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Health Consequences of Eating Disorders in Athletes: Underlying Mechanisms and the Role of Relative Energy Deficiency in Sport (RED-S) - A Narrative Review.

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Abstract

Background: Eating disorder is a common mental health condition, where one uses the control of food to cope with overwhelming situations and feelings. Unhealthy habits include eating too little, too much or worrying about the amount of food consumed [1].

Aim: The aim of this study is to discuss the prevalence, manifestations and consequences of eating disorders among athletes.

Methods: A focused literature review was conducted using the PubMed database. The search strategy included the following terms: “eating disorder sport athletes”, “eating disorders”, “disordered eating”, “athletes”, “sports”, “energy availability”, “RED-S”, and “female athlete triad”. Relevant studies concerning the physiological, psychological, and performance-related consequences of eating disorders in athletic populations were analyzed.

Results: The reviewed literature indicates that eating disorders and disordered eating behaviors are particularly common in sports emphasizing leanness, endurance, or aesthetic appearance. Low energy availability and RED-S were associated with menstrual dysfunction, decreased bone mineral density, increased injury risk, impaired recovery, and reduced athletic performance. Psychological consequences included anxiety, depression, body dissatisfaction, and maladaptive personality traits. These factors collectively contribute to impaired athletic performance and disrupted training continuity.

Conclusions: Eating disorders among athletes represent a complex health concern associated with substantial physiological, psychological, and performance-related consequences. Relative energy deficiency appears to be a central underlying mechanism linking many of these effects. Early identification and multidisciplinary management are essential to prevent long-term health complications and performance decline. Future research should focus on standardized assessment methods and improved screening strategies to better address the issue in athletic populations.

Key words: eating disorders, athletes, relative energy deficiency in sport, low energy availability, female athlete triad, sports performance.

Introduction

Eating disorder is a common mental health condition, where one uses the control of food to cope with overwhelming situations and feelings. Unhealthy habits include eating too little, too much or worrying about the amount of food consumed [1]. EDs are one of the most debilitating mental illnesses of current times. The constant pursuit of an ideal body leads to an increasing number of individuals developing unhealthy habits that can easily evolve into eating disorders. Similarly, athletes, in order to maintain an ideal physique often resort to adopting restrictive diets [2]. To assess the consequences firstly it is essential to consider the causes and risk factors of disordered eating in sport. The most common include over-training, frequent weight cycling, participation in sports that emphasize the thin body shape, calories counting and sociocultural pressure whether it comes from coaches, parents or other teammates [3].

In recent years, the understanding of eating disorders in athletes has evolved beyond the traditional concept of Female Athlete Triad toward a broader and more comprehensive framework known as Relative Energy Deficiency in Sport (RED-S). This model encompasses a wide spectrum of health and performance consequences, including impairment in metabolic rate, immune function, cardiovascular health, protein synthesis, and psychological well-being.

Importantly, it highlights that both male and female athletes are at risk, thereby expanding the clinical relevance beyond the earlier female-centred perspective. It is an important conceptual advancement, emphasizing that energy deficiency is the primary underlying mechanism driving a range of systemic dysfunctions rather than isolated clinical outcomes. This broader perspective is essential for understanding the full impact of disordered eating in athletic populations and for developing more effective prevention and intervention strategies [4,5].

The aim of this study was to discuss the prevalence, manifestations and consequences both mental and physical of disordered eating in athletes.

Materials and methods

A targeted review of relevant literature was undertaken to explore the impact of eating disorders on athletes' health and the consequences that may arise from unhealthy eating habits. A comprehensive analysis of articles available in the PubMed database was conducted as it provides reliable and detailed articles, particularly in the field of health.

During the search of the PubMed database, the following keywords were used: "eating disorder", "sport", "athletes".

