PRACTICAL APPROACHES TO IMPROVING NUTRITION AND ENERGY AVAILABILITY IN RED-S

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INTRODUCTION

Participation in sport places significant demand on the body to sustain performance and support recovery. Nutrition provides the substrates needed for sport and to support normal physiological function. Inadequate nutrition creates a deficit in these substrates, which can negatively affect health and athletic performance. Correction of nutrient intake and balance can, in many cases, restore an athlete's health status and support optimal athletic performance.

ENERGY AVAILABILITY AND RELATIVE ENERGY DEFICIENCY IN SPORT (RED-S)

The human body requires nutrition in the form of calories and nutrients in order to perform the various processes needed to support survival and wellbeing. For the athlete, additional calories are needed to support the demands placed on the body during and following physical activity. The term energy availability (EA) refers to the calories ingested [energy intake (EI)] less the calories expended through exercise [exercise energy expenditure (EEE)], normalized for fat free mass (FFM) and expressed as kilocalories per kg of FFM per day (kcal/kg FFM/day). Adequate energy availability has been suggested in the literature to be 45 kcal/kg FFM/day[1]. Research has demonstrated that below 30 kcal/kg FFM/day, physiological changes alter the signaling of hormones, resulting in impaired function[2]. The Female Athlete Triad (Triad) describes the interplay among EA, bone mineral density (BMD) and menstrual function. While this model originally described the impact of LEA as disordered eating (DE), amenorrhea, and osteoporosis, it is now recognized as a spectrum disorder spanning from optimal EA to low EA (LEA) with or without an eating disorder (ED), optimal bone health to osteoporosis, and eumenorrhea to functional hypothalamic amenorrhea (FHA)[3].

In 2014, the International Olympic Committee (IOC) published a consensus statement describing Relative Energy Deficiency in Sport (RED-S), a syndrome which details the effects of LEA on numerous body systems in both male and female athletes, including the endocrine system, metabolism, hematological system, growth and development, cardiovascular system, gastrointestinal system, immune system, and reproductive system. LEA additionally can affect and be affected by psychological conditions such as stress, anxiety, depression, or an EA[4–6]. The RED-S model also details the potential performance effects of LEA, including decreased endurance performance, increased injury risk, decreased training response, decreased glycogen stores, decreased muscle strength, impaired judgement, decreased coordination and concentration, irritability, and depression. (Figure 1)[6]. Surveying athletes has illustrated the high prevalence of LEA and the systemic health and performance effects that can occur[8]. The 2018 IOC RED-S update described

