Awareness and Knowledge of the Female Athlete Triad and Relative Energy Deficiency in Sport (REDs) among Multi-Specialty Healthcare Professionals

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I truly hope that our efforts will contribute to better health and well-being for all exercising individuals, athletes, and dancers.

ABBREVIATIONS

ACSM: American College of Sports Medicine
AN: anorexia nervosa
BMD: bone mineral density
BSI: bone stress injury
CBT: cognitive behavioural therapy
CPD: continuing professional development
DEXA: dual-energy x-ray absorptiometry
EA: energy availability
EI: energy intake
EE: energy expenditure
EEE: exercise energy expenditure
FFM: fat-free mass
FHA: functional hypothalamic amenorrhea
FSH: follicle stimulating hormone
GH: growth hormone
HCP: healthcare professional/practitioner
HPA: hypothalamic pituitary adrenal
IGF-1: insulin-like growth factor
LBM: lean body mass
LEA: low energy availability
LH: luteinizing hormone
OCP: oral contraceptive pill
IOC: International Olympic Committee
REDs or RED-S: Relative Energy Deficiency in Sport
RMR: resting metabolic rate
Triad: The female athlete triad
TSH: thyroid stimulating hormone

Chapter 1: ABSTRACT

Background

The female athlete triad (Triad) and Relative Energy Deficiency in Sport (REDs) are serious conditions with harmful health and athletic performance consequences. International research suggests that awareness and understanding of these terms and their associated repercussions among healthcare professionals is lacking. The awareness and knowledge of the Triad and REDs among healthcare providers in South Africa is unknown.

Objective

The aim of this study is to investigate the knowledge and awareness of the Triad and REDs, and the comfort of multi-specialty healthcare professionals in diagnosing, treating, and referring individuals with these and related conditions.

Methodology

An online expert-reviewed questionnaire was designed and distributed to healthcare professionals to assess awareness and knowledge.

Results

Of the 162 survey participants, 51% were aware of the Triad and 40% were familiar with the term REDs. Of those aware of the Triad, 46% were able to identify all 3 components. Among those familiar with REDs, 69% were able to recognise that low energy availability (LEA) is the main underlying cause, 80% had good knowledge of potential REDs consequences, and 60% were able to correctly identify potential symptoms of REDs. Investigatory practices regarding certain health manifestations including low bone mineral density and menstrual dysfunction were found to be lacking. Overall, 6%, 8% and 44% reported feeling very comfortable diagnosing, treating, and referring those with REDs respectively. Only 14% felt very comfortable diagnosing disordered eating and eating disorders.

Conclusion

Overall, healthcare professionals have generally poor awareness of the Triad and REDs, as well as low rates of comfort in diagnosing, treating, and referring those with REDs. Education strategies to address the gaps in awareness and knowledge among multi-specialty healthcare providers is warranted.

Chapter 2: INTRODUCTION

2.1 Background

Sports and physical activity participation boast numerous health, social and psychological benefits, and the benefits far outweigh the risks. However, in the 1990's researchers and clinicians identified a condition in female athletes and dancers now known as the Female Athlete Triad (Triad), which is characterised by 3 inter-related components: (1) low energy availability (LEA), (2) menstrual dysfunction, and (3) impaired bone health, existing on a spectrum of health to disease[1]. More recently it has been recognised that LEA can also affect athletes and exercisers of all sexes; and can potentially have many more consequences beyond the female reproductive system and bone health[2,3]. As a result, the International Olympic Committee (IOC) recently introduced the term Relative Energy Deficiency in Sport (REDs)[2].

LEA is the underlying cause of both the Triad and REDs and can be described as insufficient energy available for normal physiological processes once energy expended through exercise is subtracted from total dietary energy intake. REDs incorporates the multiple health consequences of LEA including but not limited to cardiovascular, gastrointestinal, endocrine, psychological, immune, bone health, metabolic and reproductive dysfunction; as well as detrimental impairments to exercise performance such as endurance performance, muscle strength, judgement, coordination, training response and increased injury risk[3]. The effects of LEA are particularly critical to the adolescent athlete, affecting peak bone density accrual and growth, and neurological and reproductive development, with potentially severe long-term consequences[4–6]

In many sports and dance contexts, there is an emphasis on achieving a lean physique or low body fat with the perception that this may enhance performance and/or aesthetic appearance, which in turn encourages dietary restriction and/or an increased exercise energy expenditure in order to achieve this. However, these practices put athletes and dancers at risk of LEA, the Triad and REDs. Other situations that can also result in the Triad and REDs include eating disorders, disordered eating, and food insecurity; as well as high training volumes with reduced opportunities to eat, suppressed appetite, or poor nutritional knowledge[7–10].

Early identification of REDs, as well as appropriate and timeous treatment thereof, are essential to prevent the deleterious long-term complications[11]. Although prevalence and risk of LEA and REDs has been found to be concerning among certain groups of athletes worldwide[12], awareness and knowledge among athletes, coaches and medical practitioners is limited[3,13]. Internationally, awareness and knowledge of the Triad amongst healthcare professionals appears to be improving, however feelings of comfort in treating athletes with the Triad and REDs is still poor[14–16]. No previous research has investigated Triad and REDs knowledge and understanding among healthcare professionals in South Africa.

In order to improve diagnosis, treatment and prevention of the Triad and REDs, further research to assess the awareness and knowledge of these conditions amongst multi-specialty healthcare providers is warranted. This in turn may help to improve health and performance outcomes of athletes at all levels of exercise and sports participation.

2.2 The history and evolution of the Triad and REDs

A link between menstrual disturbances and suboptimal bone health in female athletes was established in the 1980's through the work of Dr Barbara Drinkwater[17]. The term 'Female Athlete Triad' was first officially recognised by the American College of Sports Medicine (ACSM) in 1992, and in 1997 the first ACSM Female Athlete Triad position stand was published, where it was hypothesized that the hypothalamic-pituitary-ovarian axis is disrupted by LEA, menstruation is suppressed, and the consequent hypoestrogenism subsequently affects bone mineral density (BMD)[18]. The Triad position stand was updated in 2007 to reflect the work done by Dr Anne Loucks and colleagues on recognising the causal role of LEA (and not stress of exercise) on reproductive and bone health outcomes via endocrine and metabolic adaptations and dysfunction, and identifying that each of the Triad components can exist on a spectrum of health to disease and that the presence of any one of the three symptoms poses a risk for the female athlete[19,20]

The term Relative Energy Deficiency in Sport (REDs) was first described by the IOC in 2014 (updated in 2018) as an extension of the Triad, and was defined as: "impaired physiological function including, but not limited to, metabolic rate, menstrual function, bone health, immunity, protein synthesis, cardiovascular health caused by relative energy deficiency", in order to recognise the broader and more comprehensive adverse health and performance effects that LEA can have[2,3].

Considerable research has been undertaken since the Triad and REDs terms were coined, to further understand the physiological and performance effects of LEA. However, it is only recently that research has progressed to recognise these issues in men, where similar metabolic and endocrine changes have been observed due to LEA, and their associated negative effects on reproductive and bone health, as well as injuries and performance[21–23]. In

2021 the Female and Male Athlete Triad Coalition released a 2-part consensus statement on the Male Athlete Triad, which recognised an interrelationship between LEA, functional hypogonadotropic hypogonadism, and poor bone health in men. This has further highlighted that the effects of LEA are prevalent and problematic in male athletes and exercisers, and addresses strategies for management and prevention in this population[24,25].

More recently, the 2023 IOC consensus statement on REDs was published. This incorporates the substantial scientific advancements made in the REDs research domain since 2018, which have enhanced our understanding of REDs signs and symptoms, the complexity of the effect of LEA on health and performance outcomes for individual athletes, the psychological factors that contribute to LEA, the potential mental health consequences of REDs, and different clinical presentations between male and female athletes[26].

While the two terms (i.e. Triad and REDs) may significantly overlap in the clinical syndrome presented, currently consensus on incorporating the two terms into one clinical entity have not yet been reached and therefore the two terms remain at present[19].

2.3 Low energy availability (LEA)

LEA is the underlying aetiological factor of the Triad and REDs syndromes and is defined by the IOC as a “mismatch between an athlete’s energy intake and the energy expended in exercise, leaving inadequate energy to support the functions required by the body to maintain optimal health and performance”[3].

LEA occurs when either energy intake is reduced or when exercise load is increased, or both, which results in the body systems needing to adjust in order to conserve energy, leading to endocrine, metabolic and functional disruptions[2]. This is in line with human and animal studies which have found that energy-sparing occurs during times of energy deprivation, where fuel is redistributed away from growth and reproduction to prioritise physiological functions essential for survival[27,28]. A common analogy used by practitioners when explaining these adaptations that occur to save energy, is that of a mobile phone changing to ‘power-saving mode’ when its battery life is low.

Energy availability (EA) is calculated as energy intake (EI) (kcal) minus exercise energy expenditure (EEE) (kcal) divided by lean body mass (LBM)[3]. Strict laboratory-controlled trials in sedentary females have shown that an optimal EA for healthy physiological functioning is >45kcal/kg LBM/day, and that even short periods (4-5 days) of EA of < 30kcal/kg LBM/day resulted in markedly impaired endocrine markers, thus defining this as the threshold for low

EA[29,30]. However, subsequent laboratory studies have not supported this threshold (30kcal/kg LBM/day) as a strategy to prevent menstrual disruption and other LEA symptoms, and rather that there is individual variability in levels of EA at which disturbances may occur[21]. In a study on exercising men, 40kcal/kg LBM/day was found to be a sufficient threshold to ensure optimal EA[31], but there is currently not enough data to identify a threshold for LEA in men[24].

Furthermore, applying these thresholds in the field setting is challenging due to large variability and poor accuracy when performing field-based body composition, EI and EE assessments and measurements[32].

It has recently been proposed that LEA should be described as existing on a continuum – from adaptable to problematic, whereby adaptable LEA is mild and transient with potentially minimal impact on long-term health and performance, and problematic LEA exposure (longer duration, magnitude and/or frequency) being associated with adverse physiological and performance outcomes. However, it has also been recognised that certain moderating factors (such as gender, age, genetics, individual characteristics, and environmental factors) may influence the outcome of varying degrees of LEA[26]. Further research is required to improve understanding of these various factors.

2.4 Reasons and risk factors for LEA

There are a plethora of factors that may put an athlete at risk of developing LEA. It is common for athletes to pursue specific body composition or weight changes, and in order to achieve their desired outcome may intentionally restrict their food intake and/or increase their training. However, athletes may also experience LEA inadvertently during periods of increased training volume or when engaging in sports with a high energy expenditure without a subsequent increase in food intake, and/or due to suppressed appetite during periods of high-intensity training, or as a result of food insecurity, poor nutritional knowledge or lack of time. Disordered eating behaviours and eating disorders are also common contributors to LEA in athletes[7,8,10].

2.4.1 Training demands, dietary knowledge and eating behaviours

Previous research has indicated that athletes often tend to underestimate their energy requirements, which can predispose them to a higher risk of LEA. Many athletes, including those training for endurance and ultra-endurance events, have extremely high energy requirements (or go through certain phases of their training schedule where this is the case) which need to be matched by a corresponding amount of food, which some find challenging[7,33]. Other factors that may prevent athletes from meeting their energy requirements are lack of time to prepare meals, inadequate cooking skills, financial constraints, and limited access to food options and cooking space or equipment (especially when travelling or when living in boarding establishments). Many athletes have very busy schedules with other life stressors (e.g., study, work, and family responsibilities) on top of their training and competition demands[8,34]. Research consistently shows that athletes tend to have a lack of appropriate sports nutrition knowledge and are commonly exposed to nutrition misinformation likely via coaches, teammates, parents, the internet, and social media[35–38]. Knowledge amongst athletes and their support systems regarding the negative consequences of LEA and REDs is also poor[3,12,13,34,39]. As a result, athletes may follow inappropriate diets or eating patterns (such as intermittent fasting, low carbohydrate diets, 'clean eating', skipping meals), or adopt strict healthy diets (in the pursuits of being a dedicated, disciplined athlete), or restrict certain food groups (i.e., carbohydrate), which puts them at risk of LEA[7,40]. Diets very high in fibre may also increase risk due to early gastrointestinal fullness[41].

2.4.2 Body image, disordered eating, and mental health

Participation in certain sports such as aesthetic, weight-category, or any sport where it is presumed that body mass influences performance, may increase risk. Athletes often feel pressure to conform to a certain body type or aesthetic appearance, or are exposed to the belief that 'lighter is faster' or that they need to be 'thin to win', and this in turn predisposes them to restrictive dieting, body dissatisfaction and disordered eating[7,42,43]. Often an initial weight reduction does lead to improved performance which may then drive the athlete to continue dietary restriction in the pursuit of further weight loss, and a subsequent slip into an eating disorder. Body changes are often praised by people around the athlete, which can motivate them even further[44,45].

Recent studies implicate that even when athletes are aware of the detrimental health and performance implications of REDs, they are simultaneously contending with pressures to achieve or maintain an 'ideal' physique which can undermine their abilities to attain adequate EA[46]. Athletes are exposed to the same body appearance pressures that are prevalent in general society, in addition to socio-cultural pressures specific to the sporting world (e.g., to 'look like an athlete')[47,48]. In 2019 elite runner Mary Cain publicly shared her story of body-shaming and excessive pressure to lose weight by her coach, and her subsequent injuries and health issues due to REDs[49,50]. A study in 2015 found that 60% of athletes across a range of sports experienced feeling pressure from their coaches regarding their body[51]. Keay et al found that 44% of female and 32% of male dancers reported being instructed to lose weight by teaching staff[52], and coaches appeared to show preference for lower body fat levels in a recent study on female soccer players in the UK[40]. In a qualitative study by Carson et al, female distance runners reported that coach's comments about body weight and shape, as well as food and body policing, contributed to body image disturbances and disordered eating patterns[48]. Negative body comments from coaches, teammates, parents, and judgemental expectations from wider society can have a severe impact on body image and satisfaction, and ultimately influence dietary behaviour and enhance the progression of LEA and disordered eating[40,53]. Many athletes have also reported being victims of body shaming and cyber bullying via social media. Another reason that social media is problematic, is that athletes tend to compare their body shape and size, meals and training volume with fellow athletes, competitors and sporting 'idols', which can contribute to poor body image, body dissatisfaction, dietary restriction, disordered eating, and potentially contribute to LEA[8,40,54,55]. The common practice of monitoring of body weight and body composition may also impact negatively on body image and dietary intake, and trigger disordered eating behaviours in certain athletes[40,56–58].