Methodology

The present paper was prepared as a narrative literature review focused on summarizing current evidence concerning the prevalence, clinical manifestations, and health consequences of eating disorders in athletes. Particular attention was given to both the physiological and psychological effects associated with disordered eating behaviors and low energy availability in sports populations. Although this review was not conducted as a formal systematic review, an organized and transparent search strategy was implemented to improve methodological consistency and reproducibility. The review process included predefined search terms, structured article selection, and critical evaluation of the relevant literature.

Literature search strategy: The literature search was carried out using the PubMed database, chosen due to its extensive collection of peer-reviewed publications in the fields of medicine, psychiatry, nutrition, and sports science. The search process included studies related to eating disorders and their consequences in athletic populations. The main search terms included: "eating disorder", "disordered eating", "athletes", "sport", "low energy availability", "Female Athlete Triad", and "Relative Energy Deficiency in Sport (RED-S)". These terms were combined using Boolean operators such as AND and OR to identify studies relevant to the

topic. Additionally, reference lists of selected publications were reviewed manually in order to identify further relevant articles.

Inclusion and exclusion criteria:

Publications were included if they:

1. were published in peer-reviewed journals;
2. were written in English;
3. involved athletes or physically active individuals;
4. examined the prevalence, mechanisms, psychological manifestations, physiological consequences, or performance-related outcomes associated with eating disorders or low energy availability.

Eligible publications included original research articles, observational studies, systematic reviews, and meta-analyses.

Studies were excluded if they:

1. lacked sufficient methodological information;
2. were editorials, brief commentaries, or opinion papers without analytical value;
3. consisted solely of isolated case reports;
4. were not directly related to eating disorders in sport populations.

Study selection and analysis: Initially, titles and abstracts were screened to determine their relevance to the subject of the review. Articles considered potentially suitable subsequently underwent full-text evaluation. Final selection was based on relevance to the objectives of the study, quality of methodology, and contribution to understanding the impact of eating disorders on athletes' health and performance. Because the included studies differed substantially in terms of population characteristics, sport disciplines, diagnostic methods, and measured outcomes, quantitative synthesis was not feasible. Therefore, the findings were analyzed using a qualitative narrative approach. The collected evidence was grouped according to major thematic areas, including prevalence of eating disorders, low energy availability, endocrine and skeletal complications, psychological effects, and consequences for athletic performance.

Methodological limitations: Several limitations of the present review should be acknowledged. The available literature demonstrates considerable variability in diagnostic criteria and assessment tools used to evaluate eating disorders, menstrual disturbances, and low energy availability. Many studies also relied on self-reported questionnaires and dietary data, which may reduce measurement accuracy and increase the risk of reporting bias. Furthermore, differences in sex, sport type, training level, and study methodology limit direct comparability between studies. Another limitation is that only the PubMed database was searched, which may

have resulted in omission of relevant studies indexed in other scientific databases. Nevertheless, the structured search process and critical analysis of peer-reviewed evidence provide a reliable overview of the current knowledge regarding eating disorders and their consequences in athletes.

Results

Eating disorders are among the more frequently diagnosed disorders in both athletes and non-athletes. Numerous studies have attempted to determine whether they occur more often in one of these groups, although athletes appear to represent a higher-risk group. A systematic review analyzing 22 studies on eating disorders among 11,000 women can be cited in this context. The results revealed the presence of eating disorders in 0-27% of female athletes compared to 0-21% of women in the general population [6]. Similarly, studies involving men suggest that men who participate in sports have a higher risk of eating disorders [7]. Studies also highlight that certain sports, particularly aesthetic and antigravity disciplines, are associated with higher rates of subclinical or clinical ED. A large-scale study conducted in Norway also supports these findings, showing that more athletes than non-athletes exhibited subclinical or clinical ED, particularly those participating in antigravitation sports (22% of male) and aesthetic sports (42% of female) [8]. Given the documented prevalence of EDs, it is important to consider the potential consequences these conditions may have on athletes' physical health, psychological well-being and performance.

