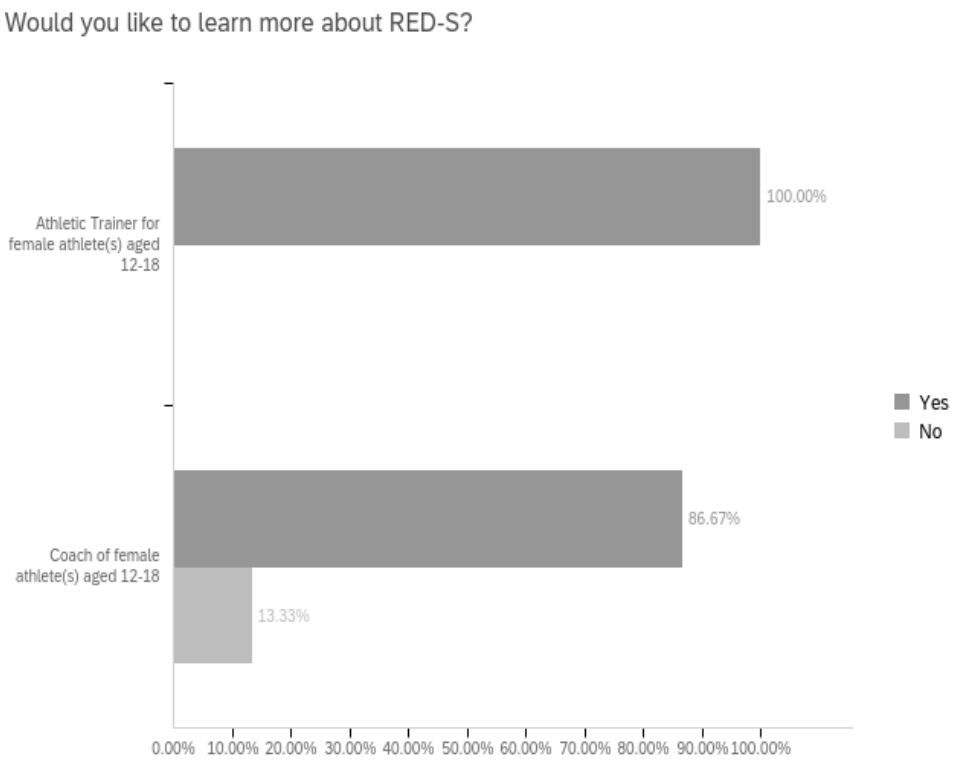

Figure 14 Interest in Learning More About RED-S in Athletic Trainers and Coaches

4.0 Discussion

Knowledge of RED-S, especially in those working with young female athletes, remains scarce for how many complications it can cause to a young woman's health. The purpose of this study was to identify the knowledge and confidence levels regarding RED-S of stakeholders involved with young female athletes. The knowledge and confidence scores are used to help us understand how much stakeholders know about the syndrome regarding consequences, symptoms, and components & confidence in their knowledge. Additionally, it aimed to gain awareness of what educational training, policies, and practices are available and used to help defer the impact of RED-S on these athletes. To the author's understanding, this is the first study evaluating knowledge, confidence, and practices in stakeholders of female athletes lower than collegiate level. The results of the study indicate that stakeholders at this level don't have much awareness or knowledge of RED-S, nor does it seem like they are completely confident in their knowledge surrounding the topic. However, majority of the coaches and ATs would like to learn more about RED-S to better help their female athletes.

4.1 RED-S Awareness

The first aim of this study was to identify awareness levels of RED-S among athletic trainers and coaches of adolescent female athletes, being that it is a condition adolescent females may be at risk of. The first question asking if participants have heard of RED-S revealed that 74.5% of all participants had not previously heard of RED-S. The largest percentage of stakeholders having awareness of RED-S were the ATs, with 37.5% having heard of it before. When looking at the highest degree of education received according to role, 68.8% of ATs have received a master's degree and the other 31.3% received at least a bachelor's degree which could correlate to their awareness of RED-S. Additionally, 22 out of 31 of ATs were female possibly leading to higher awareness levels since it is a syndrome that occurs primarily among women. Stakeholders with additional roles as parents (5 males; 1 female) had also indicated they had never heard of RED-S (100%), additionally 2 out of 3 of the stakeholders with the secondary role as a personal trainer also indicated they had never heard of RED-S. The personal trainer that selected "yes" also held the role of an AT; with this we can postulate that some form of additional education in either their AT or personal training programs/certifications led to increased awareness of RED-S. Many previous studies point to the fact that there is a lack of awareness of RED-S and its detrimental effects. The RED-S study conducted by Miller et al. determined that a significant proportion of adult female exercisers in Australia are not aware of the detrimental impact of amenorrhea on bone health and still believe irregular periods are a normal consequence of intense training.[44] The participants of this study were 18-40 years of age, indicating that no matter the age there needs to be more awareness around RED-S and its effects. Additionally, a study conducted by Kroshus et al. examined the differences in awareness of female athlete triad versus RED-S within collegiate

ATs.[18] Results showed that the 98.6% of all participants had heard of the female athlete triad, yet only 33% had heard of RED-S.[18] As we shift into different verbiage and language around the syndrome, it is increasingly important for ATs and coaches to gain clarity and awareness of RED-S.