Any athlete with disordered eating patterns is at increased risk for LEA and REDs. Research repeatedly shows that athletes are more predisposed to developing eating disorders and disordered eating compared to the general population. The current overall estimated prevalence of disordered eating and/or eating disorders in male athletes is 0-19%, and 6-45% in female athletes across a range of sports, with estimates of clinically diagnosed eating disorders occurring three times as often than in non-athletes (prevalence of 2-45%)[7,10,47]. In a recent study, Buckley et al found that 21% of current and former athletes showed EAT-26 scores indicative of clinical eating disorder pathology (n = 43)[56] . Dervish et al reported that 9% and 40% of female endurance runners were at risk of eating disorders and disordered eating respectively (n=524)[57], Fahrenholtz et al discovered that 21% of female endurance athletes (n=202) had disordered eating[43], and Karlsson et al found that 18% of female recreational runners had eating disorder symptoms[58]. Among young athletes from a variety of sports, Magee et al identified that 69% of females (n=52) and 43% of males (n= 42) were classified at risk for eating disorders[59]. Studies on prevalence rates among South African athletes show that 14.7% (n=278) of amateur athletes across a range of sports[60], 54% (n=27) of netball players[61], 32% (n=306) of female ultra-endurance runners[62], and 62.5% (n=16) of track and field athletes[63] show evidence of disordered eating behaviour.

In a qualitative study on REDs, athletes reported that psychological and social mechanisms such as perceived need for control, perfectionism, low self-worth or confidence, trauma, grief, social approval, sporting culture, and pre-existing disordered eating or eating disorders were considered contributors to LEA onset[44]. Gibbs et al demonstrated that a high drive for thinness was associated with energy deficiency and a higher prevalence of menstrual dysfunction in exercising women[64], and Torstveit et al found that male athletes with higher exercise dependence scores were more likely to have eating disorder symptoms and REDs biomarkers[65].

2.5 Prevalence of LEA, The Triad, AND REDs

Although there is currently no gold standard when it comes to diagnosing LEA, a narrative review by Logue et al in 2020 found estimated prevalence rates across a variety of sports ranged from 22% to 58%[12]. While participation in certain sports may increase risk of LEA, recent evidence shows that it can be problematic in any sport, and at any level (recreational to elite).

In elite middle and long-distance runners LEA was prevalent in 31% (females) and 25% (males)[23] and Melin et al reported that 18 – 58% of track and field athletes were detected with LEA with the highest prevalence among endurance and jump events[66]. Among 1000 female athletes presenting at a sports medicine clinic directed by Dr Kathryn Ackerman, 47.3% were identified with LEA and REDs symptoms[67]. Similarly, within a group of 524 recreational and competitive endurance runners in the UK, 47% were identified as high risk for LEA[57], and 65% of European female endurance athletes (n=202) were categorized with LEA[43]. Keay et al found that 28% of male cyclists (n=50) were classified with LEA and health and performance consequences[68], and 57% of female and 29% of male high-level dancers displayed indicators of LEA (n=247)[52]. A recent study assessing 47 British female soccer players identified that 88% of players presented with clinical LEA[69], and REDs symptoms were prevalent in up to 80% of a cohort (n=112) of elite and pre-elite athletes in Australia[70]. Magee et al found that 52% of female high school and collegiate athletes from a variety of sports were at risk for LEA[59].

Only three studies have investigated prevalence rates of LEA in South Africa: Folscher et al showed that 44% of female ultra-marathon runners (n=306) were at high risk of LEA (keeping in mind that this study may also have included international runners)[62]. Havemann et al found that 31% (n=27) of student netball players presented with amenorrhea and inadequate energy intake[61], and Robbeson et al discovered that 73.3% (n=16) of female student track and field athletes had estimated LEA and 87.5% displayed components of the Triad[63].

2.6 Current awareness and knowledge of the Triad and REDs among health professionals

Despite the mounting scientific evidence for the risk of serious health and performance consequences of LEA, and high estimated prevalence rates [12], there is little research exploring the knowledge and treatment of REDs among health professionals. Awareness of the Triad among health professionals has been previously investigated. A study of 240 health and coaching professionals (n=240) in 2006 determined that just under half could identify components of the Triad [14]. In a survey of 931 multi-specialty physicians, only 37% were aware of the Triad, and only a half of these said that they felt comfortable treating or referring a patient [15]. More recently, a survey performed at a sports medicine meeting in the United States in 2018 found that of the 163 healthcare providers, 76% had heard of the Triad, whereas only 29% had heard of REDs. Thirty-three percent (33%) of respondents reported feeling comfortable treating athletes with the Triad, while fewer (13%) agreed that they felt comfortable treating athletes with REDs [16]. Athletes also report that they have felt unsupported and dismissed when seeking assistance from medical staff (including general practitioners and sports physicians) regarding symptoms of REDs[44]. The knowledge and understanding of the Triad and REDs among health professionals in South Africa are unknown.

2.7 Consequences of LEA, the Triad, and REDs

As mentioned previously, the Triad represents the clinical presentation of LEA, menstrual dysfunction, and poor bone health, whereas the REDs model represents an expanded clinical picture recognising that there is a wider range of health consequences associated with LEA, and that athletic performance may also be adversely affected. As it is recognised that the key cause is that of LEA, we describe below some of the consequences of LEA which result in the clinical presentations of the above.

2.7.1 Health effects of LEA

I. *Endocrine and reproductive function*

Under circumstances of LEA, energy is diverted away from the reproductive system as a survival mechanism, which can result in the disruption of gonadotropin-releasing hormone (GnRH) secretion and alterations in other sex hormones. This may be demonstrated by changes in luteinizing hormone (LH) and follicle stimulating hormone (FSH), and reductions in oestradiol (in females), and testosterone (in males). Functional hypothalamic amenorrhea (FHA) and menstrual dysfunction (including subtle disturbances such as anovulatory cycles and luteal phase defects) in females is a well described manifestation of these endocrine changes[3,22,71]. The effect on male athletes is less well-studied, however there is evidence that LEA can lead to low testosterone levels, or hypogonadotropic hypogonadism. Symptoms of low testosterone levels can be low libido, erectile dysfunction, and decreased shaving of facial hair[25].

Increased stress (physical and psychological) on the hypothalamic pituitary adrenal (HPA) axis as a result of LEA, may lead to increased tissue exposure to serum cortisol, which can negatively affect bone health and athletic performance[22,71].

Studies on LEA consistently show lowered levels of triiodothyronine (T3) in females and a 'sick euthyroid' profile is regularly noted. This is a result of a downregulation of the hypothalamic pituitary thyroid axis as an adaptation to an energy deficiency, and can result in a lower metabolic rate in an attempt to save energy, and as well as potentially affect growth and reproduction. There can be changes to thyroxine (T4) and thyroid stimulating hormone (TSH) levels, but this seems to be less consistent[22,71,72]. The impact of LEA on thyroid hormones in male athletes is currently less clear[28].

Studies in females with anorexia nervosa (AN) have shown patterns of increased growth hormone (GH) secretion, decreased insulin-like growth factor (IGF-1), and elevated GH resistance[73], as well as linear growth retardation[74]. Similarly, Murphy and Koehler demonstrated that resistance trained individuals that were exposed to LEA, had disrupted GH/IGF-1 responses after exercise, indicating possible impaired anabolic adaptations[28,75].

Leptin, a key hormone involved in energy homeostasis that signals satiety to the brain, has shown to decrease in response to LEA in females and males, and strongly correlates with sex hormone functioning[22,28,71]. Some research has shown evidence of low serum insulin levels in exercisers in a LEA state, which may negatively affect energy storage and anabolism after exercise[22,31].

II. Bone health

Decreased bone mineral density (BMD), altered bone microarchitecture, changes to bone turnover markers, decreased bone strength, and increased bone stress injuries are commonly associated with menstrual dysfunction and LEA[76,77]. Many of these negative effects can be contributed to the endocrine alterations caused by LEA[22]. There is strong evidence of lowered BMD, and increased bone stress injury (BSI) and fracture risk in female and male athletes with LEA. Female collegiate athletes identified as 'high-risk' for the Triad were four times more likely to experience a bone stress injury (BSI) than the 'low-risk' group[78]. A study by Heikura et al showed that female athletes with amenorrhea and male athletes with low testosterone were 4.5 times more likely to suffer from stress fractures than their controls[23]. Male competitive road cyclists (n=50) identified with LEA were found to have significantly lower BMD scores, particularly in the lumbar spine, than those with optimal EA[68], and Hilkens et al found an association between LEA biomarkers and low BMD in elite male and female cyclists (n=93)[79].

III. Metabolic rate and body composition

A reduced resting metabolic rate (RMR) has been observed in groups of ballet dancers, jockeys, rowers and endurance athletes presenting with LEA[3,71,80,81], and researchers suggest that a low RMR ratio may be a potential surrogate marker for LEA[12,82].

It may be presumed that inadequate energy intakes would lead to lower body mass and body fat levels, and some studies have shown this to be the case. However, other studies have shown athletes with cumulative LEA have not reduced body weight nor have they experienced a plateau in weight loss. This finding may potentially be explained by metabolic rate adaptations to LEA[3,8,71], and may make it easier to miss.

IV. Hematological

Poor iron status is regularly observed in those with LEA and has been suggested to be an early indicator of inadequate energy availability. Ackerman et al reported that haematological issues were 1.6 times more likely in female athletes with LEA[67]. It has been recognised that LEA may contribute to low iron stores due to insufficient intake (dietary restriction), exercise-induced losses (i.e., haemolysis, gastrointestinal bleeding, sweating, inflammation), and/or altered hepcidin levels. However, it has also been acknowledged that low iron stores may contribute to LEA and its physiological manifestations, possibly due to impaired metabolic efficiency resulting in increased energy expenditure. In addition, low iron stores may exacerbate some of the negative clinical outcomes associated with LEA, particularly bone health, thyroid function, growth, fertility, psychological well-being, and immunity[3,67,83,84].

V. Immunologic

An observational study on Australian athletes preparing for the 2016 Rio Olympic games, showed that athletes with LEA were 7.5 times more likely to get upper respiratory tract and gastrointestinal illnesses[85]. In support of the REDs model, Sarin et al demonstrated that energy restriction in female physique athletes was associated with alterations in immune markers (including white blood cells, immunoglobulin G glycome, and cytokine profile)[86].

VI. Cardiovascular

Endothelial dysfunction, poor lipid profiles and early atherosclerosis have been shown to be prevalent in athletes with FHA, associated with hypoestrogenism[5,87]. In a cohort of female athletes in the United States, those with LEA were 2.5 times more likely to be identified with cardiac abnormalities[67]. More serious cardiovascular complications (such as bradycardia and orthostatic hypotension) can occur with severe prolonged LEA, as observed in patients with anorexia nervosa (AN)[88].

VII. Gastrointestinal

Gastrointestinal complaints are commonly reported by patients in severe LEA states associated with anorexia nervosa (AN), including constipation, pain, bloating, delayed gastric emptying and increased intestinal transit time[89]. Similarly, among a group of female athletes (n=1000) presenting at a sports medicine clinic, those with LEA reported 1.5 times more gastrointestinal issues than those with adequate EA[67].

VIII. Psychological

The negative manifestations of LEA on psychological well-being are not emphasised enough. Research findings have suggested that LEA may contribute to or be caused by psychological distress, which can additionally prolong and exacerbate REDs symptoms and the recovery process[3,44]. Athletes with inadequate energy intake are more at risk of presenting with anxiety, depression, higher stress levels, irritability, mood changes, substance misuse, disordered eating and eating disorders[3,44,67,90]. Ackerman's group reported that psychological issues were 2.4 times more likely in female athletes with LEA[67]. Female endurance runners with LEA and FHA present with higher drive for thinness scores[9], and male and female endurance athletes with LEA symptomology appear to have increased tendencies towards exercise dependence or addiction[43,91].

2.7.2 Performance effects of LEA

Research showing the direct influence of LEA on sports performance is lacking, however there is ample evidence to prove that an adequate energy supply is essential to enhance athletic performance. It is speculated that prolonged LEA could be detrimental to physical performance via indirect mechanisms such as reduced muscle protein synthesis, altered anabolic hormonal milieu, impairment of glycogen storage, inadequate recovery, and loss of training days due to illness and injury[3,8,28,85]. Ackerman et al found evidence that LEA in female athletes was significantly associated with negative effects on training response, judgment, coordination, concentration, endurance performance, irritability, and depression[67].

In a well-controlled laboratory study, Oxfeldt et al showed that 10 days of LEA impaired myofibrillar and sarcoplasmic muscle protein synthesis with reductions in lean mass in well-trained females, suggesting that LEA may have adverse consequences for skeletal muscle adaptations in this population[92].

Young elite swimmers with ovarian suppression secondary to LEA reported a 9.8% decline in 400m time trial performance after 12 weeks of training, in contrast to their eumenorrheic teammates who improved their times by 8%[93]. Despite having lower body weight and fat mass (which is often perceived as preferable for running performance) Tornberg et al found that elite endurance runners with secondary FHA had decreased neuromuscular strength and endurance, and reaction time compared to eumenorrheic runners, with no difference in aerobic capacity[94]. Another study in east African runners[95] showed similar results, suggesting that pursuing or maintaining lower body weights via prolonged energy restriction is likely to be detrimental to performance. Among a group of young elite Finnish runners, those that were amenorrhoeic were injured more and ran less, and only the eumenorrheic runners improved their performance over the course of a year[96]. In competitive male cyclists, Keay et al identified that chronic LEA resulted in underperformance over a 6-month race season, with no association between body fat and performance[68]. During interviews for a qualitative study by Logue et al athletes reported improved training consistency, fewer injuries and illnesses, and stronger resilience when increasing EA with the support of a sports dietitian[34].

In certain sporting situations it is common for some athletes to be exposed to short periods of LEA (for example, when weight-making in weight category sports, or to alter body composition for a targeted race in endurance sports)[28]. While prolonged and/or severe LEA can have a detrimental effect on performance and health, the effect of shorter duration, controlled LEA is not well understood. However, preliminary data from case studies show that during acute or the initial stages of LEA aerobic performance may not necessarily be impaired[28].