Eating disorders in athletes encompass a spectrum of distinct clinical conditions, including anorexia nervosa, bulimia nervosa and binge eating disorder, which differ in their behavioural and physiological characteristics. Anorexia nervosa is characterized by severe energy restriction leading to significantly low body weight, accompanied by intense fear of weight gain and body image distortion, and is associated with endocrine disturbances and reduced bone mineral density [9]. In athletes, these features are particularly concerning as chronic energy deficiency may impair physiological function, increase injury risk and negatively affect long-term skeletal health [4]. Bulimia nervosa is defined by recurrent episodes of binge eating followed by compensatory behaviours such as self-induced vomiting, excessive exercise or misuse of laxatives, which has been associated with significant electrolyte disturbances, including hypokalaemia, and increase the risk of cardiac arrhythmias and potentially life-threatening complications [10]. These effects are particularly relevant in athletes, as even subtle disturbances can impair performance and increase health risks during intense physical exertion.

Binge eating disorder is characterized by recurrent episodes of consuming large amounts of food accompanied by a sense of loss of control, without regular compensatory behaviours, and is associated with psychological distress, impaired quality of life and metabolic consequences [11]. Although less frequently discussed in the context of sport, binge eating behaviours may occur in athletes, particularly as a response to restrictive dieting and energy imbalance. In athletic populations, restrictive eating patterns and compensatory behaviours remain more commonly observed in aesthetic and weight-sensitive sports [12], whereas binge eating is less consistently associated with these disciplines.

In 1993 in “Medicine and Science in Sports and Exercise" an article was published in which the so-called “female athlete triad” was described [13]. It consists of three conditions: disordered eating, amenorrhea and osteoporosis. The authors of this study mention several consequences of poor nutrition, such as fatigue, anemia, electrolyte abnormalities, depression, which ultimately lead to reduced performance and athletic results. In this paper, it has been reported that amenorrhea, which is defined as the absence of three to six consecutive menstrual cycles, affects 3,4% to 66% female athletes compared to 2-5% of non-athletic women [13]. They also point to osteoporosis as a potential outcome of poor dietary habits, which may result in an increased risk of fracture.

In a more recent study from 2007 [14], the classification was only slightly modified and it included menstrual dysfunction, changes in bone mineral density and low energy availability. To assess BMD and the risk of osteoporosis in adults the T-score is commonly used. However, clear WHO guidelines are lacking for women and children, therefore the Z-score is recommended for the evaluation of BMD in these populations. Most professional athletes demonstrate BMD values approximately 5-15% higher than non-athletes. Consequently, a Z-score below -1.0 in athletes should raise concern and warrant further diagnostic evaluation. Because most competitive sports are pursued from a young age, inadequate nutrition carries a proven risk of failing to achieve peak bone mass, which consequently may result in weaker bones throughout life and an earlier onset of osteoporosis than average [14]. Many researchers find lowered BMD among athletes who suffer from subclinical menstrual disturbances, which suggests that these subjects may be linked [15].

Within this topic, a notable term that has grown considerable attention is Low Energy Availability [14]. Energy availability is defined as the portion of dietary energy that remains for vital physiological functions after the energy cost of exercise has been accounted for. When this availability is insufficient, the body initiates adaptive mechanisms that conserve energy by

downregulating key processes, including cellular maintenance, growth and reproductive function. Such adaptations highlight the critical role of adequate energy intake in supporting both athletic performance and overall health.