4.2 Knowledge and Confidence Scores

The second aim was to identify the current knowledge levels of the stakeholders regarding RED-S related factors through a Qualtrics survey questionnaire consisting of 15 knowledge questions. Additionally, the survey evaluated confidence levels by indicating their level of confidence in their knowledge answer. A sub-aim was to describe the differences in knowledge and confidence scores based on demographics such as coaches v. athletic trainers, coaching parents v. athletic training parents, personal/specialized trainers, ages, highest education completed, etc. The classification for level of knowledge used to evaluate the scores indicates a score of <60% to be a poor level of knowledge, 60-79% to be a moderate level of knowledge, and >80% to be a good/high level of knowledge.[78] When evaluating the confidence score, a confidence score ≥ 3 exhibits high confidence levels and a confidence score ≤ 2 shows a low level of confidence, and scores between 2 and 3 show a moderate level of confidence.[78] The description in Table 1 shows that ATs had an average knowledge score of 11.4+/-1.6 (averaging 76%) with a confidence score of 2.4+/-0.4. The coaches had an average knowledge score of 11.2+/-2.5 (averaging 74%) with a confidence score of 1.8+/-0.5. The average scores for both groups were within the moderate level of knowledge range. These results show that the difference in knowledge scores between ATs and

coaches was only 0.2, however their difference in confidence scores was 0.6. Additionally, if we look at the high end of the total range of knowledge scores, for coaches it was 13.7 and for ATs it was 13. Although, the coaches' confidence scores ranged from 1.3 to 2.3 and range of the ATs confidence score was 2.0 to 2.8. So even though the coaches' high end of the knowledge score was + 0.7 points more for coaches than ATs, their highest confidence score (2.3) was nearly the average confidence score for ATs (2.4). Coaches tended to have a lower confidence score even though they did score well on the knowledge portion of the questions, meaning we may want them to be more confident in their answers since they did score fairly well. Although the ATs level of confidence was shown to be higher, it still was not a considerable high confidence score averaging within being somewhat confident in their answers throughout the knowledge section. We can see this in Figure 15 and Figure 16 featured in Appendix B below which represent that as ATs scores get lower their confidence remains relatively the same even when an individual score is at a 9, their confidence score is 2.6. However, in Figure 16 below representing the coaches their confidence remains low even when individuals are scoring higher. A coach who scored a 13 averaged a confidence score of 1, whereas an AT who scored a 13 averaged a confidence score of 2.9.

When looking at the question that received the lowest score in both the ATs and the coaches "What are the three components of RED-S?", only 43.7% of athletic trainers and 40% of coaches selected the correct response. Only 23% of the respondents were confident in their answer (choosing a 3 on the Likert scale) yet none of the respondents were completely sure about their answer (would score a 4 on the Likert scale). When looking at similar literature and research, it is abundantly clear that a lot of athletes, coaches, ATs, and others working with athletes lack knowledge on what the components of RED-S are. A study conducted by Kroshus et al. examining knowledge of collegiate ATs demonstrated that 12.6% of respondents correctly identifying all 3

components.[18]A study conducted by Pantano et al. examined knowledge of high school coaches regarding the female athlete triad where only 14% (17 of 123) were able to correctly identify all of the components.[35] Another low scoring question was "Which is the MAIN cause of RED-S", where 46.8% of ATs and 46.6% of coaches scored correctly. The study conducted by Kroshus et al. also revealed only 13.3% of respondents correctly identified energy imbalance as being one of the three components.[18]

The highest scoring question was, "True or False: Repeated stress fractures should serve as a warning with regard to low bone mineral density" with 100% of athletic trainers and 93.3% of coaches answering correctly. This correlates back to the study conducted by Kroshus et al. where 93% of participants were able to correctly identify that bone-density issues were a component of the female athlete triad or RED-S. Kroshus et al. also demonstrated that more women were more likely than men to correctly identify this component (99% v. 86%). However, this current study did not reveal the same results where we saw very similar scoring for males (44%) and females (43%) regarding correctly identifying components.