2.8 Assessment, screening, and diagnosis of LEA, the Triad, and REDs

Early recognition of athletes at risk of LEA and identification of the Triad and REDs symptoms is crucial to ensure timely intervention and to prevent long-term health sequelae [97]. However, given that the symptoms of REDs are often subtle, it can sometimes be difficult to recognise, particularly early on. This may also be confounded by other potential causes of the clinical presentation[11].

As discussed, real world measurement of EA is challenging as there are reliability and validity limitations to current techniques used to assess dietary intake and exercise energy expenditure. In addition, these measures are valid only at the point of time of the assessment, and LEA thresholds (<30kcal/kg FFM/d) don't always correlate with health markers known to be affected by LEA (bone, reproductive and metabolic health)[21,23,32]. The clinical ramifications of LEA are further complicated by the findings of some researchers suggesting that small to moderate within-day periods of LEA are associated with detrimental health outcomes despite adequate daily total EA[81].

There are currently a few questionnaires that are used to screen for risk of LEA, the Triad and REDs in sporting populations. However, the sensitivity of their ability to identify athletes with LEA has been questioned, as well as their appropriateness for use with different sexes and sports[98]. The Low Energy Availability in Females Questionnaire (LEAF-Q) has been validated but is only appropriate for female endurance athletes[99], and the Sport-specific Energy Availability Questionnaire and Clinical Interview (SEAQ-I) was developed for male cyclists[68]. The IOC RED-S Clinical Assessment Tool (RED-S CAT) has commonly been used by clinicians to assist with screening and return to play of athletes with REDs[100], and has recently been revised, whereby the updated version (IOC REDs CAT2) aims to further improve screening[26,101]. The Triad Cumulative Risk Assessment tools (separate tools exist for females and males) are also used to screen at-risk athletes and to guide an athlete's clearance for sport but are limited to symptoms associated only with the Triad[5,25]. The Brief Eating Disorder in Athletes Questionnaire (BEDA-Q) is validated to screen for eating disorders in elite adolescent athletes and the Eating Disorder Examination Questionnaire (EDE-Q) is often used as a screening tool for identifying athletes with eating disorder symptoms[10,98].

Although these questionnaires may be useful as screening measures, they should not be used as sole diagnostic tools for LEA, the Triad or REDs, and should be followed up with in-depth clinical interviews[3,66,98]. Quantitative measurements such as blood reproductive and metabolic hormone concentrations, reproductive function signs, and BMD may provide suitable measures of identifying and monitoring LEA[23,25,32,102].

Changes to menstrual bleeding is an easily identifiable potential clinical marker of LEA, however it may be masked by the use of oral contraceptives[103]. Erectile dysfunction, low libido, and decreased frequency of shaving facial hair can be signs of hypogonadism due to LEA in post-pubertal males[25]. Laboratory assessment of reproductive hormones (FSH, oestrogen, LH, testosterone) can be markers of LEA, but may only be apparent with medium to longer-term LEA and can be influenced by medications such as hormonal birth control[32]. Total T3 has consistently been shown to be downregulated with LEA and may be a useful indicator[29,72], and a low RMR ratio (between measured and predicted RMR) is emerging as a potential surrogate marker of LEA depending on the prediction equation and laboratory protocols used[82]. Body weight is not always a reliable indicator of LEA and athletes can have a stable body weight and have LEA, due to metabolic suppression[104], however low body weight (BMI<18.5) in adults and rapid weight loss and/or change in growth trajectory in children and adolescents may indicate an energy deficiency[25,105]. Although body composition assessment may be a useful part of screening for LEA, best-practice protocols and standards should be followed, with particular sensitivity to those with a history or at risk of developing disordered eating, eating disorders and poor body image[10,49,106].

BMD should be measured by dual-energy x-ray absorptiometry (DEXA) in at-risk athletes (i.e. those with suspected problematic LEA or recurrent bone stress injuries). In contrast to the general population, a Z-score < -2.0 is considered below the normal range in the athletic population, and in athletes participating in weight-bearing sports low BMD is defined as a Z-score of < -1.0, especially in those with any additional risk factors[5,25]. It has also recently been suggested that sports-specific Z-score thresholds are needed, so that low BMD is not underestimated in athletes taking part in high impact training[107].

As a result of the stigma, shame and denial associated with eating disorders, they are not always easily identified. Therefore, a comprehensive individual clinical interview needs to take place in order to diagnose[5,10].

Other symptoms and risk factors that may be useful to identify in order to complete a thorough assessment include low iron stores, high cholesterol, vitamin deficiencies, any dietary restrictions, weight cycling, behaviours to control weight, recurrent injuries or illnesses, previous bone stress injuries or stress fractures, mood changes, gastrointestinal complaints, insomnia, poor athletic performance, inconsistent training, poor recovery, chronic fatigue, pressure to lose weight, and other mental health diagnoses (e.g., depression, anxiety). Any other potential causes of symptoms should also be considered and ruled out[5,11,25,100].

An accurate diagnosis of LEA, the Triad and REDs is dependent on a thorough evaluation by a multi-disciplinary medical team, which should consist of at least a sports physician, a registered dietitian (with sports and eating disorder experience) and a mental health professional. Additional members of the healthcare team may include other appropriate specialists depending on the circumstances. As LEA can impact on all biological systems, health professionals in different specialties should be able to identify or screen for potential symptoms, signs or risk factors of the Triad and REDs, and refer to the appropriate practitioners for treatment[5,11,25].

The newly developed and validated IOC REDs CAT2 is a promising tool that aims to assist clinical professionals in early and accurate diagnosis of REDs. It incorporates a three-step process which includes initial screening, severity/risk stratification based on any identified REDs signs or symptoms, and diagnosis by a physician and treatment plan with a multi-disciplinary team.

2.9 Treatment of the Triad and REDs

The recommended treatment for the Triad and REDs is to reverse LEA, as LEA is the main underlying cause of these conditions [108]. Treatment should be undertaken by a multi-disciplinary team of health professionals including the appropriate medical specialists, a sports dietitian, and a sports psychologist as needed, to foster appropriate management of the interrelated components [3,26]. During the treatment process it is essential that the underlying causes of LEA and barriers to improving EA are identified and addressed for optimal recovery and to prevent recurrence of the Triad or REDs[34,44].

EA can be improved by either increasing EI or reducing EEE or a combination of both. Achieving optimal EA by improving EI has been shown to restore menses in female athletes afflicted with FHA, with the addition of one rest day a week[109],as well as without any prescribed changes to EEE[110]. Lagowska et al found that 9 months of individualised dietary counselling to correct LEA (without alterations to EEE) resulted in resumption of menstrual function in a group of ten female athletes and dancers[111]. However, it has been observed that chronic and excessive EEE can put additional stress on the HPA axis which may also contribute to disrupted reproductive function in female and male athletes, indicating that a reduction in EEE may be recommended for certain athletes[112,113]. In situations where athletes are unable to increase EI sufficiently, alterations to training may also need to be made[25,100].

Athletes need to be provided with education and practical strategies to improve dietary energy intake, which is best done by a registered dietitian with sports nutrition experience[3–5,25,108]. It is also important to address timing and frequency of food intake particularly around training sessions. There is evidence to suggest that despite similar 24hr EA, endurance athletes who had higher within-day energy deficits were more likely to have menstrual dysfunction, lower RMR and higher cortisol levels[80,81,108]. Within-day EA fluctuations can result in more time spent in a catabolic state leading to endocrine alterations and increased HPA axis activity contributing to reproductive dysfunction[108].

Macronutrient composition of dietary intake may also be an important factor to consider. Heikura et al found altered bone markers indicating impaired bone turnover in elite race walkers following a 3.5 week ketogenic diet (low carbohydrate, high fat) compared to a high carbohydrate energy equivalent diet[114]. Carbohydrate availability appears to have a positive effect on bone markers, leptin levels, immune parameters and reproductive function, therefore athletes with the Triad or REDs may further benefit from aiming to increase EA with adequate carbohydrate intake[32,108]. High fibre diets may hamper EA recovery due to increased satiety making it difficult to meet high energy requirements. High fibre intakes may also have a detrimental effect on oestrogen reabsorption which can contribute to menstrual dysfunction and associated REDs health consequences[41,115]. Gaskins et al found that a high fibre intake in healthy premenopausal women was associated with lowered circulating oestrogen levels and increased anovulation[116]. Therefore, healthcare providers should be wary of recommending very high fibre foods to those recovering from REDs. Adequate intake of bone-building nutrients (including calcium, vitamin D, protein, magnesium) is also important to prevent further negative effects on bone health[77], and the inclusion of resistance training may help to improve BMD, providing EA is adequate as well[117].

In underweight athletes with FHA, weight gain may be required before normal menses are regained. Weight gain was the strongest predictor of menstrual function normalisation in collegiate athletes undergoing treatment for FHA, and various studies in women with anorexia nervosa (AN) have shown that weight and body fat gain have been effective for menstrual restoration[118,119]. The time frame for menstrual recovery depends on the severity of LEA and duration of menstrual alterations, and typically takes months of adequate EA[5,118].

Current evidence does not support the use of the combined oral contraceptive pill (OCP) for treating amenorrhea or low BMD in athletes with the Triad or REDs, as it masks the menstrual dysfunction and therefore may delay treatment of LEA and has been shown to be ineffective in improving bone health[120,121]. If the normalisation of menstrual function does not occur timeously with non-pharmacologic treatment the use of transdermal oestradiol therapy may be considered on a case-by-case basis[122].

Psychological support is an important component of treatment for those with REDs and may help to facilitate long-term recovery. Psychogenic manifestations may be the underlying cause or consequence of LEA and can be a barrier to achieving adequate EA[46]. Cognitive behavioural therapy (CBT) has been shown to be more effective in the treatment of female athletes with amenorrhoea, than nutritional counselling alone, and the effect of psychogenic stress on the HPA axis should be considered during the treatment process[123]. Disordered eating and eating disorders need to be treated by a multidisciplinary team experienced with these mental health conditions[10].

As LEA can impact on all biological systems, has hugely detrimental consequences, and high prevalence rates, health professionals in different specialties should be aware of the Triad and REDs. In fact, all healthcare practitioners that work with athletes (from recreational exercisers to elite level) should be able to identify or screen for potential signs and symptoms of these conditions, as well as those at risk, and should be able to refer to appropriate healthcare practitioners for multidisciplinary treatment[11].

Chapter 3: AIMS

Aim of the study

The study aims were to investigate the awareness and knowledge of the Female Athlete Triad (Triad), and Relative Energy Deficiency in Sport (REDs) amongst multi-specialty healthcare professionals.

The secondary aims were:

I. To evaluate the comfort and ability among multi-specialty healthcare professionals in diagnosing, treating, or referring these individuals for appropriate intervention.
II. To identify where there may be gaps in clinical knowledge within the medical community, where targeted education could be directed.

We hypothesized that the knowledge, awareness, and comfort in treating athletes with the Triad and REDs would be low across professions.

Chapter 4: METHODOLOGY

4.1 Study design

A descriptive cross-sectional study was performed using a survey among appropriate multi-speciality healthcare professionals. The data was collected and managed using a voluntary online anonymous questionnaire which was expert reviewed and pretested, including closeended and multiple-choice questions. The questionnaire was designed to be time-efficient and took participants approximately 5-10 minutes to complete. Study data were collected and managed using REDCap electronic data capture tools hosted at the University of Cape Town[124,125]. REDCap (Research Electronic Data Capture) is a secure, web-based software platform designed to support data capture for research studies providing 1) an intuitive interface for validated data capture; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for data integration and interoperability with external sources.

The following variables were collected (see appendix 2):

1. Demographic details including, but not limited to, profession, gender, and work setting.
2. Awareness of the Triad and REDs as medical conditions.
3. Knowledge of the components of the Triad.
4. Knowledge of the main underlying cause, consequences, and signs or symptoms of REDs.
5. Knowledge of appropriate BMD assessment in the athletic population.
6. Knowledge around menstrual irregularity in athletes as a result of LEA, and the appropriate medical management thereof.
7. Level of comfort diagnosing, treating, and referring athletes with REDs.
8. Level of comfort detecting an eating disorder or disordered eating.

The questionnaire was developed using the following steps:

1. An in-depth review of the literature was performed to ascertain the most important concepts to assess. Pubmed was used for the literature search.
2. Relevant and appropriate questions were identified from similar type studies in the current literature [14] [15] [16] [13] [126] [127] [128].
3. The questionnaire was assessed by 10 appropriate experts with knowledge and experience of the Triad and REDs (including experienced sports dietitians, musculoskeletal radiologists, a sports endocrinologist, orthopaedic surgeons, and sports physicians) and was pre-tested among a group of health professionals.
4. Through an iterative process appropriate revisions were made and assessed.

The study was performed in accordance with the principles of the declaration of Helsinki (2013), and the Department of Health: Ethics in Health Research. It was approved by the University of Cape Town, Department of Surgery as well as the University of Cape Town, Faculty of Health Sciences, Human Research Ethics Committee (HREC REF 305/2022). No funding was received for this research.

4.2 Research Participants

The questionnaire was distributed via email to approximately 1000 healthcare professionals (as estimated from the specialty association membership numbers), and the expected response rate was 20-30% as per similar type surveys in the current literature [13,15,16]. The questionnaire was aimed at and primarily targeted qualified and appropriate healthcare providers within South Africa that would be likely to treat patients participating in professional and recreational sport and dance, including but not limited to orthopaedic surgeons, radiologists, gynaecologists, endocrinologists, sports physicians, general practitioners, physiotherapists, biokineticists, and registered dietitians. It was distributed via database administrators from speciality associations within South Africa (such as the Association for Dietetics in South Africa, the South African Sports Medicine Association, the Radiological Society of South Africa, the South African Orthopaedic Association, the Society for Endocrinology, Metabolism and Diabetes of South Africa, Non-Diet Health Professionals South Africa, and the South African Society of Obstetricians and Gynaecologists). Although the questionnaire was only distributed within South Africa, we did not specify that international practitioners were not eligible to complete it. Healthcare providers were asked to participate in the questionnaire voluntarily and anonymously. Participants received a link to complete the questionnaire at their leisure and were given 4 weeks within which to respond. REDcap was used to capture the responses, which ensured that the responses were from the intended healthcare professionals.