Even though the Female Athlete Triad provided a reasonable explanation for the aforementioned issues, there remained a need for a concept that would more comprehensively define the problem. In 2014 the broader concept of Relative Energy Deficiency in Sport (RED-S) was introduced. This framework was developed to acknowledge that the consequences of LEA extend beyond the three classical components and can affect athletes of both sexes. With RED-S model Low Energy Availability is considered the underlying cause of a diverse clinical manifestations involving several body systems such as metabolic, endocrine, reproductive, immunological, cardiovascular and psychological functions. Consequently athletes experiencing LEA may present with a wide and heterogeneous spectrum of clinical manifestations. Importantly, RED-S may also occur in athletes with stable body weight and apparently normal body composition, indicating that the absence of visible weight loss should not exclude the diagnosis [16]. It has been shown to negatively impact metabolic rate, leading to reduced resting energy expenditure, as well as impairments in glucose metabolism and lipid regulation. Additionally, compromised immune function may result in increased susceptibility to infection and prolonged recovery times [4,5]. From a cardiovascular perspective, RED-S has been associated with endothelial dysfunction and unfavorable lipid profiles, which may contribute to long-term cardiovascular risk. Furthermore, impairments in protein synthesis and muscle function can negatively affect strength, endurance, and overall athletic performance [4,5]. Evidence suggests that adolescents may also experience growth retardation, loss of dental enamel due to chronic vomiting and structural brain changes [17]. Other consequences of ED in athletes - although numerous - are largely comparable to those observed in non-athletic populations. These may include symptoms such as bradycardia, hypotension, prolongation of the QT interval, cardiac muscle remodeling, electrolyte imbalances, impaired renal function, intestinal dilatation, reduced gastrointestinal motility, among others [18]. Importantly, in individuals engaged in high-level athletic activity, these manifestations may appear earlier and lead to complications more rapidly. This is likely due to the fact that an athlete’s body is continuously exposed to intense physical stress, under which even minor dysfunctions in physiological systems may pose significant health risks. These systemic effects highlight that RED-S is not merely a nutritional issue but a complex syndrome with widespread physiological implications.

When examining the consequences, it is also important to recognize the broad spectrum of psychological issues and disorders linked to ED among athletes. Female athletes with eating disorders often experience heightened body dissatisfaction, a strong drive for thinness and elevated anxiety, which can affect both mental well-being and daily functioning. They are also more likely to exhibit maladaptive personality traits, such as higher harm avoidance and lower self-directedness, reflecting increased vulnerability to stress and difficulties in emotional regulation. Additionaly, these athletes show higher prevalence of suicidal ideation, emphasizing the serious mental health risks linked to disordered eating in the population [19]. A significant negative influence of ED on athletes' well-being may also manifest in a spectrum of other conditions such as depression, anxiety, social withdrawal, substance abuse and self-harm [20]. Moreover, ED can increase susceptibility to injuries and illnesses, thereby disrupt training continuity, adaptation processes and recovery from fatigue. Such interruptions in training can subsequently compromise competitive performance. There are also studies that indicate an association between ED and depression, with findings showing that, in the population examined, athletes' initial levels of eating related psychopathology predicted depressive symptoms emerging approximately six months later [21].

Eating disorders in male athletes are increasingly recognized as a significant clinical problem, although they remain underdiagnosed and underreported compared to female populations [22]. Emerging evidence suggests that men may experience clinically relevant consequences of LEA even in the absence of formally diagnosed eating disorders suggesting that subclinical energy deficiency represents an important but often overlooked condition [23]. In this context, studies have shown that RED-S in men can lead to suppression of the hypothalamic-pituitary-gonadal axis, resulting in disturbances in libido and sexual function, which may serve as early clinical indicators of underlying endocrine disruption [23]. Importantly, these symptoms may occur even when testosterone levels remain within the lower end of the normal range, indicating that standard hormonal assessment may not fully capture functional impairment [24]. In addition, research suggests that energy deficiency in male athletes has been suggested to negatively affect their cognitive function, including concentration, reaction time, and decision-making processes, which are critical for sport performance [25]. Another important aspect is that male athletes may maintain normal body mass index despite significant energy deficiency, which can mask the presence of underlying metabolic and endocrine disturbances [26]. This highlights the limitation of relying on body composition alone as an indicator of health status in this population.