The question "Hormonal contraception is recommended in athletes with RED-S to resume menses" was answered correctly by 37.5% of ATs and 60% of coaches. However, this question is widely misunderstood even by doctors who prescribe the medication. In a study conducted by Cheng et al. it revealed that athletes with past menstrual irregularity (MI) were more likely to use hormonal contraceptives to regulate their menstrual cycles compared athletes who did not have previous MI.[41] Increased use of hormonal contraceptives to regulate menstrual cycles can actually mask symptoms rather than treat them causing the components of RED-S to worsen rather than improve.[41] Although, we still see physicians prescribing hormonal contraceptives to these athletes

which implies that more education is needed across healthcare professionals, not just with the ATs and coaches.

Table 2 found in Appendix B describes knowledge and confidence scores between coach parents (n = 2) and athletic trainer parents (n = 4). When comparing differences between parents who are athletic trainers and parents who are coaches, the AT parents had an average score of 10 (66%) whereas the coach parents had an average score of 12.75 (85%). However, the average confidence score was higher in the AT parents (2.5) compared to the coach parents (1.5). Although there were not enough personal trainer coaches (2) to compare scores between each other, the two individuals' confidence scores were 2.3 and 2.9 which are much higher than the overall average confidence score for coaches. Implying that more education can lead to having higher confidence. There was one athletic trainer who was also a personal trainer that had a knowledge score of 14 and confidence score of 3, postulating that more education led to higher knowledge and confidence. Table 3 featuring personal trainer data is also included below in Appendix B.

4.3 Workplace and Education Results

The next aim was to identify the current educational training provided to stakeholders through the education section of the Qualtrics online survey questionnaire. Additionally, the aim was to identify any policies and procedures in place for identifying and helping athletes with suspected RED-S. The first section of questions in the workplace and education section focused on policies and resources available to both athletes and stakeholders. The first question regarding workplace policies for when a stakeholder suspects an athlete is presenting with RED-S symptoms

revealed that 3.8% of ATs did have a policy, but the remaining ATs and all coaches do not follow any policies of this sort. Programs like concussion education have proven effective in increasing awareness, knowledge, and treatment across both athletes and staff.[17] In the author's opinion, there are policies for when an athlete sustains a concussion or when symptoms are noticed, so a similarly implemented policy for RED-S symptoms may also be effective in reducing risk for developing, and improving management, of RED-S. A similar question was then asked regarding if participants are aware of any resources available to stakeholders or athletes surrounding RED-S support and education; 9.4% of ATs answered yes with the remaining ATs and all coaches answering no. This makes sense when combining these two questions together because what policies would be in place for the stakeholder if they don't even have a resource to refer the athletes to. Looking at the components and symptoms of RED-S, referring an athlete to someone with resources surrounding disordered eating, menstrual function, bone health, etc. can help provide some aspect of help which is better than none. Unfortunately, what happens in most of these scenarios is that the athletic departments and institutions don't have the necessary financial resources to give athletes and stakeholders valuable personnel.[59]

The next section of questions looked at educational programming for stakeholders and athletes, along with any continuing education that the stakeholders take part in. The first goal was to identify if their athletic department/program provided the athletes with any educational programming surrounding RED-S. Once again, all the coaches responded "no" and only 6.3% of ATs responded yes. Mountjoy et al. identified many recommendations to help reduce the prevalence of RED-S which included providing educational programs on RED-S, healthy eating, nutrition, energy availability, and many more to be available to athletes through programs and institutions.[12] Along with that, a FUEL (Food and Nutrition for Endurance Athletes) 16-week

learning program implemented by Fahrenholtz et al. improved female endurance athletes' nutrition knowledge by 28% during the intervention period. Applying educational programming and courses for these female athletes would be beneficial when trying to reduce the risk for developing RED-S. Additionally, the question was asked if the ATs and coaches have been provided with any training/educational programming through their employer regarding RED-S. All the coaches responded "no", while 18.7% of ATs responded "yes". The minimum score of those who received educational programming was 10, whereas the minimum score of those who did not was a 4. Similar results have been found in other studies like one conducted by Lodge et al. where 69% of female cross-country athletes, 52% of coaches, and 51% of athletic trainers reported never receiving education on the Female Athlete Triad or RED-S from their athletic department.[37] However, sport organization recommendations that have been made highly encourage the implementation of preventative educational programs and policies mostly for coaches to help prevent occurrence of RED-S.[12] Those who said they received educational programming were asked what components they received education on, revealing that only 80% had received training on the amenorrhea feature. One of the most severe consequences of LEA in female athletes is menstrual dysfunction, which can manifest in its most severe form as amenorrhea.[5] When looking specifically at high school female athletes, the negative effect of amenorrhea on bone mass during this phase of growth can be severely detrimental and may affect the athletes being able to reach peak bone mass.[56] Therefore, focusing on providing the amenorrhea component of RED-S in educational programming may be one of the most beneficial aspects to learn. The last two questions were focusing on continuing education, firstly as general continuing education then continuing education directly related to RED-S. Regarding general continuing education, all ATs said they took part in some type of continuing education and all but 6.5% of coaches said the same.