4.3 Measures

Prior to commencement of the questionnaire, survey participants were asked to provide informed consent and were advised that their responses would remain anonymous. The questionnaire consisted of 19 questions. Questions 1-5 were aimed at collecting demographic data from the healthcare professionals (HCPs) including professional specialty, work environment (private, public, or combined), gender, country of practice (South Africa or other), whether they treated patients participating in sport, and whether they participated in sport themselves. Question 6 and 8 asked the participants if they were familiar with the term Female Athlete Triad and Relative Energy Deficiency in Sport. If they answered ‘yes’ then the questions proceeded to assess knowledge of the components of the Triad as well as the underlying cause, symptoms, and consequences of REDs. These questions were structured in the form of a checklist for the Triad components and multiple choice for the REDs knowledge questions. If they answered ‘no’ these questions were skipped. Question 12 and

13 were multiple choice answers and investigated knowledge regarding bone health assessment practices. Question 14 and 15 assessed knowledge regarding menstrual dysfunction associated with LEA and the treatment of 'athletic amenorrhea' with the OCP. Answer options for these 2 questions were yes, no, or unsure. Question 16 to 18 asked the participants about their comfort in diagnosing, treating, and referring patients with REDs, and question 19 about their comfort in diagnosing eating disorders and disordered eating. Options for these were very, somewhat, and not at all.

4.4 Data analysis

Data were obtained from the questionnaire and analysis was performed using Microsoft Excel and SPSS (version 1.0.0.1461; IBM corp). Statistical significance was accepted when $p<0.05$. Data are presented as mean ± standard deviation, median (with interquartile range), or count (number and %), unless otherwise stated. The Shapiro-Wilks test was used to determine whether data were normally distributed. Between groups comparisons were conducted using Fisher's exact or Chi Squared tests.

Chapter 5: RESULTS

5.1 Participant characteristics

A total of 162 healthcare professionals (HCPs) gave consent and participated in the questionnaire (table 1), of which 54% were male, 44% were female, 1% identified as gender variant/non-conforming, and 0.6% preferred not to say, as presented in Table 1. Orthopaedic surgeons (29%) represented the largest percentage of specialists to complete the questionnaire, followed by radiologists (21%), sports physicians (10%), registered dietitians (9%), general practitioners (7%), physiotherapists (8%), gynaecologists (6%), other (6%), biokineticists (3%), and endocrinologists (1%). Sixty-seven percent of practitioners reported that they worked in private healthcare settings, 16% in public health, and 17% in combined private and public healthcare environments, with 92% reported that they practiced in South Africa and 8% in other countries. Eighty-five percent reported that they treated patients participating in recreational or professional sport or dance, and 76% participated in sporting or dance activities themselves.

For the purpose of gaining greater understanding into the knowledge distribution amongst healthcare professionals and the possible areas of future intervention, some of the analyses compared the findings from the participants separated into two groups – medical doctors (radiologists, orthopaedic surgeons, endocrinologists, sports physicians, and gynaecologists;

n=120, 74%) and allied health practitioners (dietitians, physiotherapists, biokineticists, and other; n=42, 26%).

Table 1

Demographic information and descriptive characteristics of participants (n=162)

VARIABLE	N (%)
Gender	
Male	87 (54%)
Female	72 (44%)
Gender variant/non-conforming	2 (1%)
Prefer not to say	1 (0.6%)
Profession	
Orthopaedic surgeons	47 (29%)
Radiologists	34 (21%)
Sports physicians	16 (10%)
Registered Dietitians	15 (9%)
General practitioners	12 (7%)
Physiotherapists	13 (8%)
Gynaecologists	9 (6%)
Biokineticists	5 (3%)
Endocrinologists	2 (1%)
Other	9 (6%)
Healthcare setting	
Private	108 (67%)
Public	26 (16%)
Combined	28 (17%)
Location	
South Africa	148 (92%)
Other	13 (8%)
Treat patients participating in sport	
Yes	138 (85%)
No	24 (15%)
Participate in sport	
Yes	123 (76%)
No	39 (24%)

5.2 Awareness and knowledge of the Triad

Overall, just over half of the participants (51%; n=83) were familiar with the term, Female Athlete Triad (the Triad), whereas the remaining 49% (n=79) were not (figure 1). When comparing the two groups of respondents – i.e., medical doctors and allied health practitioners, significantly more allied health practitioners were aware of the Triad (85% vs 40%; p<0.001). More specifically, 23 out of 47 (49%) orthopaedic surgeons, and 2 out of 34 (6%) radiologists reported awareness. Although smaller cohorts, 15 out of 16 (94%) sports physicians, 13 out of 15 (87%) registered dietitians, 12 out 13 (92%) physiotherapists, and 4 out of 12 (33%) general practitioners were familiar with the term (figure 1). Within the gynaecologists 2 out of 9 showed awareness, whereas all 5 biokineticists, 6 out 9 other, and 1 out of 2 endocrinologists had heard of the term (although these comprised of small group numbers and therefore conclusions should be drawn with care).

When assessing awareness between genders, the results of the Fisher's exact test indicated that statistically significantly more women than men were familiar with the Triad (63% vs 41%; p = 0.011). A higher percentage of those participants who reported participating in sport compared to those that do not, were familiar with the Triad, however the difference was not significant (55% vs 41%; p=0.145). In addition, no significant difference was found between those working in private vs public settings - in private 51% were aware vs 54% in public (p=0.959).

Of those that had heard of the condition, 46% (n=38) were able to identify all three components of the Triad. Menstrual irregularity was the most identified component with 96% (n=80) being able to recognise this, followed by low bone mineral density (82%; n=68). LEA (the main underlying cause of the Triad) was only identified by 59% (n=49) of these participants. Interestingly, 32% (n=27) were under the impression that a low BMI (<18.5) was one of the components. When assessing knowledge of the Triad components among specialties, 10 out of 23 (43%) orthopaedic surgeons, 11 out of 15 (73%) sports physicians, 3 out of 13 (23%) registered dietitians, 5 out of 12 (42%) physiotherapists, 2 out of 6 other, 1 out of 5 general practitioners, 4 out of 5 biokineticists, 1 out of 2 gynaecologists, 1 out of 2 radiologists, and 0 out of 1 endocrinologist, were able to identify all 3 components (figure 2).

5.3 Awareness and knowledge of REDs

Forty percent (40%; n=65) of the total respondents had heard of REDs, whereas 60% (n=97) were not familiar with the term (figure 1). Level of awareness was significantly different between medical doctors and allied health practitioners, with allied health practitioners having a higher awareness (27% vs 81%; p<0.001). When taking a closer look at the various specialties it was demonstrated that only 11 out of 47 (23%) orthopaedic surgeons and 1 out of 34 radiologists (3%) were familiar with the term, whereas 14 out of 16 (88%) sports physicians, 13 out of 15 (87%) registered dietitians, and 10 out of 13 (77%) physiotherapists showed awareness. Four out of 12 (33%) general practitioners, 1 out of 9 gynaecologists, 5 out of 9 others, all 5 biokineticists, and 1 out of 2 endocrinologists were familiar with the term REDs (figure 1).

Similar to findings with the Triad, significantly more women than men reported awareness of REDs (54% vs 31%; p = 0.006). No significant difference was found between those who participate in sport compared to those who do not (43% vs 31%; p=0.191). There was also no significant difference between workplace setting and REDs familiarity, however it was found that a larger percentage of those working in a private setting were seemingly more aware of the term as opposed to those in the public sector (46% vs 23%; p=0.091).

Of those that were familiar with REDs, 69% (45 out of 65) correctly identified that the main underlying cause of REDs is LEA (figure 2). Eighteen percent thought it was due to overtraining, 3% heavy training load, 3% an unhealthy diet, 3% an eating disorder, 3% were unsure, and none (0%) considered psychological stress a cause. When these REDs aware participants were asked to identify the potential consequences of REDs, 80% were able to do so, and correctly indicated that all the following were potential consequences: BSI, decreased endurance performance, gastrointestinal problems, reproductive dysfunction, cardiovascular impairment, psychological problems, and decreased muscle strength. For those that did not identify all of the above, the most popular choice was reproductive dysfunction, BSI and increased injury risk (17% chose this option). The least common choice was BSI, decreased endurance performance, and gastrointestinal problems (none chose this option). Sixty percent (60%) of the participants who reported awareness of REDs were able to identify all the potential symptoms, signs, or investigation results of REDs, including irritability, constipation, stress fracture, fatigue, menstrual irregularity, unfavourable lipid profile, low ferritin, poor concentration, low testosterone, and insomnia. Among the group that did not select ‘all of the above’, 37% chose fatigue, stress fracture, and menstrual irregularity, and none chose irritability, constipation and stress fracture, or unfavourable lipid profile, low ferritin, and poor concentration (refer to appendix 2).

When reviewing the findings within the specialty groups, among those practitioners that were aware of REDs, 12 out of 14 (86%) sports physicians, 10 out of 13 (77%) registered dietitians, 3 out of 11 (27%) orthopaedic surgeons, 7 out of 10 (70%) physiotherapists, 4 out of 5 biokineticists, 4 out of 5 other, 3 out of 4 of general practitioners, 1 out of 1 radiologist, 1 out of 1 gynaecologist, and 0 out 1 of endocrinologist, indicated that LEA is the main underlying cause of REDs (figure 3).

Regarding potential consequences of REDs, 13 out of 14 (93%) sports physicians, 10 out of 13 (77%) registered dietitians, 7 out of 11 (64%) orthopaedic surgeons, 9 out of 10 (90%) physiotherapists, all 5 biokineticists, 3 out of 5 other, 2 out of 4 general practitioners, 1 out 1 endocrinologist, 1 put of 1 gynaecologist, and 1 out of 1 radiologist showed good knowledge (figure 2).

Ten out of 14 (71%) sports physicians, 10 out of 13 (77%) registered dietitians, 6 out of 11 (55%) orthopaedic surgeons, 7 out of 10 (70%) physiotherapists, 2 out of 5 other, 1 out of 4 general practitioners, and 1 out of 5 biokineticists, 1 out of 1 endocrinologist, 1 out of 1 gynaecologist, and 0 out of 1 radiologist, were able to correctly recognise all potential signs and symptoms of REDs (figure 2).

In addition, there was a statistically significant difference between levels of awareness of the Triad in comparison with REDs ($P<0.001$), with more participants aware of the Triad. Forty-five percent of participants were not familiar with either condition, while 15% were familiar with the Triad but not REDs, 4% were familiar with REDs but not the Triad, while 37% were familiar with both.

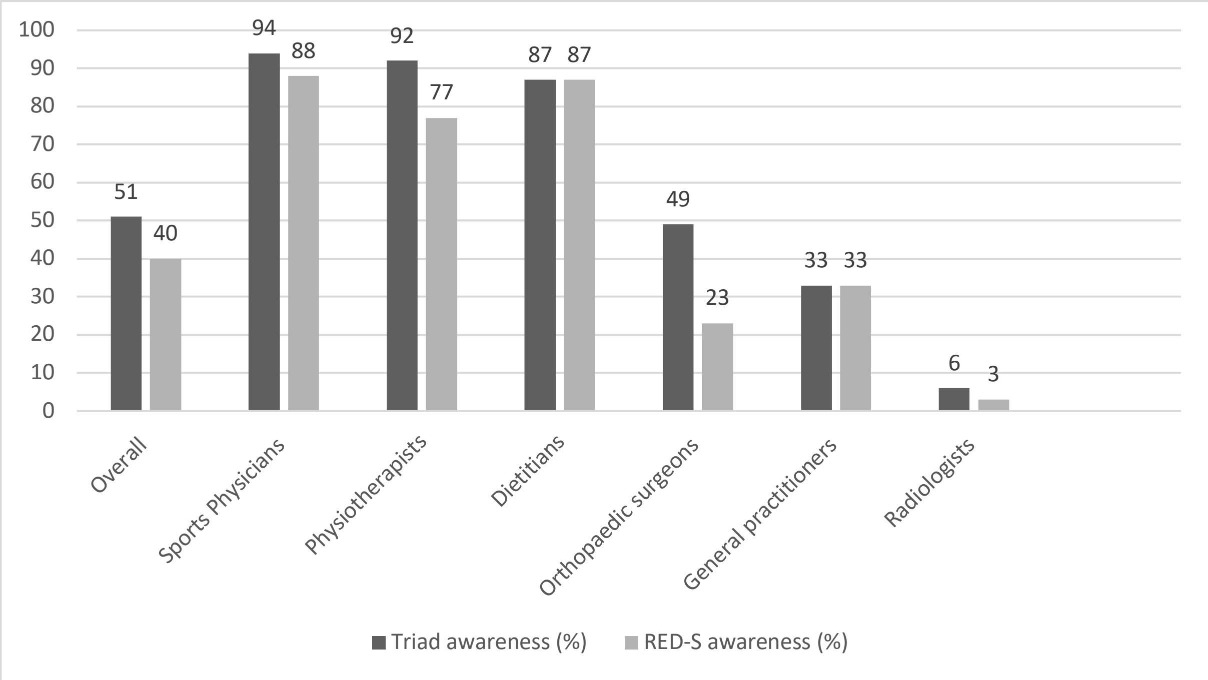

Figure 1. Awareness of the Triad and REDs (%) overall and among specialties where n = 10 or greater.