CLINICAL IMPLICATIONS AND RISK STRATIFICATION IN RED-S

Beyond its physiological manifestations, RED-S has important implications for clinical decision-making and athlete management, The International Olympic Committee emphasizes that the identification of RED-S should not be limited to diagnosis alone, but should also guide risk stratification and participation decisions in sport. In this context, athletes are classified into different risk categories based on the severity of symptoms and clinical findings.

High-risk athletes include those presenting with severe energy deficiency, significant weight loss, ongoing eating disorders, or serious medical complications such as marked hormonal suppression or recurrent stress fractures. These individuals may require temporary restriction from training and competition until their condition stabilizes. Moderate-risk athletes may continue to participate under medical supervision with appropriate modifications to training load and nutritional support, while low-risk athletes can typically maintain full participation with continued monitoring.

This risk-based approach represents an important shift from traditional models, as it integrates medical safety with performance considerations. It also highlights that the consequences of low energy availability are not only long-term but may have immediate implications for training capacity, injury risk, and competition readiness.

Furthermore, the IOC underscores the importance of multidisciplinary approach in managing RED-S, involving physicians, dietitians, psychologists and coaches. Such collaboration is essential, as the condition often involves complex interactions between physiological, psychological and environmental factors. Effective management requires not only restoring adequate energy availability but also addressing underlying behavioral and cognitive patterns associated with disordered eating [27,28].

SCREENING AND IDENTIFICATION OF ED IN ATHLETES

Screening for eating disorders and energy deficiency in athletes remains primarily on validated self-report questionnaires, which offer a practical, cost-effective, and scalable method for early identification of at-risk individuals. Among the most commonly used tools is the Eating Disorder Examination Questionnaire (EDE-Q), which assesses eating behaviours, body image concerns and psychopathology related to eating disorders, and has been widely applied in athletics populations of both sexes [29]. Another brief and widely used instrument is the SCOFF questionnaire, which has shown high sensitivity in detecting eating disorder cases among athletes, identifying up to 94% of clinically diagnosed individuals in comparison with

structured interviews [30]. In addition to tools targeting eating disorder psychopathology, screening for Low Energy Availability and Female Athlete Triad risk is commonly performed using the Low Energy Availability in Females Questionnaire (LEAF-Q), which evaluates physiological symptoms such as menstrual dysfunction, gastrointestinal disturbances and injury history [31]. The LEAF-Q has demonstrated acceptable diagnostic performance, with sensitivity around 78% and specificity approximately 90% in identifying athletes at risk for LEA and related conditions [32]. However, its applicability may vary depending on sport type, as some studies indicate reduced predictive accuracy in non-endurance populations, highlighting the need for context-specific validation [33]. Importantly, while questionnaires are valuable for large-scale screening and early detection, they do not replace clinical assessment and should be used as part of broader diagnostic approach combining medical evaluation, dietary analysis and, where possible, objective physiological measurements.

In addition to questionnaire-based screening tools, the IOC has introduced the RED-S Clinical Assessment Tool (RED-S CAT), which provides a structured approach for evaluating athletes and guiding return-to-play decisions. This tool categorizes athletes into high, moderate or low risk based on clinical indicators such as significant weight loss, hormonal dysfunction, psychological symptoms, and physiological impairments. The RED-S CAT is particularly valuable in sports medicine settings, as it integrates medical, nutritional, and psychological factors into a unified risk assessment model. It also supports clinical decision-making regarding training modification and competition eligibility, emphasizing athlete safety and long-term health outcomes [28].

Discussion

The findings presented highlight the multifaceted impact of eating disorders on athletes, encompassing both physiological and psychological domains.