However, looking at continuing education directly related to RED-S, 80% of coaches and 48.4% of ATs responded with not participating in any continuing education related to RED-S. The 2018 IOC consensus statement identified a lack in prevention programs on RED-S in 26 out of 28 Olympic International Federations, indicating the need for education of sport leaders on the consequences of RED-S. The implementation of preventative educational programs, required continuing ed, and polices for coaches and ATs to follow could help improve female athletes' health and longevity in the sport.[12]

4.4 Providing Health Care to Athletes with RED-S

The first question asked in this section was asking stakeholders if they would know how to recognize signs and symptoms of RED-S. There were more ATs they said they would know how (59.4%) compared to coaches (6.7%). A study conducted by Pantano et al. demonstrated similar results, where 85% of coaches said they would not know how to recognize or intervene if signs and symptoms of RED-S were present.[58] Shockingly, the coaches in that study were coaching for 6-10 years and coached female athletes 75-100% of the time.[74] When comparing to the results in this study 77.8% of stakeholders that have been providing health care or coaching for between 15-20 years said they would not know how to recognize signs and symptoms. Then stakeholders were asked on their comfortability referring their athlete to a resource to get help with any RED-S symptoms they are experiencing. Although most coaches would not know how to recognize any symptoms, 60% of them would still not refer to their athletes to get help. This may indicate a topic of discussion that warrants further research to determine the reason why they would not refer their

athletes for assistance on a health issue. Additionally, research should determine if there should be a policy put in place that requires coaches to refer their athletes to get help. On the other end, 71.9% of ATs would refer their athletes to help possibly because they are more involved in the health care role than coaches. Reasons that female athletes do not report amenorrhea has been researched previously with some top reasons being experiencing shame and taboo, prioritization of sport performance, and denial.[39] This could be the case in why some coaches and ATs may not be eager to refer their athletes to get help. However, factors to improve this problem consist of breaking the taboo on menstrual problems and having a multidisciplinary approach combining different specializations.[39] If are individual is choosing the role to lead these female athletes, this is something that should be expected as a health care provider or coach. Stakeholders were then asked if they would feel confident fully identifying RED-S in their female athletes, only 28.1% of ATs and 6.7% of coaches said they would feel confident. Following that they were asked about their confidence in their peer stakeholders to be able to identify and understand RED-S where ATs has less of a belief in others, while coaches had more of a belief in others than they did in themselves. However, there were still 90.6% of ATs and 73.3% of coaches who thought their peer stakeholders would have difficulty identifying and understanding RED-S. We can see the correlation between their confidence answering questions in the knowledge section and their confidence actually applying the knowledge, where ATs were at least somewhere between somewhat confident and confident (2.4), but coaches were between not at all confident and somewhat confident (1.8). Their confidence in their own knowledge translates into applying it in the field, but theoretically if we increase knowledge of stakeholders, they should feel more confident in relaying the knowledge to others and athletes.

4.5 Interest in Learning About RED-S

The final aim was to identify if stakeholders have an interest in wanting to be more educated around the topic of RED-S. Current research shows educational programs on RED-S are limited and very minimal continuing education is offered through workplaces. Established programs should be considered when developing RED-S education, although adherence plays a big role in the impact of the education. This section was created to determine the stakeholders' interest in learning more about RED-S to determine their potential attendance and adherence to educational programming. The results showed that 96.8% of ATs and 86.7% of coaches were interested in attending training provided by their workplace. This shows a large interest from the stakeholders, hopefully leading to better adherence, increased knowledge, and confidence as a result. Educational training should focus on increasing knowledge and confidence along with utilizing the modality that most effectively maintains the highest degree of knowledge post-training.[17]This led to the question examining if they would prefer online or in-person training. Those who preferred online training consisted of 81.3% of ATs and 18.8% of coaches. Future research should explore the most effective method of delivery (in-person, online), materials, amount of time spent on training, frequency, environment, and other factors. The implementation of policies can also help teams mandate education to better assist athletes. Lastly, stakeholders were asked if they would like to learn more about RED-S through a closing out question and were provided a link giving them access to the RED-S website. Unfortunately, the number of link clicks was not available information to analyze, but since a large percentage of participants responded they had the desire to learn more about RED-S, hopefully this was utilized as an educational tool.

The high number of participants wanting to learn about RED-S is encouraging as we continue to research educational programming in this realm.

4.6 Limitations

There are several limitations of the present study that need to be recognized. The first is the small sample size of the participants. Out of the 300 email invitations sent out to PIAA and WPIAL members, committees, coaches, and athletic trainers, 66 surveys were started and only 58 were completed. In addition, of the 58 surveys completed, 11 participants did not answer all the questions leaving only 47 responses for data analysis. This completion rate led to decreased representation overall and potentially impacted some of the results of this study. This equates to a 71% completion rate and 15.6% response rate. All participants completed the demographic section, however participants that did not finish stopped answering at some point during the knowledge section. The knowledge section did require some amount of focus towards the questions and possibly a longer amount of time than what the respondents had, which may have resulted in a smaller completion rate.