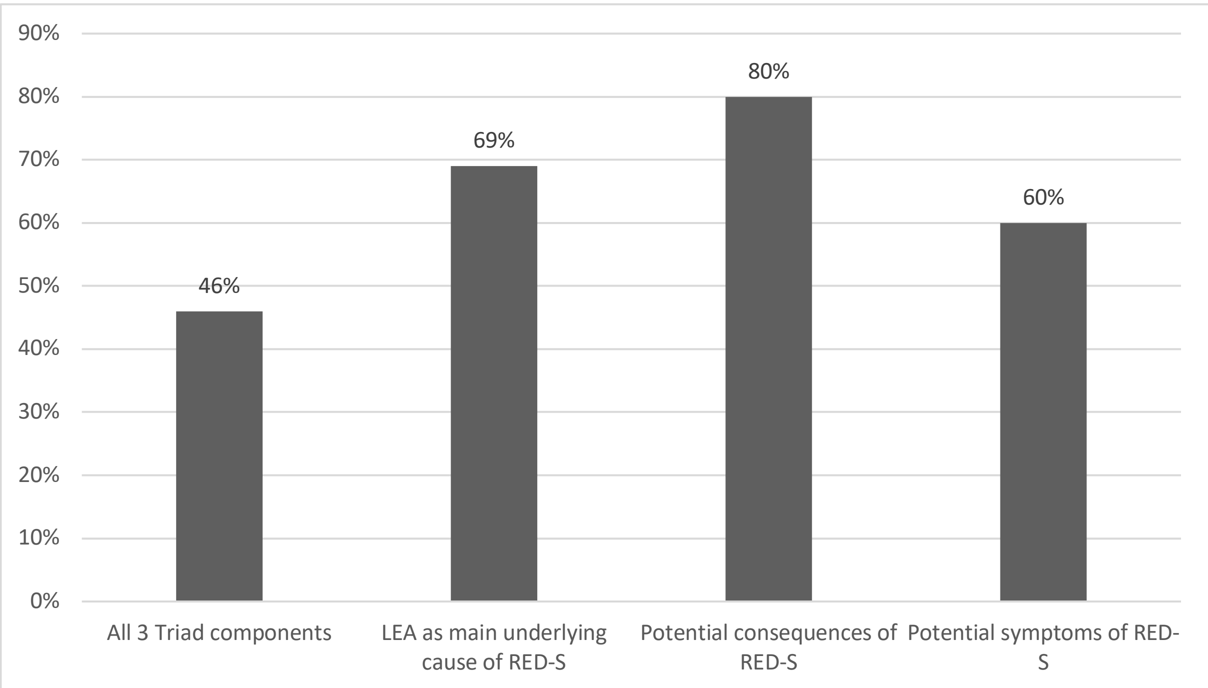

Figure 2. The overall percentage of participants who were able to correctly identify: 1) all 3 components of the Triad (of those who reported to be familiar with the Triad), 2) that LEA is the main underlying cause of REDs, 3) the potential consequences of REDs, and 4) the potential symptoms of REDs (of those who reported to be familiar with REDs).

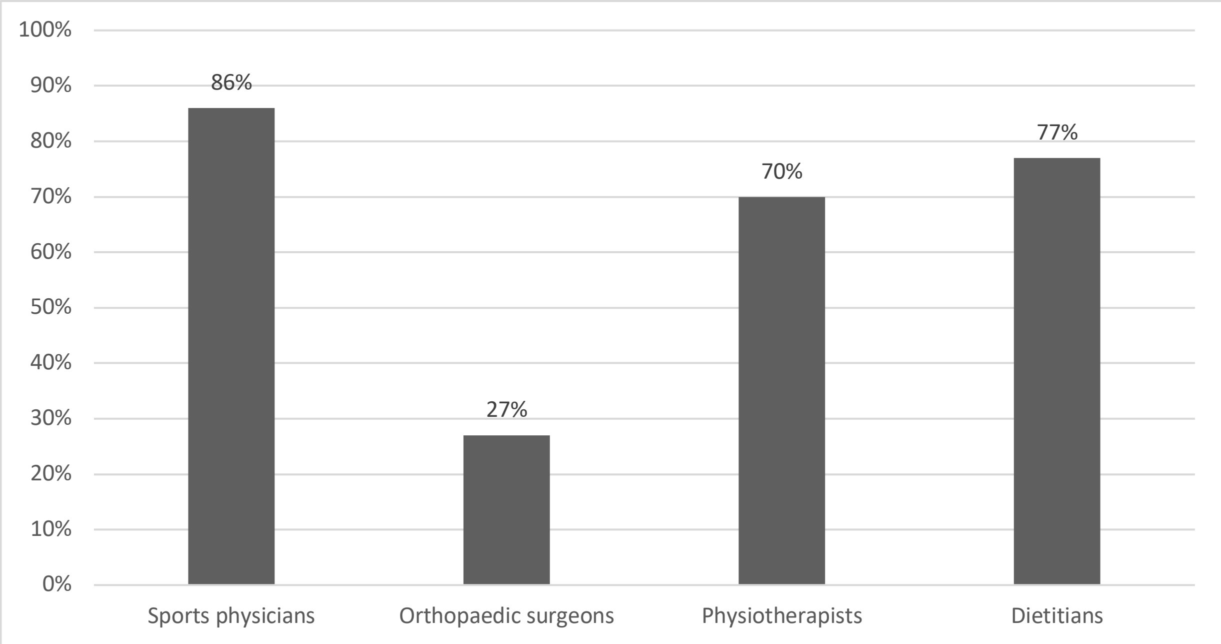

Figure 3. Knowledge of LEA as the main underlying cause of REDs (%) among those participants familiar with REDs, within specialties where n=10 or greater.

5.4 Knowledge regarding bone mineral density assessment

As shown in figure 4, 45% of the practitioners were able to identify the appropriate score currently used to assess BMD in athletes (Z-score: DEXA comparison for age and gender equivalent), however only 18% were aware that a low BMD in female athletes <40 years old in weight-bearing sports is currently defined as Z-score < -1.

Certain specializations may play more of an important role in assessing bone health. Taking this into account, 23 out of 47 (49%) orthopaedic surgeons, 14 out of 34 (41%) radiologists, 10 out of 16 (63%) sports physicians, and 2 out of 12 (15%) general practitioners were able to identify the score to use to assess BMD. When comparing radiologists, orthopaedic surgeons, general practitioners and sports physicians, and their ability to identify the appropriate score to assess BMD in athletes, there was a significant difference between the four specialties (p=0.006).

Only a mere 7 out of 47 (15%) orthopaedic surgeons, 5 out 34 (15%) radiologists, 6 out of 16 (38%) sports physicians, and 1 out of 12 (8%) general practitioners, were aware of the appropriate threshold score for defining low BMD in athletes participating in weight-bearing sports (Z-score <-1).

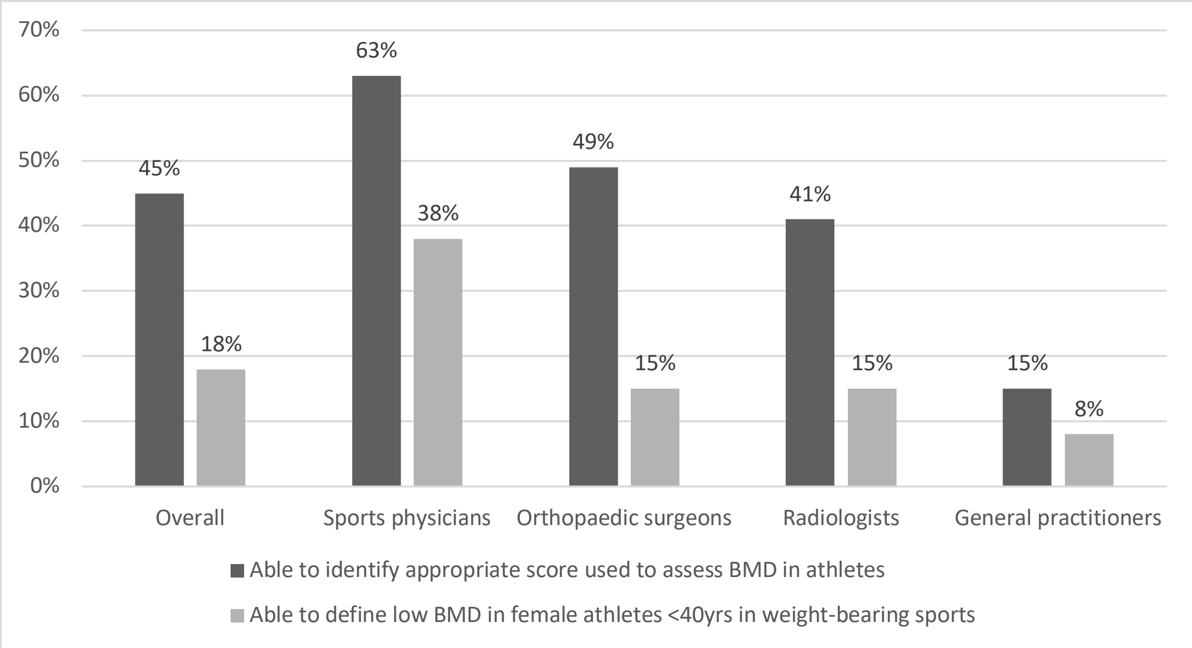

Figure 4. Knowledge regarding BMD (bone mineral density) assessment in athletes (%): percentage of practitioners (overall and among those specialisations who are most commonly involved in assessing bone health) who were able to identify the appropriate score used to assess BMD in athletes (Z-score: DEXA comparison for age and gender equivalent), and those that were able to correctly define low BMD in female athletes <40 years old in weight-bearing sports (Z-score < -1).

5.5 Knowledge regarding menstrual irregularity due to LEA

Only 23% of the survey participants were aware that menstrual dysfunction is not a normal or expected consequence of heavy athletic training (figure 5). Two thirds (75%) were under the impression that it is a normal or expected consequence, while the remaining 2% were unsure. When comparing the two groups of respondents – medical doctors and allied health practitioners, a significantly higher percentage of allied health practitioners recognised that menstrual dysfunction is not a normal consequence of heavy training (56% vs 12%; $p<0.001$).

On closer review, as represented in figure 6, only 6 out of 47 (13%) orthopaedic surgeons, and none out of 34 (0%) radiologists showed awareness. Five out of 16 (31%) sports physicians, and 3 out of 12 (25%) of general practitioners reported awareness and were the most knowledgeable among the medical practitioner groups, whereas none of the 9 gynaecologists or the 2 endocrinologists were aware. Within the allied healthcare group, 10 out of 15 (67%) of dieticians and 6 out of 13 (46%) of physiotherapists suggested the highest awareness overall. Four out of 9 other and 3 out of 5 biokineticists were able to identify that menstrual dysfunction is not a normal consequence of heavy training.

With regards to the use of the OCP as a recommended treatment for athletic amenorrhea, 41% of respondents correctly reported that it is not, whereas 19% said that it was the recommended treatment, while the remaining 40% were unsure. There was no significant difference between medical doctors and allied health practitioner's knowledge regarding the use of OCP as treatment (p=0.540).

Although a smaller cohort, 13 out of 16 sports physicians (81%) were aware, compared to 15 out of 47 orthopaedic surgeons (32%), 12 out of 34 radiologists (35%), 10 out 13 registered dietitians (67%), 6 out of 13 physiotherapists (46%), 4 out of 12 general practitioners (33%), 4 out of 9 other, 2 out of 9 gynaecologists, 1 out of 5 biokineticists, and none of the 2 endocrinologists had the appropriate knowledge around this treatment. Refer to figure 6.

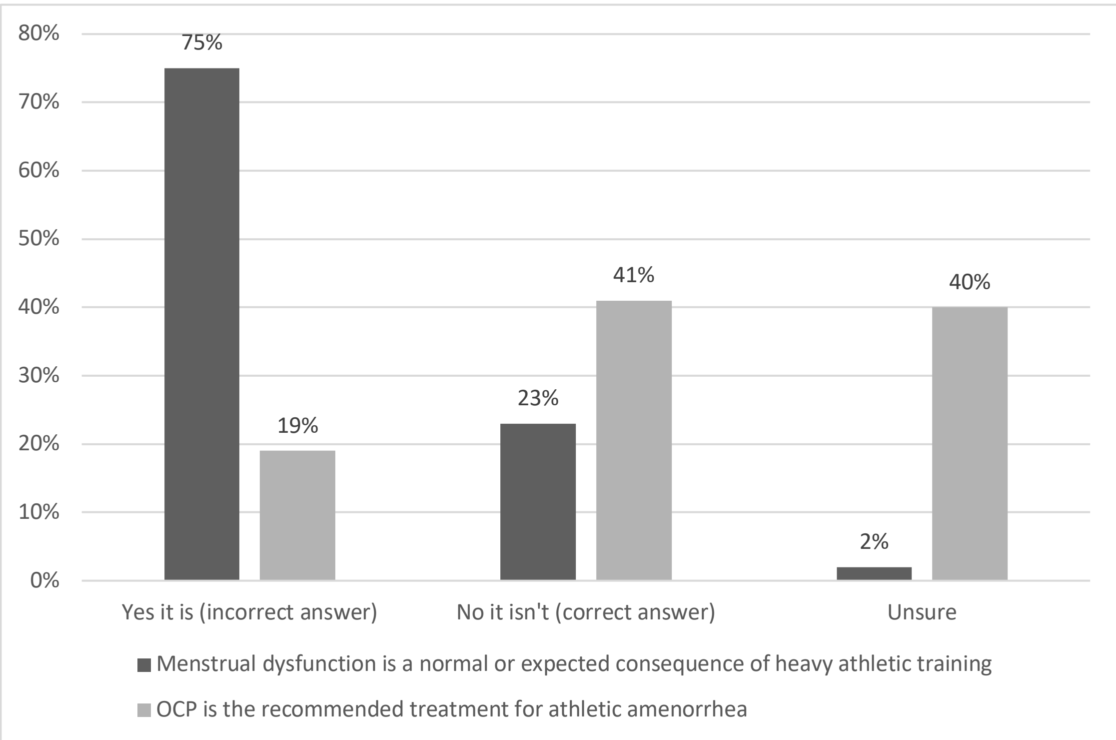

Figure 5. Participant responses to questions regarding menstrual dysfunction as a normal or expected consequence of heavy training and the recommendation of the oral contraceptive pill (OCP) as treatment for athletic amenorrhea (%).