Having examined the physiological consequences of disordered eating, it is equally important to consider their mechanisms. In the context of RED-S, functional hypothalamic amenorrhoea (FHA) represents one of the reproductive consequences of LEA. Insufficient energy intake relative to energy expenditure disrupts the hypothalamic-pituitary-gonadal axis, leading to decreased pulsatile secretion of gonadotropin-releasing hormone (GnRH) and subsequent reductions in luteinising hormone (LH) and follicle-stimulating hormone (FSH). This neuroendocrine suppression results in hypoestrogenism, menstrual disturbances, and in female athletes, amenorrhoea [14,16]. Psychological factors, including heightened stress, perfectionism and restrictive eating behaviors, interact with metabolic stress to reinforce the

suppression of the hypothalamic-pituitary-ovarian axis. Altered levels of neuroendocrine regulators such as leptin, ghrelin and beta-endorphins, alongside elevated cortisol, highlight the role of both energy deficit and stress in maintaining amenorrhoea [34]. Resistance to dietary and training modifications can further prolong menstrual dysfunction, creating a cycle where psychological and physiological factors perpetuate one another.

In athletes affected by RED-S, reduction in bone mineral density (BMD) arises from the combined effects of insufficient energy availability and hormonal alterations. Persistent low energy intake impairs bone formation and accelerates bone resorption, independently of estradiol levels. Nevertheless, estrogen plays a key role in maintaining bone health by limiting resorption and promoting formation, so hypoestrogenism exacerbates the skeletal consequences of energy deficiency. Research indicates that when energy availability drops below approximately 30 kcal/kg FFM/day, bone resorption increases and formation decreases, with a similar dose-response effect observed for metabolic hormones such as T3, IGF-1, cortisol and leptin. This demonstrates that the simultaneous impact of LEA and reduced estrogen places athletes at particularly high risk of compromised BMD.

From a clinical and performance-oriented perspective, these alterations carry a particular significance in athletic populations. Menstrual dysfunction, often perceived as a benign or even expected consequence of intensive training, may in fact serve as an early indicator of underlying energy deficiency and endocrine disruption. Failure to recognize and address amenorrhoea in a timely manner has been associated with a prolonged hormonal imbalance, thereby exacerbating downstream physiological consequences.

Similarly, reductions in bone mineral density represent not only a long-term health concern but also an immediate risk factor for injury. It increases susceptibility to stress fractures, which may result in prolonged absence from training. Given that peak bone mass is established during adolescence or early childhood, the presence of LEA during this critical period may have lasting consequences, limiting the attainment of optimal skeletal health [14].

While FAT remains a clinically valuable framework, particularly identifying interactions between energy availability, menstrual function, and bone health, it represents a more limited model compared to RED-S. The American College of Sports Medicine (ACSM), emphasizes that the components of the Triad exist along a continuum, ranging from optimal health to severe clinical manifestations. The continuum-based perspective allows for earlier identification of at-risk athletes, even in the absence of overt clinical symptoms. However, RED-S extends this model by incorporating additional physiological systems and by recognizing the presence of similar mechanisms in male athletes. For example, in men, low energy availability has been

associated with reduced testosterone levels, decreased libido, and impaired bone health. These findings further support the notion that energy deficiency has universal biological consequences regardless of sex [16,27]. A critical issue in the evaluation of eating disorders and RED-S in male athletes is the lack of validated, sex-specific screening tools, which may contribute to systematic underdiagnosis in this population [25]. Most commonly used instruments such as EDE-Q or SCOFF, were originally developed and validated primarily in female populations, potentially limiting their sensitivity in detecting male-specific symptom patterns [22]. Furthermore, the clinical manifestation of LEA in men may be more subtle and less linear than in women, as it lacks a clearly observable marker such as menstrual dysfunction [23]. As a result signs such as reduced libido, persistent fatigue, or decreased training adaptation may be overlooked or misattributed to training load alone[23]. This diagnostic ambiguity underscores the need for greater clinical awareness and the development of more sensitive assessment strategies tailored to male athletes [25]. Future research should therefore prioritise the identification of early, non-specific markers of energy deficiency in men, as well as the validation of screening tools that account for differences in symptom expression and sport-specific demands.