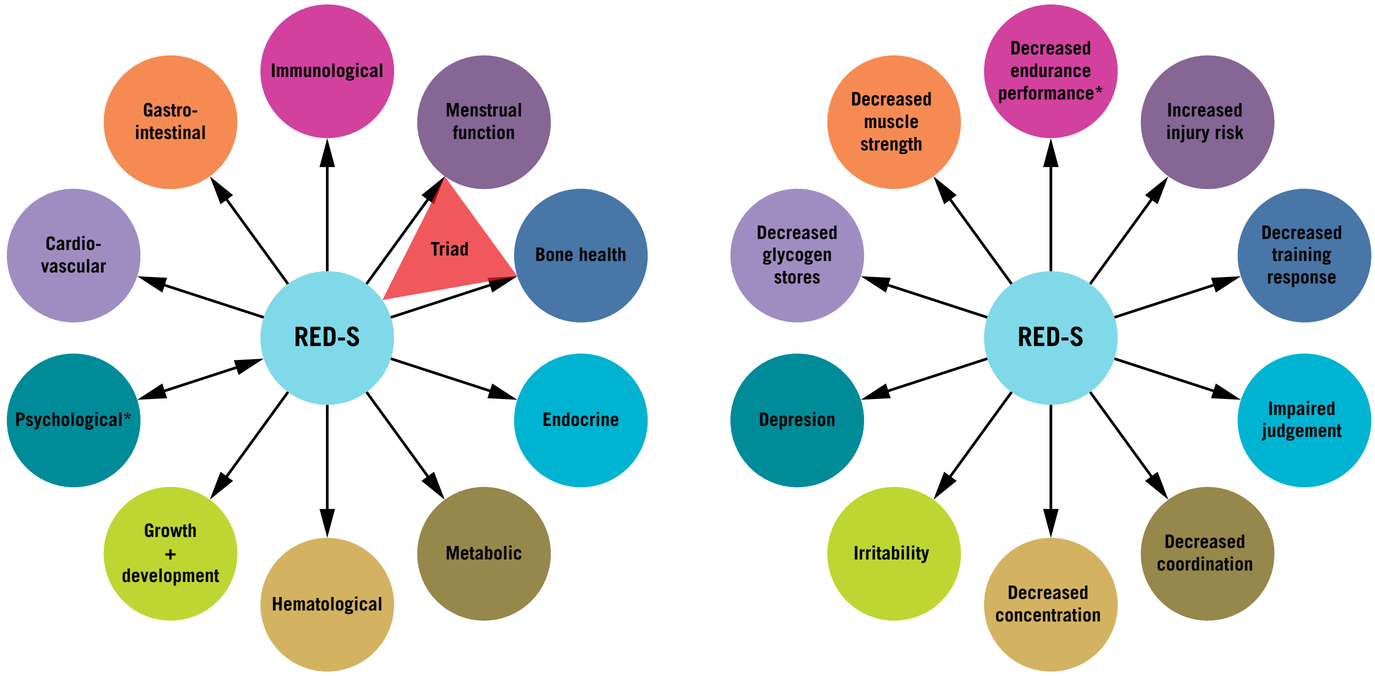

Figure 1: Health and Potential Performance Consequences of Relative Energy Deficiency in Sport[7].

the scientific progress that has been made in studying RED-S and the gaps in knowledge that remain, including assessment of EA and validated prevention measures[9].

PREVALENCE OF LEA AND RED-S IN SPORT

Prevalence of LEA varies across sports and between different athlete populations, with a higher prevalence found in those sports with a focus on weight and/or aesthetics. In athletics, prevalence of LEA and its subsequent complications varies across events, with higher prevalence seen in middle-to-long distance runners and jumping events[10]. In an examination of 40 elite female endurance athletes using food and exercise logs, Melin, et al found that 63% had low/reduced EA (<45 kcal/kg FFM/day)[11]. In female high school athletes participating in various sports, 36% had LEA as indicated by EA ≤ 45 kcal/kg FFM, with 6% < 30 kcal/kg FFM. EI was calculated using the results of 3-day food diaries and EEE was determined using the compendium of physical activities classification and included details regarding sport participation, exercise intensity, age, weight, and sex[12,13]. Elite sprinters assessed for EA were found to have a risk of LEA prevalence from pre-season (31%) to post-season (54%) by analysis of primary (amenorrhea, bone mineral density, follicle-stimulating hormone, luteinizing hormone, estradiol, resting metabolic rate, Low Energy Availability in Females Questionnaire (LEAF-Q) score) and secondary (fasting blood glucose, free triiodothyronine, ferritin, low-density lipoprotein cholesterol, fasting insulin, insulin-like growth factor-1, systolic blood pressure and diastolic blood pressure) LEA markers[14]. LEA has been examined in recreational athletes as well, with as many as 45% classified as "at risk" for LEA using the LEAF-Q[15].

While female athletes have been the focus of many EA studies, research in male athletes has increased in an effort to further understand how LEA presents in each sex. LEA in male athletes has been examined in cycling, distance running, rowing, and combat sports such as judo[16–18]. Male jockeys have low BMD and increased bone resorption, suggestive of hormonal changes due to the common practice of weight cycling in the sport[19]. Assessment of 108 recreationally-trained male athletes using the EA cut-points categorized in females (LEA < 30 kg/kg FFM, adequate EA≥45 kg/kg FFM) found that 47.2% were categorized as LEA and nearly 80% of the study participants were below adequate EA[20].

Specialists have additionally described the prevalence of LEA in the para-athlete population. A survey of 260 male and female para-athletes found that signs associated with Triad/RED-S, such as bone stress injuries, oligomenorrhea/amenorrhea, and an elevated Eating Disorder Examination Questionnaire (EDE-Q) score, were present in this population[21]. These findings are not consistent across studies, however, and more research is needed to fully characterize LEA in athletes with disabilities[22,23].

ADDRESSING RED-S WITH NUTRITION

Assessment

When treating RED-S, experts recommend the coordination of an interdisciplinary team, including at least a sports medicine physician and registered dietitian (RD/RDN), and often a psychologist[6,9]. Nutrition is a critical component of EA and as such, an important point of intervention when working with athletes with RED-S and LEA. An RD/RDN, and preferably one specialized in sports dietetics, is a valuable provider for this population given their knowledge and experience in guiding athletes and understanding sport culture. Furthermore, a sports RD/RDN experienced in treating DE and EDs is ideal given the prevalence of eating pathology in athletes with RED-S.