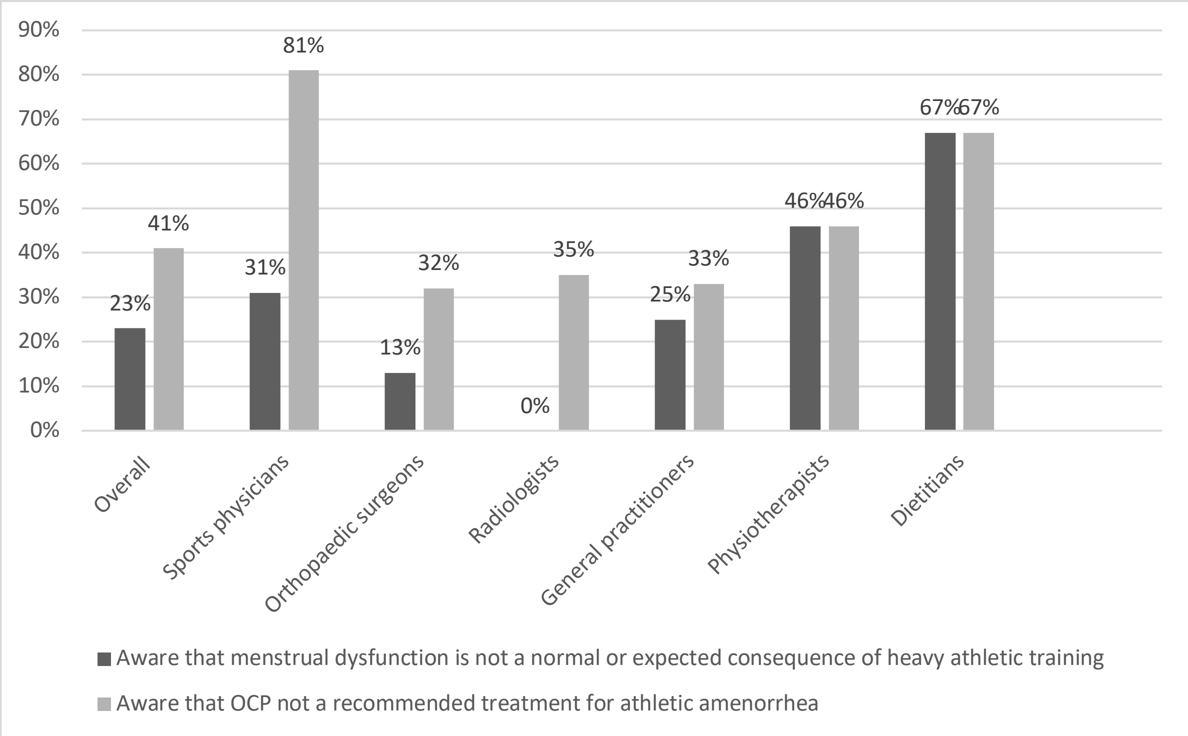

Figure 6. Percentage of practitioners (overall and among those specialties where n = 10 or over) that were aware that menstrual dysfunction is not a normal or expected consequence of heavy athletic training and those aware that the oral contraceptive pill (OCP) is not currently the recommended treatment for athletic amenorrhea.

5.6 Diagnosing, treating, and referring athletes with REDs

When comparing allied healthcare practitioners and medical doctors, there was a significant difference between the two groups regarding comfort in diagnosing, treating, and referring athletes with REDs (figure 8). For diagnosis, the percentage of medical doctors that felt very comfortable, somewhat comfortable, and not at all comfortable, was 7%, 18%, and 74% respectively, whereas for allied healthcare practitioners it was 0%, 56%, and 44% ($p<0.001$). Five percent, 23%, and 73% of medical doctors felt very comfortable, somewhat comfortable, and not at all comfortable with treatment, versus 17%, 54%, and 27% of allied healthcare practitioners ($p<0.001$), and 34%, 35%, and 31% of medical doctors felt very comfortable, somewhat comfortable, and not at all comfortable with referring, compared to 76%, 22%, and 2% of allied healthcare practitioners ($p<0.001$).

Overall, only 6% of all respondents felt very comfortable with diagnosing REDs, whereas 28% felt somewhat comfortable, and 67% did not feel comfortable at all (figure 7). Seven out of 16 sports physicians (44%), 1 out of 12 general practitioners (8%), 1 out of 34 radiologists

(3%), and then 0 of the remainder of specialties reported that they felt very comfortable with diagnosis.

With regards to treatment of REDs, 8% of participants felt very comfortable, 30% felt somewhat comfortable, and 62% did not feel comfortable at all. When taking a closer look at the different specialties, 4 out of 16 sports physicians (25%), 3 out of 15 registered dietitians (20%), 1 out of 12 general practitioners (8%), 1 out of 13 physiotherapists (8%), 1 out of 34 radiologists (3%), 3 out of 9 other, and 0 of the rest felt very comfortable with treatment.

Comfort in referring athletes with REDs was reported as high in 10 out of 13 physiotherapists (77%), 10 out of 34 radiologists (67%), 10 out of 15 registered dietitians (67%), 10 out of 16 sports physicians (63%), whereas it was only reported as high in 1 out of 12 general practitioners (8%), and 2 out of 47 orthopaedic surgeons (4%). Two out of 9 gynaecologists, 6 out of 9 other, all 5 biokineticists, and none of the 2 endocrinologists expressed that they felt very comfortable referring athletes with REDs. Overall, 44% of the practitioners reported that they felt very comfortable referring, 32% somewhat, and 24% not at all.

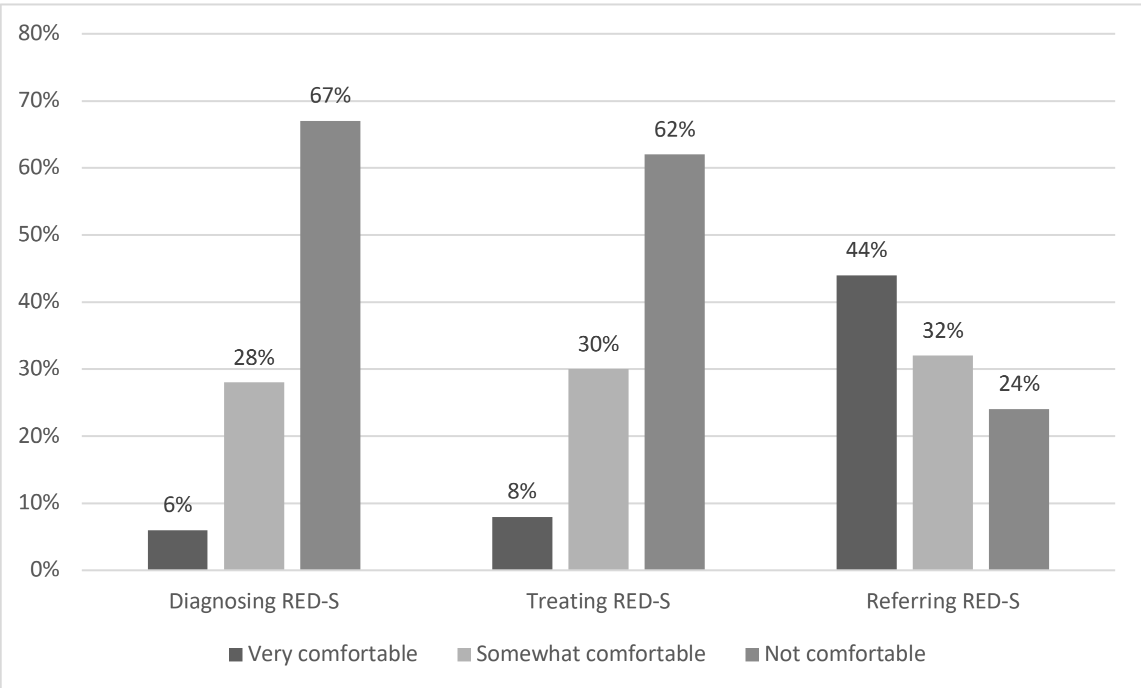

Figure 7. Levels of comfort among practitioners (overall) in diagnosing, treating, and referring athletes with REDs (%).

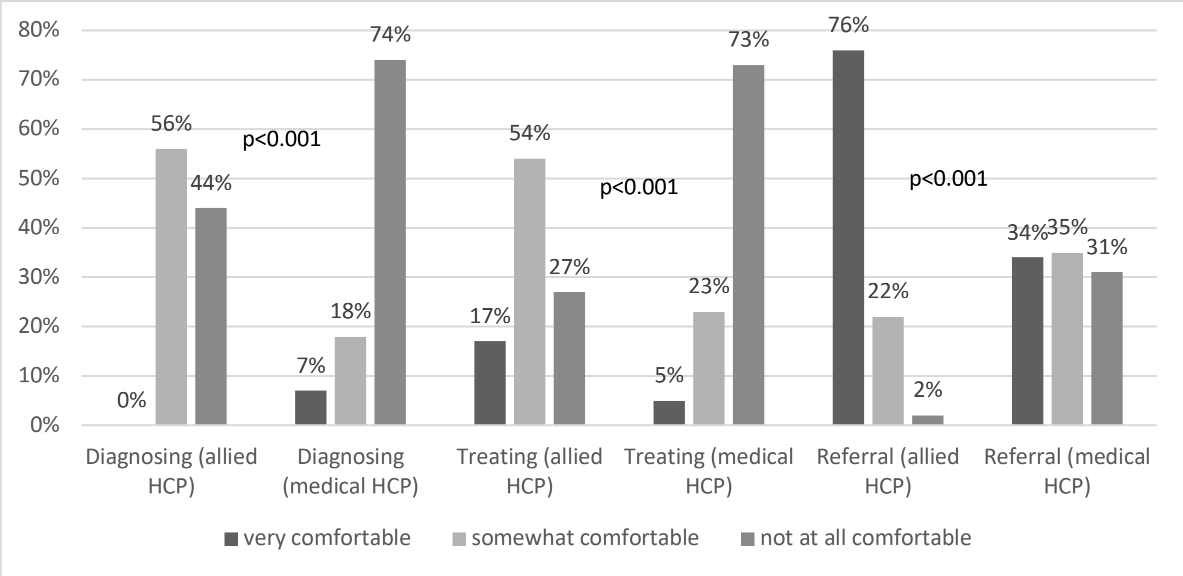

Figure 8. When comparing allied HCPs and medical HCPs, there was a significant difference between the two groups regarding comfort in diagnosing, treating, and referring athletes with REDs (%).

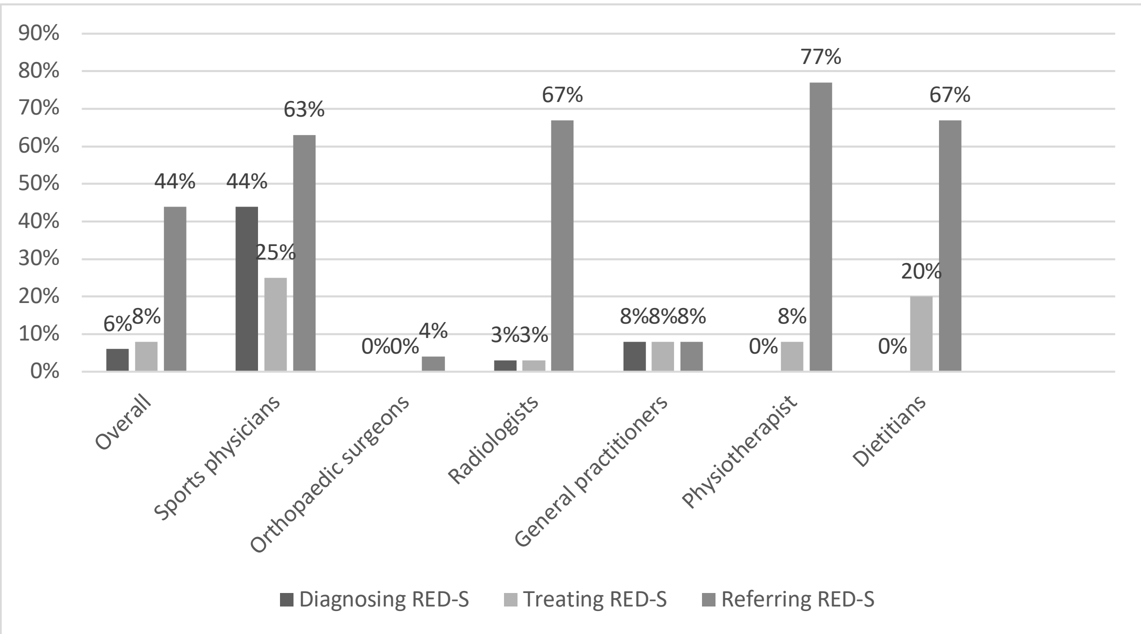

Figure 9. Practitioners who reported feeling very comfortable in diagnosing, treating, and referring athletes with REDs (%) (overall and in those specialties where n = 10 or greater).

5.7 Diagnosis of disordered eating and eating disorders

Only 14% of all respondents indicated that they felt very comfortable diagnosing disordered eating and eating disorders. Forty percent felt somewhat comfortable and just below half (46%) reported that they did not feel comfortable at all (figure 10). The breakdown of responses showed that 5 out of 16 sports physicians (31%), 3 out of 12 general practitioners (25%), 3 out of 16 registered dietitians (20%), 2 out of 13 physiotherapists (15%), 3 out of 47 orthopaedic surgeons (6%), 1 out of 34 radiologists (3%), 5 out of 9 other, 1 out of 9 gynaecologists, 0 endocrinologists and biokineticists, felt very comfortable in the diagnosis of disordered eating and eating disorders.

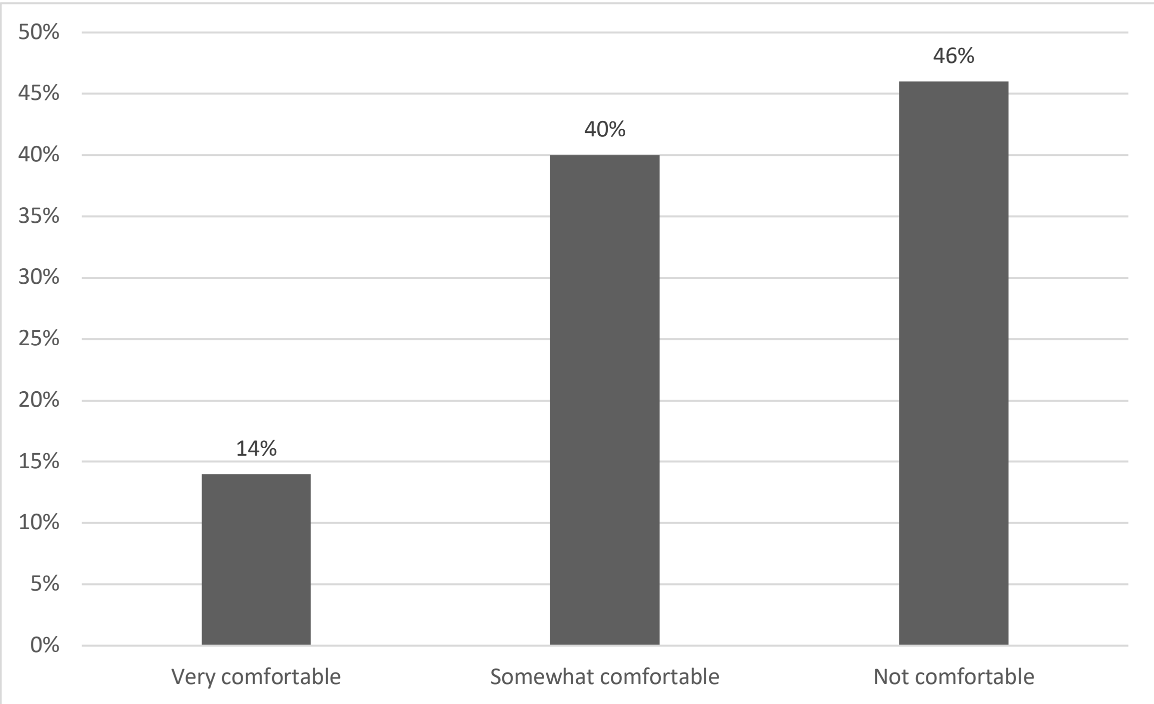

Figure 10. Levels of comfort among practitioners (overall) in diagnosing eating disorders and disordered eating.