Importantly, these outcomes highlight a key challenge in sports medicine, as the physiological adaptations associated with RED-S may initially remain subclinical, while still negatively affecting performance recovery. This underscores the need for early identification and intervention, particularly in high-risk groups, where the cumulative effects of energy deficiency, hormonal suppression, and mechanical loading may significantly impact both short-term athletic outcomes and long-term health.

The findings suggest that the psychological burden associated with eating disorders in athletes extends beyond the presence of discrete clinical symptoms and reflects a complex interplay of individual predispositions and environmental influences. Disturbances in body image appear to play a central role, often persisting despite objectively appropriate body composition and being reinforced by habitual comparison with peers and other competitors, as well as by comments from coaches [35]. This may contribute to a progressive decline in self-esteem, with personal value becoming increasingly dependent on physical appearance and the ability to maintain strict control over diet. In addition, certain personality characteristics, particularly perfectionism and an elevated need for control, may further intensify vulnerability to disordered eating patterns [30]. In this context, the regulation of food intake may serve not only a functional purpose but also a psychological one, providing a sense of structure, predictability, and achievement. However, this perceived control may become maladaptive, reinforcing rigid

behaviours and limiting psychological flexibility. At the same time, athletes are frequently exposed to competing demands arising from performance expectations, health consideration, and sociocultural ideals of physique [36]. The necessity to simultaneously maintain strength, endurance, and a specific body composition may create a persistent internal conflict. This tension may contribute to persistent internal conflict, which, when combined with pressures of high-level training, can intensify overall distress and contribute to progression of disordered eating behaviours.

Many studies in the literature have examined whether athletes are more susceptible to ED and related symptoms than non-athletic populations, with evidence generally indicating a higher prevalence of EDs in athletes, but also some important nuances depending on sport type, competitive level, and study methodology. For instance, as mentioned previously, Sundon-Borgen et al. found that elite athletes had significantly higher prevalence of ED (13.5%) compared to non-athletic controls (4.6%), and that the highest rates were observed in female athletes competing in aesthetic sports (42%) and male athletes in antigravity sports (22%) [8], compared with lower rates in endurance, technical, and ballgame sports, clearly highlighting sport-specific risk patterns.

This pattern of increased ED prevalence among athletes in sports where body weight or leanness is emphasized is supported more broadly: multiple reviews and empirical studies report that individuals participating in aesthetic, lean, or weight-sensitive disciplines (e.g. dance, gymnastics, endurance running) are at elevated risk for both disordered eating behaviours and clinical eating disorders relative to general population samples [37].

However, not all investigations uniformly find greater ED symptoms in athletes compared with inactive peers, underscoring methodological variability and contextual factors. A recent Norwegian cross-sectional survey found that recreational and national-level athletes actually reported lower global disordered eating symptom scores than sedentary and physically active non-athletes, though athletes in leanness-focused sports did exhibit greater concern and restrain related to eating behaviours compared to athletes in non-leanness sports [38]. In another study from 2010, no difference in prevalence of eating disorders were observed in 55% of participants when compared to non-athletes. However, in the same study, athletes exhibited a higher prevalence of menstrual disturbances.

Large meta-analyses suggest that athletes may be at a slightly increased risk of eating problems, particularly in disciplines such as dance but for gymnasts increased risk has not been

consistently confirmed. At the same time, athletic participation may in certain contexts exert a protective effect [39].

Further evidence from form collegiate athlete samples shows that female athletes are more likely than male athletes to screen at risk for ED and LEA, and that within athletic populations aesthetic sports participants demonstrate highest prevalence of ED risk, whereas other sport types show elevated risks relative to general estimates but with variation by sex and sport context [40].

Overall, the available evidence indicates that the relationship between athletic participation and eating disorders is complex and multifactorial [41], with risk varying substantially depending on sport type, competitive level, and individual characteristics. These inconsistencies, together with methodological differences across studies, suggest that athletic participation cannot be uniformly classified as either a risk or protective factor, but rather should be considered within a broader contextual framework. Greater emphasis should therefore be placed on the health consequences of eating disorders (both physiological and psychological) in affected individuals, as they constitute a significant clinical problem impacting overall health, regardless of whether their prevalence is higher among athletes or non-athletes.