Another limitation that may explain the reduced response rate was the difficulty in directly contacting coaches and ATs involved with female athletes aged 12-18. PIAA and WPIAL websites gave public access to emails for members, committees, athletic directors, and boards however none of which was direct access to coaches or athletic trainers. The names of ATs in Pennsylvania were found through UPMC Athletic Training & Development Services, but contacts were found through each schools' directory including name, phone number, and email address. Additionally, in some

of the school directories the same information was posted for coaches although this was not present for every PA school. Therefore, there were limited direct contacts for coaches and were most likely sent to additional coaches via word of mouth. Due to this, there is no way to ascertain if the survey reached the maximum number of study participants that it was intended to.

4.7 Future Research

This study was the first of its kind to examine all aspects of RED-S regarding knowledge, confidence, and education in multiple stakeholders in a younger female athlete population. More research should be conducted in this younger population due to the early occurrence of low energy availability being detrimental to athletes in this age range. This also allows a multidisciplinary team to intervene early to catch signs and symptoms like disordered eating and low bone density. Additionally, future research should be focused on the development of a multidisciplinary team and implementation of policies involving that team. Developing a multidisciplinary team for RED-S intervention, prevention, and treatment can take stress off ATs and coaches knowing they have a team to fall back on. The multidisciplinary team could include a sports physician, sports dietitian, mental health professional, etc. Due to RED-S being such a complex syndrome this can allow athletes to get proper education and treatment. Examining knowledge levels across the multidisciplinary team may be useful as well, if we plan on creating a team to refer athletes to it should be a priority to make sure they have the correct information. The approach of a multidisciplinary team may increase the stakeholder's confidence in approaching the situation because they know they don't have to take it on by themselves. Future research should focus on

how this dynamic could work along with policies that should be put in place to make this an effective and necessary approach.

Future research should be aimed at implementing more educational training for coaches and ATs that work with female athletes now that we are aware of the low levels of both knowledge and educational programming. Previous research and the results from the present study have shown that knowledge levels of stakeholders are seemingly low for the high occurrence of RED-S in female athletes. Separating future research into different sporting populations may allow for a deeper dive into education in sports that are at a higher risk for developing RED-S. After more research on knowledge levels in different populations, educational programming should be researched in a more comprehensive manner. There are a lot of factors that go into how people prefer to learn, how they learn best, and how they retain the information. Similar studies to a few others conducted in the past should be done across various populations by implementing programs, workshops, and interventions to decide how to approach educational training on RED-S.

Additionally, more research focused on female sport culture could be utilized when examining how to approach this emerging syndrome by addressing smaller aspects of it. Examining lean based sports surrounding their ideas, culture, and environment around eating disorders/disordered eating can help address the problem without directly addressing it. Approaching RED-S in a smaller scope by looking at specifics like disordered eating, low bone density, nutritional education, etc. can help make the approach less jarring. Approaching different sporting populations to examine the prevalence can help find stand out signs and symptoms to find an easier approach, if necessary. In conclusion, there is a lot of research that needs to be done on the educational and policy side of RED-S. Understanding the effectiveness of educational programming and interventions may provide a motive behind approaching this goal. Exploring

different populations, approaches, and expanding educational efforts can make a change in the prevalence and impact of RED-S on young athletes.

4.8 Conclusion

The results of this study are an important first step in approaching educational training and implementation of policies in stakeholders involved with young female athletes. This study provides us with additional insight along with previous studies, that there is a lack of awareness and knowledge surrounding RED-S. This lack of knowledge leads to decreased confidence surrounding the topic, causing athletes suffering with RED-S to not have a support system to approach the signs and symptoms of what they are experiencing. Although there is a current lack of education, there is a desire to learn more about RED-S in the future. These results are promising moving forward as educational programming is being developed. The interest in learning more shows that stakeholders are eager to help their athletes combat any aspect of RED-S they may be experiencing. However, the next step is for educational materials and policies to be developed and implemented. The implementation of a policy for education, approaches, and access to medical care and support could help with every aspect of RED-S from start to finish. As previous research shows, the approach of multidisciplinary teams for preventing and treating RED-S is ideal. Future research just needs to focus on how this team can work within the system and creating a framework for athletes. Lastly, the lack of educational programming is very apparent from the results of this study. Finding an effective way to implement educational programming for athletes and stakeholders can change the trajectory of RED-S. Creating more awareness and education around

this topic is the overall goal that we need to achieve to help prevent RED-S from continuing to increase in prevalence.