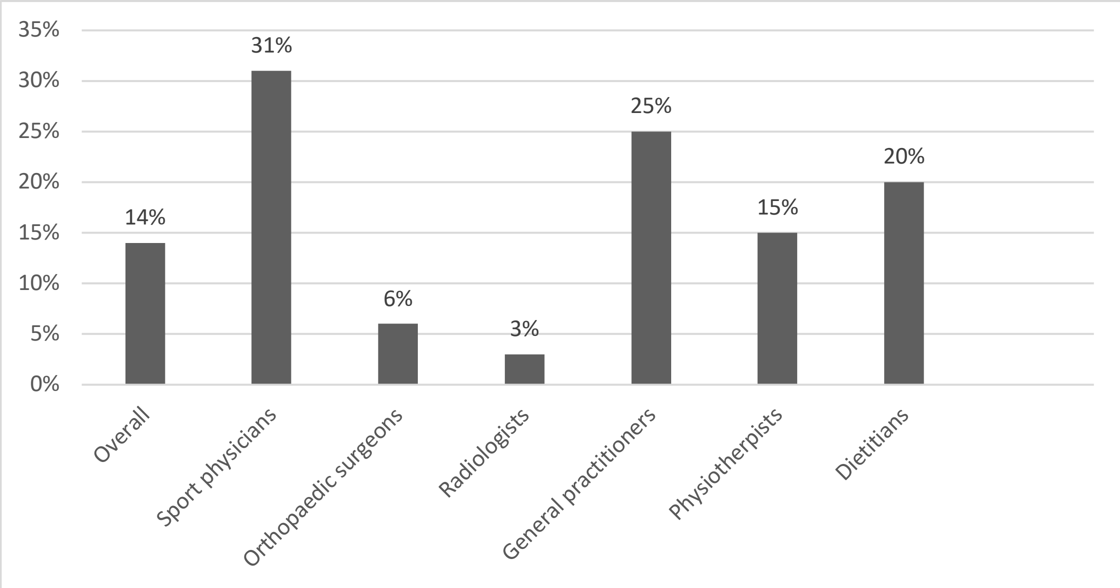

Figure 11. Practitioners who reported feeling very comfortable in diagnosing eating disorders and disordered eating (overall and in those specialties where n = 10 or greater).

Chapter 6: DISCUSSION

6.1 Awareness of the Triad and REDs

The main findings of this study suggest that overall awareness of the Triad and REDs among healthcare professionals is low, with just above half (51%) aware of the Triad and only 40% aware of REDs. Of concern is that 45% of this cohort were not aware of either of the conditions. These findings reflect a greater awareness of the Triad when compared to a similar study in 2015 by Curry et al which found that 37% of multi-specialty physicians had heard of the Triad[15]. However, in comparison to a more recent study by Tenforde et al in 2020 which found that 76% of healthcare practitioners attending a sports medicine conference had heard of the Triad[16], awareness in our study was considerably poorer. However, Tenforde et al also demonstrated that only 29% of practitioners had heard of REDs[16], which was slightly lower than our findings, but supported our finding of less awareness with regards to REDS as compared to the Triad. This is to be expected as the Triad was first officially recognised in 1997, whereas the REDs model was much more recently described in the published literature in 2014.

It might be expected that awareness of the Triad and REDs should have vastly improved over the last few years, considering the substantial increase in published research conducted on the topics[26]. The apparent lack of increased awareness among this cohort is concerning and future research may need to explore the reasons for this, as well as ways to improve information translation and education methods. However, the previous studies included participants predominantly from the United States, whereas our study consisted mostly of healthcare providers practising in South Africa (92%). Therefore, the current study provides a unique understanding of the situation in South Africa and perhaps reflects healthcare challenges within a different geographical setting. There is currently limited understanding of the prevalence rates of REDs in South Africa, so it is difficult to ascertain whether this may have an impact on the awareness levels among healthcare practitioners based in this location. However, the small number of studies investigating prevalence rates of estimated LEA, and Triad and REDs symptoms, among South African athletes reflect similar numbers to those performed in the United States and elsewhere[62,63,129].

The slightly different specialty profiles in the three studies may also have influenced the varying results. The Triad study by Curry et al included only medical doctors, while allied healthcare providers also participated in our study. The study by Tenforde et al consisted only of attendees at a sports medicine conference who may have been more likely to have higher awareness due to working predominantly with the athletic population, whereas our study included a more diverse spectrum of specialties. When taking a closer look among the different specialties in our study, it appears that a higher percentage of sports physicians (94% and 88%), registered dietitians (87% and 87%), and physiotherapists (92% and 77%) reported awareness of the Triad and RED-S terms respectively, in comparison to the other specialties (however some of these groups had small cohorts so this should be interpreted with caution). If this is a true representation, it may be a result of recent continuing professional development (CPD) events on these topics provided by ADSA (Association for Dietetics in South Africa) and SASMA (South African Sports Medicine Association).

Overall, the level of awareness of the Triad and REDs was significantly higher among allied health practitioners compared to medical doctors. One of the reasons for this may also be the recent CPD events as mentioned above. These particular allied health groups (especially physiotherapists and biokineticists) may also be more likely to be exposed to a greater proportion of patients involved in sport compared to the medical practitioner groups. Registered dietitians have a pivotal role with regards to and are specifically trained to assess dietary intake, so this may also contribute to increased awareness of these conditions. In general, allied health professionals tend to see patients more regularly over time and may develop stronger working and therapeutic relationships with them, so may be more likely to be exposed to and pick up subtle changes and symptoms related to LEA and REDs. However, ours was a different finding to Tenforde et al, who found that awareness did not significantly differ between physicians and non-physicians, but that there was a trend towards physicians being more likely to be aware of REDs compared to non-physicians.

Our study showed that significantly more female practitioners were familiar with the Triad and REDs versus male practitioners. This may be attributed to the fact that the Triad was previously described only in female athletes, and it was only in 2014 that it was acknowledged that male athletes can also be affected. However, Curry et al found no significant differences between physician genders regarding awareness of the Triad.

Despite disparate challenges experienced in private versus public healthcare settings in South Africa, it was interesting to find that there was no significant difference in awareness of these conditions between the participants practicing in the different settings.

These results may provide more insight with regards to the specific populations within the healthcare professions in South Africa that should be prioritised with focused education.

6.2 Knowledge of components, underlying cause, symptoms and consequences of the Triad and REDs

Knowledge regarding the Triad by physicians was first assessed in a study in 2006 by Troy et al[14] which found that only 48% were able to identify all 3 components of the Triad, which is in line with our study which showed that 46% of healthcare providers (that were aware of the Triad) were able to do the same. Most of these participants (96%) in our study were cognisant of menstrual irregularity being a component of the Triad, and majority of them (82%) identified the link to low bone mineral density. However only two thirds (59%) were able to connect the role of LEA to the Triad, which is problematic as LEA is the main underlying cause of the Triad. Although the Triad can be present in athletes of varying body weights[104], a surprising number of participants suggested a low BMI (32%) to be one of the primary components.

Despite less participants being aware of REDs as compared to the Triad, those aware of REDs seemed to have slightly better knowledge and understanding of the role that LEA as the main underlying cause (69%) has to play in the pathophysiology of the condition. Overtraining as the main underlying cause was indicated by 18% of these respondents, which is understandable as there are many overlaps in pathways and symptoms between over training syndrome (OTS) and REDs[130], however more recently, there is a shift towards considering that overtraining in fact represents LEA rather than excessive training. This is supported by more recent research that shows that many of the negative outcomes of training overload and OTS may be primarily due to misdiagnosed REDs due to LEA[130]. Confidence amongst these participants in recognising potential consequences of REDs seemed to be high (80%), although only two thirds (60%) were able to correctly identify potential signs and symptoms. There are many less obvious potential symptoms of REDs that some healthcare providers appear not be aware of (such as unfavourable lipid profile, constipation, low ferritin, irritability, and poor concentration), which are important considerations when managing patients presenting with these signs and symptoms.

6.3 Knowledge regarding bone health assessment

Poor bone health outcomes arising from short and long-term LEA are well identified in the literature particularly in female athletes, while there is growing evidence that male athletes may also experience negative bone health consequences because of LEA. These athletes are likely to develop low BMD, reduced bone strength, altered bone microarchitecture, and are at increased risk of experiencing BSI, stress fractures, and developing osteoporosis[23,68,76,77,131]. The effects of LEA on bone health can also have long-term ramifications and the consequences are often irreversible. Many athletes seek treatment from various healthcare professionals for BSI and stress fractures, providing an opportunity to consider or screen for the Triad and REDs. Therefore, it is critical that healthcare providers are aware of these conditions as well as the appropriate methods and threshold scores to use when assessing BMD.

Athletes taking part in weight-bearing and high impact sports are likely to have a 5-30% higher BMD compared to age-matched non-athletes, therefore the IOC and ACSM define a normal BMD in these athletes to be Z-score > -1, as opposed to > -2 in the non-athlete population. They recommend that those presenting with a Z-score < -1 require further investigation, clinical examination of secondary risk factors (such as disordered eating/eating disorders, and other REDs risk factors), and subsequent follow up[5,20,107]. The International Society for Clinical Densitometry (ISCD) has further proposed a need for a sport/event specific Z-score range and that any high-impact sport athlete with a Z-score of 0 and below requires further investigation of secondary risk factors, as this may help to identify at-risk athletes earlier and will help to prevent more serious impairments[107].

In this study, the awareness among healthcare practitioners of the cut-off range to assess BMD in athletes was very poor, and only 18% were able to identify the appropriate Z-score threshold. Radiologists and orthopaedic surgeons have a critical role in identifying bone complications, yet only 15% of each of these groups were able to correctly identify the appropriate Z-score threshold. Similarly, sports physicians play an important role in treating athletes, but only 38% in this study were aware of this threshold in this study. This is particularly concerning as many athletes with existing low BMD as well as those at risk of developing impaired bone health may be overlooked and fail to receive timeous and appropriate clinical treatment.

Furthermore, clinicians should also be aware that although current scanners generate T- and Z-scores, when assessing BMD in adolescents and premenopausal women, they should only consider a Z-score, as opposed to the T-score which is primarily utilised in the menopausal group. A Z-score compares bone density to the average values for a person of the same age and sex[122]. In this survey 49% of orthopedic surgeons, 41% of radiologists, 63% of sports physicians, and 45% of clinicians overall were aware of this.

6.4 Knowledge regarding menstrual irregularity associated with LEA

Seventy-five percent of healthcare professionals from this study said that they thought that menstrual irregularity is a normal or expected consequence of heavy training. Although it is well established that a lack of menstruation in female athletes is an indicator of possible LEA, there is widespread belief that it is 'normal' for athletes undergoing heavy training to experience menstrual dysfunction[132]. Many athletes and coaches have reported that they believe this physiological response is a 'normal' sign of successful training and even a requirement in elite sport[14,34,133].

LEA leads to suppression of the hypothalamic-pituitary-gonadal (HPG) axis, which can result in functional hypothalamic amenorrhea (FHA). Disturbance of the HPG axis causes oestrogen deficiency, which may contribute to an increased bone loss and inability to attain peak bone mass, leading to a higher risk of bone health complications[76,122]. Evidence shows that untreated amenorrhea can result in 2-3% bone loss per year and that even 6 months of amenorrhea in adolescence can lead to a 1-2% bone loss during that time[4,134,135]. It has been consistently shown that female athletes with amenorrhea have a high prevalence of BSI, stress fractures, and other injuries[20,23,96]. Other health concerns related to FHA and hypoestrogenism include detrimental effects to the cardiovascular system, reduced neuromuscular function, and increased risk of infertility[5,20,94]. Therefore, it is erroneous to think that menstrual dysfunction is a 'normal' state, and any female athlete presenting with menstrual irregularity requires clinical investigation to rule out any medical causes[121,122,132]. Regular menstrual periods are considered a barometer of healthy endocrine function for women of reproductive age, regardless of the amount of training they are doing. Healthcare professionals should therefore be aware that menstrual dysfunction can be a warning sign that energy intake, training load and/or recovery may not be optimal, and that the potential consequences of not treating these appropriately may be dire[136].

Numerous systematic reviews and other studies have found OCP's to be ineffective in treating absence of menses and low BMD in female athletes with FHA[120,122,137–139]. OCP's suppress ovarian function and may induce a withdrawal bleed, but this is not a true menstrual period and is driven by external non-physiological hormones. Furthermore, the use of an OCP may mask menstrual dysfunction and delay appropriate treatment[121,122,136,140]. It may also negatively affect other hormones involved in bone health including IGF-1[141]. This is problematic as IGF-1 may already be lowered due to LEA and its dampening effect on the HPA axis[120,140]. The IOC statement on REDs recommends a non-pharmacological management with a multi-disciplinary approach as first-line treatment of FHA, where energy balance restoration, and training load and psychogenic stress management is essential[3]. If menstrual cycles are not restored timeously with appropriate treatment, pharmacological interventions including transdermal oestradiol may be considered to assist with bone health restoration[120,122].
Despite this information, and the fact that the Endocrine Society, IOC, and NICE (National Centre for Health and Care Excellence) guidelines advise against the use of OCP's in FHA[3,122,142], this study found that only 41% of healthcare practitioners were aware that this is not the recommended treatment. Athletes with menstrual dysfunction will commonly seek treatment from a gynaecologist[143] or general practitioner[121], however in this study only 2 out of 9 gynaecologists and 5 out of 12 (38%) general practitioners were aware of the appropriate role of the OCP in this clinical setting. This finding is in line with reports from current literature and lived experience of athletes as medical professionals often prescribe OCP's for FHA in women[120,122]. A more positive finding included the the sports physicians who showed good knowledge (81%) regarding this treatment in this study.