Limitations

Despite these findings having substantial contribution to understanding the influence of ED on athletes' health it is important to highlight some of their limitations.

The reported prevalence of amenorrhoea in athletic populations varies widely (3,4% to 66%) [13] reflecting substantial inconsistencies in its definition and detection. The variability is probably due to reliance on self-reported menstrual history and the failure to capture subclinical menstrual disturbances, such as anovulation or luteal phase defects, which require hormonal verification but are rarely assessed.

Similarly, the evaluation of BMD is complicated by the inconsistent diagnostic criteria, particularly the application of T-scores versus Z-scores. The use of T-score in premenopausal women and athletes may lead to misclassification, as they do not account for age, sex or sport-specific adaptations. In contrast, Z-scores provide age- and sex-matched comparisons but are not uniformly applied across studies limiting comparability and accuracy in estimating the prevalence of low BMD. Moreover, not all studies support the fact that LEA necessarily increases the risk of injury [42].

Furthermore, the assessment of EA remains methodologically challenging, as it is typically derived from self-reported dietary intake and estimated exercise energy expenditure, both of

which are prone to measurement error and reporting bias. Collectively, these issues underscore the need for more standardized, objective, and population-appropriate assessment methods in research of the Female Athlete Triad and RED-S.

In spite of substantial advances in understanding the topic, the literature remains limited by methodological heterogeneity, including inconsistent diagnostic criteria, reliance on self-reported data, and variability in the assessment of key constructs such as energy availability and menstrual function,

In sum, differences between studies in sample characteristics, assessment tools (e.g. self-report vs clinical interviews), and definitions of disordered eating mean that prevalence estimates are heterogeneous and must be interpreted within a methodological context.

A strength of this review is the integration of current concepts such as RED-S with both physiological and psychological perspectives, providing a comprehensive overview of the problem.

Conclusions

Eating disorders represent a significant and multifaceted health concern among athletes, with a generally higher prevalence observed particularly in sports emphasizing leanness and aesthetics. The findings of this review indicate that their consequences extend beyond disordered eating behaviours, affecting multiple physiological and psychological systems.

Low energy availability appears to be a key underlying mechanism, contributing to menstrual dysfunction, reduced bone mineral density, and broader endocrine disturbances. These changes increase the risk of injury, impaired recovery, and long-term health complications. At the same time, athletes with eating disorders frequently experience psychological difficulties, including anxiety, depression, and body dissatisfaction, which may further perpetuate disordered behaviours.

Importantly, these consequences negatively impact athletic performance by disrupting training continuity and recovery processes. However, interpretation of existing literature is limited by methodological inconsistencies and variability in assessment approaches. These limitations highlight the need for standardised, objective, and sport-specific assessment tools in future research.

The growing recognition of RED-S as a unifying framework underscores the need for a paradigm shift in both research and clinical practice. Rather than focusing solely on isolated symptoms or specific populations, future approaches should prioritize early detection of energy deficiency and its systemic consequences across all athletic populations, The integration of

RED-S into routine clinical screening and athlete monitoring may significantly improve both health outcomes and performance sustainability.

Particular attention should be given to under-recognized groups, such as male athletes, in whom clinical presentation may be less obvious and therefore more easily overlooked.

Overall, eating disorders in athletes require early recognition and a multidisciplinary approach, with greater emphasis on prevention, standardised assessment, and further research to improve clinical and performance outcomes.

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Supplementary Materials

Not applicable.

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Declaration of the use of generative AI and AI-assisted technologies in the writing process:

During the preparation of this manuscript, the author made use of generative AI tools to support grammatical corrections, stylistic refinement, and translation into English to achieve an appropriate academic tone. After using this tool the authors reviewed and edited the content as needed and take full responsibility for the final version of the manuscript.

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