Appendix A Qualtrics Survey Questionnaire (RKQ)

This survey will consist of three sections. The first section will consist of questions about your demographics. The second section will have questions regarding your current knowledge of RED-S. The third section will have questions pertaining to resources and educational programming. Your answers are completely anonymous. This survey should take 10-15 minutes to complete. Your participation is completely voluntary, and you may choose to leave the survey at any point.

To take this survey you must be a coach or athletic trainer of female athlete(s) between the ages of 12-18. You may hold more than one of these roles, however please select ALL relationships you have with the female athlete(s). If you meet these requirements and would like to complete this survey, please click the button below to begin.

Are you a coach or athletic trainer of female athlete(s) between the ages of 12-18?

a. Yes
b. No

Demographic Questions:

1. What is your age in years? ___
2. What do you identify as?
    a. male
    b. female
    c. non-binary
    d. Transgender Female
    e. Transgender Male
    f. Agender/ I do not identify with a gender
    g. prefer not to respond
3. What is your relationship with your female athlete(s)? (Please select both if applicable)
    a. Coach of female athlete(s) aged 12-18
    b. Athletic Trainer (AT) for female athletes aged 12-18
4. Please select any additional roles you hold along with being a coach or athletic trainer. (NOTE: Please select ALL roles)
    a. Parent of female athlete(s) aged 12-18
    b. Health/Physical Education Teacher for female athlete(s) aged 12-18
    c. Personal/Specialized Trainer for female athlete(s) aged 12-18
5. What is the highest degree you have completed?
    a. High school diploma / GED
    b. Associate's degree
        i. area of study

c. Bachelor's Degree
    i. area of study
d. Master's Degree
    i. area of study
e. Doctoral Degree
    i. area of study

6. What level of sport are you currently coaching or providing healthcare for? Please select more than one answer if applicable
    a. Club
    b. Highschool
    c. Cup
    d. Travel
    e. Regional
    f. College
    g. Not applicable
7. What sport(s) are you currently coaching or providing healthcare for at this level? (If appropriate, choose more than one).
        i. Cross Country
        ii. Field Hockey
        iii. Soccer
        iv. Volleyball
        v. Gymnastics
        vi. Basketball
        vii. Softball
        viii. Swimming/Diving
        ix. Rowing
        x. Track & Field
            1. Sprints
            2. Jumps
            3. Throws
            4. Hurdles
            5. Multi-events
            6. Walk
            7. Middle & Long distance (800 m and above)
        xi. Dance
        xii. Other
8. How many years have you been coaching or providing healthcare for this sport?
    a. 1-5 years
    b. 6-10 years
    c. 10-15 years
    d. 15-20 years
    e. 20+ years

9. *If Coach is selected* - What is your current position in your coaching role? Please include the number of years coaching in this role.
    a. Head Coach
        i. Years
    b. Assistant Coach
        i. Years
    c. Graduate Assistant
        i. Years
    d. Student (undergraduate) coach
        i. Years
10. What female sports have you coached or provided healthcare for in your lifetime? (please check all that apply).
    a. Cross Country
    b. Field Hockey
    c. Soccer
    d. Volleyball
    e. Gymnastics
    f. Basketball
    g. Softball
    h. Diving
    i. Rowing
    j. Track & Field
        i. Sprints
        ii. Jumps
        iii. Throws
        iv. Hurdles
        v. Multi-events
        vi. Walk
        vii. Middle & Long distance (800 m and above)
    k. Dance
    l. Hockey
    m. Flag Football
    n. Other _____
11. What is the total number of years you have been coaching or providing healthcare for female athlete(s)?
    a. _____
12. Have you ever heard of Relative Energy Deficiency in Sport (RED-S), formally known as The Female Athlete Triad?
    a. Yes
    b. No
13. If answer was “yes” to the previous question, how did you first come to know of RED-S?
    a. Personal Experience
    b. Professional contact working with athletes

c. Research/Literature
d. School/Educational Seminar
e. Other ____

Knowledge Questions:

You will now complete the second section of the survey that will ask you a total of 15 knowledge-based questions. Please complete the following questions to the best of your ability.

Following each question please indicate the level of confidence you have in its correctness using the following scale: 1 = Not at all confident, 2 = Somewhat confident, 3 = Confident, 4 = Completely sure.