6.5 Diagnosis, treatment, and referral of athletes with the Triad or RED-S
The first study assessing knowledge of the Triad by Troy et al in 2006 found that 31% of physicians would screen for the Triad, and 9% of physicians felt comfortable treating athletes with the condition[14]. Curry et al in 2015[15] and Tenforde et al in 2020[16] showed that 51% and 33% of physicians respectively reported feeling comfortable treating an athlete with the Triad. Furthermore, Tenforde et al also demonstrated that only 13% of healthcare providers indicated that they felt comfortable treating athletes with REDs[16]. Similarly, in the current study it was evident that only 6% of healthcare professionals expressed comfort in diagnosing athletes with REDs, and 8% showed comfort with treatment. More promisingly,

44% of clinicians in this study reported feeling comfortable in referring patients with REDs for appropriate treatment.

Of particular interest noted from the results of the current study, were that overall, allied health practitioners reported significantly higher levels of comfort in diagnosing, treating, and referring athletes with REDs, compared to medical doctors. This may be explained by the finding that awareness levels were also higher in this group of allied health professionals, Additionally, allied health practitioners may generally consult with patients more regularly over a longer time period, developing stronger therapeutic relationships more effortlessly, and therefore may notice subtle signs more easily and timeously.

It is well recognised that the aetiology of the Triad and REDs are multi-factorial, and their manifestations are varied, therefore it is ideal if healthcare professionals of multiple specialties are able to timeously detect or diagnose athletes experiencing, or at high risk of developing the Triad and REDs. In addition, practitioners should preferably treat these conditions within a multi-disciplinary team and/or refer to the relevant practitioners[3,4,12,144]. This in turn may facilitate in the prevention of long-term harmful health consequences and better athletic performance. It is clear in current literature that a multi-disciplinary team approach where members collaborate effectively is necessary to successfully treat athletes with REDs and its inter-related components[12,14,44,102,122]. Registered dietitians (with sports nutrition experience) play a central and essential role in managing athletes with REDs with their expert skills in dietary evaluation, nutrition counselling, and individualised dietary guidance, to improve LEA, and should always be a part of the treatment team[3,44,102]. As should a sports physician to manage medical complications, and a mental health professional to manage psychogenic stress and enhance behavioural change[5,108,122]. Other practitioners would be required as a part of the team according to each individual situation[108]. One may consider it encouraging within this study cohort that the allied health care providers, who play an integral role within the multidisciplinary set up, appear to have a greater awareness of many aspects related to the management of the Triad and REDs.

6.6 Diagnosis of disordered eating and eating disorders

Athletes are at higher risk of developing disordered eating and eating disorders, particularly in certain sports (sports that emphasize leanness to succeed and those with weight class components), occurring at rates 2-3 times that of the non-athlete population[10,47,56,145]. Disordered eating and eating disorders can contribute to the development of REDs, as well as other deleterious physical and psychological impairments. Eating disorders also have one of the highest mortality rates of all mental health illnesses. It is well established that early detection and treatment of disordered eating is associated with better outcomes, therefore, it is imperative that all health personnel involved with athlete care can recognise warning signs of disordered eating and refer these athletes for timeous and appropriate treatment[10]. However, this current study indicated that only 14% of healthcare professionals felt confident diagnosing eating disorders and disordered eating in athletes, and 46% did not feel comfortable at all. This is in line with previously reported findings, where although there seems to be increasing awareness regarding mental health concerns in the athletic population, clinicians appear to have limited knowledge regarding eating disorder symptoms and have difficulty screening for and detecting disordered eating and eating disorders[10]. A survey in 2012 showed that 41% of medical providers felt they had insufficient training to adequately screen for eating disorders and 68% reported that they did not screen for an eating disorder if it was not the presenting concern[146]. In a qualitative study, medical providers reported perceiving that their training on eating disorders was inadequate, and that during their undergraduate training they received no training on this topic and at a postgraduate level training was minimal[147]. These observations further identify some of the clinical 'shortcomings' that could be targeted in future continued professional development settings.

6.7 Clinical recommendations and future research

The key findings of this study highlight the need for strategies to disseminate information on the Triad and REDs to multi-specialty healthcare providers, particularly within South Africa. It is evident that overall, there is inadequate awareness of these conditions, and that there are knowledge gaps regarding causes, consequences, and symptoms, as well as diagnosis, treatment, and referral. Knowledge and best clinical practices around assessment of low BMD, treatment of 'athletic' menstrual dysfunction, and diagnosis of disordered eating and eating disorders is also evidently lacking and should be addressed.

Introducing a focused education campaign could improve the overall awareness and appropriate referral among healthcare providers involved in treating participants in sport and dance. It is apparent that awareness of the Triad and REDs is higher among certain specialties (particularly sports physicians, registered dietitians and physiotherapists) and lower in others (including orthopaedic surgeons, radiologists, general practitioners and gynaecologists) which may give an indication of where more targeted education needs to occur. Our results also indicate that male practitioners may require prioritised education to improve awareness of the Triad and REDs.

It is apparent that education interventions regarding REDs diagnosis and best clinical treatment needs to occur across all professions, as confidence levels appear to be extremely low among most practitioners. Improved screening tools, including the new REDs CAT2, may also help to improve this.

Overall, as a group, medical doctors seem to have poorer awareness and knowledge, and comfort with diagnosis, treatment, and referral, compared to allied health practitioners, which suggests that it may be beneficial to introduce targeted education to medical students at undergraduate level, and at conferences or CPD events that target individual medical specialties. Encouraging healthcare providers from various disciplines to communicate with and work together as part of multi-disciplinary teams (instead of in silos) may also improve awareness and knowledge of these conditions, and in turn lead to early diagnosis, improved care, and better health and performance outcomes for athletes.

The same applies for disordered eating and eating disorder diagnosis among athletes, as it is evident that many healthcare providers have low confidence within this area. It would be worth further exploring referral practices among all specialists, as working in a multi-disciplinary team with appropriate providers is essential for positive outcomes.

Among those practitioners who have a pivotal role in assessing BMD in athletes, it is evident that education on appropriate BMD scores and thresholds to use is essential. Particular attention needs to concentrate on educating all appropriate healthcare practitioners (with a special focus among medical doctors) that menstrual dysfunction is never normal, even when undertaking high volumes or intense training loads. Although sports physicians reported to have good knowledge regarding the OCP being contraindicated in the treatment of FHA, most other practitioners need to be made aware of the current guidelines on the treatment of FHA, as their current practice of prescribing OCPs to athletes with menstrual dysfunction may potentially be doing harm.

Future research studies can explore possible barriers that may prevent healthcare professionals from improving knowledge and awareness in these areas, what the most effective modality of education would be, and the effectiveness of such education. The development and validation of improved and accessible screening tools also needs further study.

6.8 Limitations

There were several limitations to our study. A percentage of participants (15%) reported that they do not regularly treat patients that take part in sport or dance, which may be perceived as important to consider when interpreting the results. However, any exercising individual can potentially be affected by the Triad and REDs, so it would most likely be of value for all appropriate healthcare professionals to have awareness and the clinical skills to screen for symptoms. Additionally, the response rates in certain specialty categories (for example endocrinologists) were low, making the results difficult to analyse, and may not necessarily be an accurate representation in greater populations of these groups. The survey was distributed with a clear heading of its purpose, which may have attracted more of those with existing awareness and interest in the topic. This may potentially have influenced the likelihood of choosing to participate, and possibly an over-reporting of awareness.

Chapter 7: CONCLUSION

It is evident that healthcare professionals from a variety of specialties within South Africa have low awareness and knowledge of the disorders related to inadequate energy intake and LEA among athletes and dancers. Healthcare providers are in an ideal position to be able to timeously identify signs of the Triad and REDs, and co-ordinate appropriate treatment. This may in turn prevent harmful long-term health consequences, and result in better athletic performance. Considering the high prevalence rates of these conditions among many sports and exercising groups, and their potential deleterious consequences, our results suggest that many athletes are probably currently not receiving appropriate diagnosis and treatment. Therefore, it is imperative that efforts are made to integrate education strategies among healthcare practitioners regarding these conditions. Areas to address should include overall awareness, causes, consequences, symptoms, diagnosis, treatment, and referral. Education around BMD assessment, treatment of athletic amenorrhea, and diagnosis of disordered eating and eating disorders among athletes need special attention.

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APPENDIX MATERIAL

Appendix 1:

Letter to participants and informed consent

We would be grateful if you would be a part of our study and complete this questionnaire on the following topic:

Awareness and Knowledge of The Female Athlete Triad and Relative Energy Deficiency in Sport (RED-S) among Healthcare Professionals

We would like to get a better idea of the current awareness and understanding that healthcare professionals have of Relative Energy Deficiency in Sport (RED-S) and the associated health and performance effects, in order to help improve knowledge thereof, and be able to better target education initiatives amongst healthcare providers. This in turn will help to improve patient care.

This study is being conducted as part of a Masters in Medicine degree at the University of Cape Town.

There are no risks involved in participating in this study, and your response will remain anonymous. You may voluntarily withdraw your consent at any point during the study.

For more information regarding this study please contact the main supervisor A/Prof Laubscher, or the Masters student Rowena Visagie:

Email: maritz.laubscher@uct.ac.za Tel: 021 4045108
Email: rowenacurr@gmail.com Tel: 082 4257234

You may contact the UCT Human Rights and Ethics Committee on 021 4066338 if you have any questions regarding your rights and welfare as a research participant.

By clicking on the next button, you are giving consent to answer the questionnaire:

☐ I agree to participate in this 10-minute electronic questionnaire realizing that I can withdraw my consent (without adverse consequences). I agree that research data collected for the study may be published in a form that does not identify me in any way.

Appendix 2:

Questionnaire

1. **What is your profession/specialty?**
- Orthopaedic surgeon
- Endocrinologist
- Sports physician
- Registered dietitian
- Gynaecologist
- Radiologist
- Other please specify ---------------

2. **Which healthcare environment do you practice in?**
- Public
- Private
- Combined practice (both public and private)

3. **Please select your gender:**
- Male
- Female
- Gender variant / non-conforming
- Prefer not to say

4. **Do you treat patients that participate in recreational or professional sport or dance?**
- Yes
- No

5. **Do you participate in sport or dance recreationally or professionally yourself?**
- Yes
- No

6. **Are you familiar with the term: Female athlete triad?**
- Yes
- No (if no skip question 8)

7. **If yes, what are the 3 main components of the female athlete triad? Please choose 3 from the list below:**

- BMI <18.5
- Low energy availability
- Iron-deficiency anaemia
- Low vitamin D levels
- Menstrual irregularity
- Low bone mineral density
- Inadequate calcium intake
- An unhealthy diet

8. **Are you familiar with the term Relative Energy Deficiency in Sport (RED-s)?**

- Yes
- No (if no skip questions 9-11)

9. **If yes, what do you think is the *main* underlying cause of RED-s? Please choose one:**

- Heavy training load
- Low energy availability
- Overtraining
- An unhealthy diet
- An eating disorder
- Psychological stress
- Unsure

10. **Which of the following are potential consequences of RED-s? Please choose one:**

- Bone stress injury, decreased endurance performance, gastrointestinal problems
- Reproductive dysfunction, bone stress injury, increased injury risk
- Cardiovascular impairment, psychological problems, decreased muscle strength
- All of the above
- Unsure

11. **Which of the following are potential symptoms, signs or investigation results of RED-S? Please choose one:**

- Irritability, constipation, stress fracture
- Fatigue, stress fracture, menstrual irregularity

- Unfavourable lipid profile, low ferritin, poor concentration
- Fatigue, low testosterone, insomnia
- All of the above
- Unsure

12. What is the score currently used to assess bone mineral density (BMD) in athletes?

- Z-score: DEXA comparison for age and gender equivalent
- T-score: DEXA comparison for age and gender equivalent
- Unsure

(A Z-score compares your bone density to the average values for a person of your same age and gender. A T-score shows how much your bone mass differs from the bone mass of an average healthy 30 year old adult)

13. How would you define a low bone mineral density (BMD) in female athletes <40 years in weight-bearing sports?

- Z-score less than -1.0
- T-score less than -1.0
- Z-score less than -2.0
- T-score less than -2.0
- Unsure

14. Do you think menstrual dysfunction can be an expected or normal consequence of heavy training?

- Yes
- No
- Unsure

15. Do you think that oral contraceptive treatment is indicated for athletic amenorrhea?

- Yes
- No
- Unsure

16. Do you feel comfortable diagnosing patients with RED-s?

Not at all
Somewhat
Very

17. Do you feel comfortable treating patients with RED-s?

Not at all

Somewhat

Very

18. Do you feel comfortable referring patients with RED-s for appropriate treatment?

Not at all

Somewhat

Very

19. Do you feel comfortable diagnosing patients with disordered eating or eating disorders?

Not at all

Somewhat

Very

Appendix 3:

Ethics approval

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room 45 E-52-E-Floor- Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6492
Email: hrec-submissions@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

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15 July 2022

HREC REF: 305/2022

A/Prof M Laubscher
Division of Orthopaedic Surgery
H49, OMB
Email: maritz.laubscher@uct.ac.za
Student: rowenacurr@gmail.com

Dear A/Prof Laubscher

PROJECT TITLE: AWARENESS AND KNOWLEDGE OF THE FEMALE ATHLETE TRIAD AND RELATIVE ENERGY DEFICIENCY IN SPORT (RED-S) AMONG HEALTHCARE PROFESSIONALS. (MSC DEGREE – MRS ROWENA VISAGIE)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee (HREC) for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

This approval is subject to strict adherence to the HREC recommendations regarding research involving human participants during COVID -19. Please refer to guidance letter dated 02 February 2022 on our website:
http://www.health.uct.ac.za/fhs/research/humanethics/forms

Approval is granted for one year until the 30 July 2023.

Please submit a progress form, using the standardised Annual Report Form (FHS016) if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

The HREC acknowledge that the student: - Mrs Rowena Visagie will also be involved in this study.

Please quote the HREC REF 305/2022 in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

HREC/ref 305.2022