1. What are the three components of RED-S?
    a. Disordered eating, anemia, osteoporosis
    b. Anemia, amenorrhea, disordered eating
    c. Amenorrhea, disordered eating, osteoporosis
    d. Amenorrhea, osteoporosis, anemia

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

2. How long can the consequences of RED-S affect a female athlete?
    a. Only While she is still competing
    b. Only as long as she remains physically active
    c. Only while they are in-season
    d. For the rest of her life

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

3. Signs and Symptoms of RED-S can include all the following EXCEPT which one?
    a. Dizziness
    b. Hyperactivity
    c. Fatigue
    d. Abdominal pain

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

4. Which of the following is a performance consequence of RED-S?
    a. Insomnia
    b. Enhanced concentration

c. Increased response to training
d. Impaired judgement

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

5. Which is the MAIN cause of Relative Energy Deficiency in Sport (RED-S)?
    a. Eating disorder(s)
    b. Amenorrhea
    c. Low Energy Availability
    d. Anemia

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

6. All of the following are features of RED-S EXCEPT which one?
    a. Term that encompasses low energy availability, including components of the Female Athlete Triad
    b. Affects physiologic function, health, and athletic performance
    c. Only affects women
    d. Affects both able-bodied and disabled athletes

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

7. Can low energy availability be present without a change in weight?
    a. Yes
    b. No

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

8. What is considered menstrual irregularity for any female?
    a. No menstruation for > 3 months
    b. No period by the age of 16
    c. More than 35 day intervals between menstruation
    d. All of the above

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

9. True or False: Hormonal Contraception is recommended in athletes with the Triad/RED-S to resume menses.
    a. True
    b. False

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

10. True or False: Oligomenorrhea (6 or few menstrual cycles per year) is not a major health concern as long as the athlete is menstruating in the off-season.
    a. True
    b. False

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

11. True or False: Menstrual cycle disturbances, of any kind, are a normal part of training and there is nothing wrong with a female athlete losing her period.
    a. True
    b. False

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

12. True or False: Athletes must present all aspects of the Triad/RED-S in order to be diagnosed with either of those conditions.
    a. True
    b. False

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

13. True or False: Because of the impact of running on low bone density, bone loss does not occur in many lightweight athletes.
    a. True
    b. False

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

14. True or False: Repeated stress fractures should serve as a warning with regards to low bone mineral density.
    a. True
    b. False

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

15. True or False: Stressing an ideal weight helps an athlete understand how she can perform best in her sport.
    a. True
    b. False

Please rate your level of confidence for choosing the correct answer on the previous question:

1 2 3 4

Education

In this last block, we will ask questions pertaining to your workplace policies, resources, and continuing education for your coaching or athletic training position only. If you hold a role in multiple programs or institutions, please answer pertaining to your primary workplace. Please reflect on all experiences within your program to provide the best possible answers.

1. Does your workplace currently have a policy in place that specifies what to do when I suspect that a female athlete may be suffering from one or more aspects of RED-S?
    a. Yes
    b. No
2. Would you know how to recognize the signs and symptoms of RED-S?
    a. Yes
    b. No
3. Do you believe your coaches, athletic director, athletic trainers, and other coaching staff have a good understanding of RED-S?
    a. Yes
    b. No
4. Has your athletic department/program provided educational program for the athletes that may be affected by RED-S?
    a. Yes
    b. No
5. Have you received training/educational programming through your current institution/employer regarding RED-S?
    a. Yes
    b. No

6. If you answered yes for the previous question, which component(s) have you received training or educational programming on?
    a. Amenorrhea
    b. Disordered eating
    c. Osteoporosis
7. Indicate the type of GENERAL continuing education you take part in at least once a year (check all that apply in general): *the next question will ask about continuing education directly related to the Triad/RED-S; this is GENERAL continuing education only*
    ▢ Athletic department programs
    ▢ NCAA-sponsored programs
    ▢ Review professional journals
    ▢ Review sport/coaching-related magazines
    ▢ Attend professional conferences
    ▢ Read textbooks related to coaching, physiology, nutrition, etc.
    ▢ Consult professionals (sports physician, dietitian, etc.)
    ▢ Search/read information online
    ▢ Other (please specify): _____
    ▢ I do not participate in any continuing education

8. Indicate the type of continuing education you take part in at least once a year DIRECTLY RELATED to the Triad/RED-S (check all that apply specific to the Triad/RED-S)
    ▢ Athletic department programs
    ▢ NCAA-sponsored programs
    ▢ Review professional journals
    ▢ Review sport/coaching-related magazines
    ▢ Attend professional conferences
    ▢ Read textbooks related to coaching, physiology, nutrition, etc.
    ▢ Consult professionals (sports physician, dietitian, etc.)
    ▢ Search/read information online
    ▢ Other (please specify): _____
    ▢ I do not participate in any continuing education
9. Are you aware of any resources available to you/your female athletes regarding RED-S through your current institution?
    a. Yes
    b. No
10. Would you feel confident identifying RED-S in your female athletes?
    a. Yes
    b. No
11. Would you be comfortable referring your female athletes to a resource to get help with any RED-S symptoms?
    a. Yes
    b. No

12. If your workplace provided educational training for you with respect to RED-S, would you attend or take the course?
    a. Yes
    b. No
13. If educational training with regards to RED-S was required by your workplace, would you prefer the training be online or in-person?
    a. Online
    b. In-person

Appendix B Tables and Figures

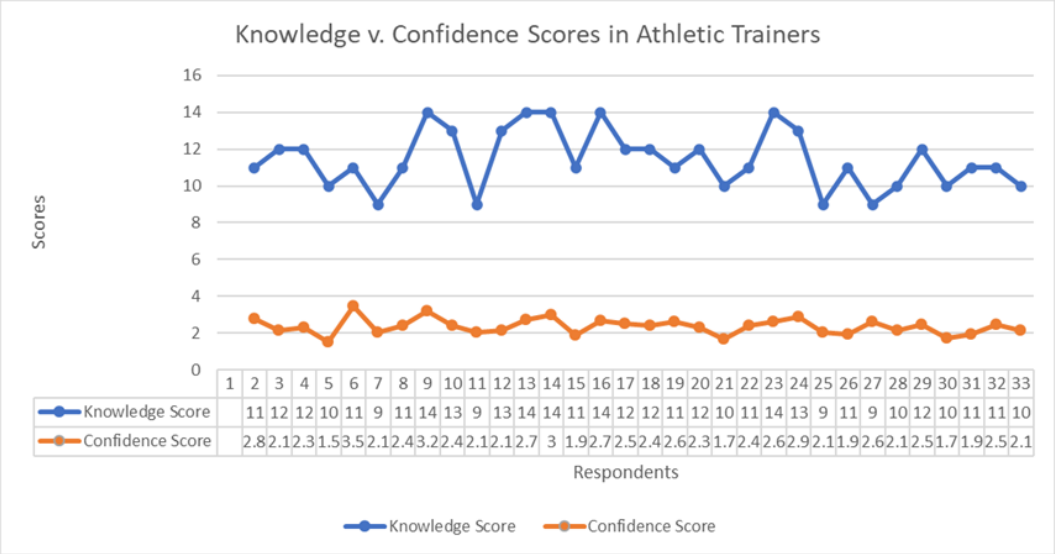

Figure 15 Knowledge v. Confidence Scores in Athletic Trainers

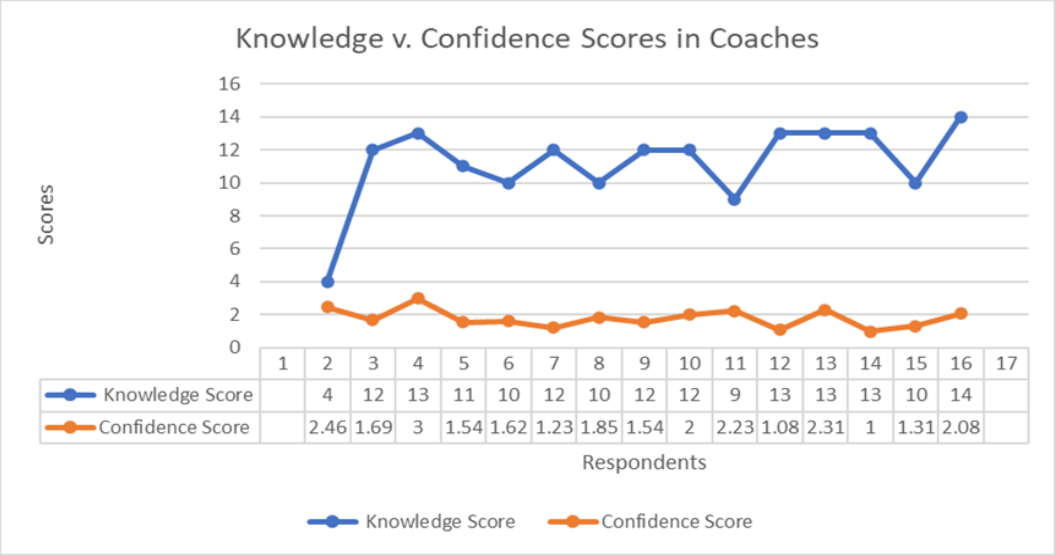

Figure 16 Knowledge v. Confidence Scores in Coaches

Roles	Knowledge Score	Confidence Score
Parent and Coach (n=4)		
	12	1.7
	12	1.2
	13	1
	14	2.1
Average	**12.75**	**1.5**
Parent and AT (n=2)		
	9	2.6
	11	2.4
Average	**10**	**2.5**

Table 2 Knowledge and Confidence Scores for Parents

Roles	Knowledge Score	Confidence Score
Personal Trainer and Coach (n=2)		
	4	2.3
	13	2.9
Average	**8.5**	**2.6**
Personal Trainer and AT (n=1)		
	14	3
Average	**14**	**3**

Table 3 Knowledge and Confidence Scores for Personal Trainers

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