Nutrition management of RED-S begins with assessment of EA by gathering data on EI and EEE. There are numerous strategies for assessing EI and EEE, each with its own limitations with regards to accuracy[24]. Predictive equations can be utilized to calculate resting metabolic rate (RMR), and with the addition of physical activity expenditure can be used to estimate energy needs. If FFM data are available, the Cunningham-Sabo equation can be utilized[25]. Other popular predictive equations include Harris-Benedict and Mifflin St. Jeor[26,27]. These predictive equations were developed using the general population and therefore may underestimate an athlete's RMR. Furthermore, these predictive equations may result in inaccuracies when calculating energy needs for those in an energy deficit[28]. The Cunningham and Harris-Benedict equations are considered the most accurate predictive equations available for assessment in athletes[29].

Assessment of EA necessitates a comparison between EI and energy expenditure. Collecting accurate energy and nutrient intake information poses challenges. Common strategies include 24-hour recalls, dietary records, food frequency questionnaires (FFQs), and food logs. Researchers commonly cite underreporting as a challenge when using 24-hour recalls and dietary records. FFQs may provide more accuracy when analyzing specific nutrients, but may not be able to capture the variability in intake that athletes often have[30,31]. Furthermore, the act of logging nutritional intake could influence food choices and behaviors, therefore making it difficult to analyze ad libitum intake[32]. Weight is not a dependable indicator of EA, as those with LEA can be weight stable due to the suppression in RMR[33].

Assessment of overall energy needs includes factoring in the expenditure of physical activity. This can be measured using pedometers, accelerometers, or GPS trackers, or estimated using metabolic equivalent of task (MET) or physical activity coefficients[34,35]. There is no standard method for assessing expenditure and there is no consensus in the literature regarding what constitutes EEE[34]. Additionally, many methods for assessing expenditure outside of a controlled research setting have the potential to inaccurately capture EEE. A study comparing various wearable devices to doubly-labelled water (DLW) found that these devices underestimated expenditure in free-living individuals by 69-590 calories[36]. Comparison of accelerometers and the energy-cost estimates via questionnaire in elite athletes found that EEE was 20-30% lower on accelerometer results[37].

Given the challenges associated with calculating EA, a fully comprehensive assessment conducted by an inter-disciplinary team increases the likelihood that LEA will be detected. Analysis of reproductive function using labs and questionnaires has been found to be more accurate and objective than self-reported intake and estimations of EA[24]. Indirect or direct calorimetry can be used to assess RMR and determine if metabolic suppression has occurred[38]. Dual-energy X-ray absorptiometry (DXA), the modern gold standard for anthropometric assessment, provides information on BMD and FFM, which can be critical for assessing bone health and body composition in those suspected to have RED-S[39,40].

Treatment

Once RED-S has been diagnosed, an important step in treatment is to determine the cause of LEA. An athlete can develop RED-S due to a lack of knowledge about energy needs, limited dietary intake due to food allergies or gastrointestinal concerns, food insecurity, or DE or an ED[6,9]. The body undergoes acute hormonal changes following exercise – the suppression of leptin and suppression or maintenance of ghrelin – that can impair appetite and could lead to LEA if an athlete is not fueling properly following training[41]. This differs from the hormonal changes present in chronic LEA which included decrease leptin and increased ghrelin[42]. While those athletes exhibiting unawareness of nutritional needs may be able to amend their EA status through nutrition education, those with DE/ED will require nutrition counseling to address disordered thoughts and behaviors[43]. Therefore, understanding the contributors to LEA can help the provider determine the most appropriate, personalized approach.

Male and female athletes cite a lack of nutrition knowledge and contradictory sports nutrition information in scientific literature, anecdotal data, and articles written for the lay public make it difficult for athletes to determine how to best fuel for their sport[44,45]. Sports nutrition education provided in a group or individualized setting, has been shown to significantly improve nutrition behaviors and knowledge and self-efficacy[46–48]. Nutrition education should focus on the unique nutritional needs of the athlete and should connect to an individual athlete's sport, when possible.

For those athletes with DE/ED, nutrition counseling is warranted in order to support behavioral change and move the athlete towards adequate EA. Commonly used counseling modalities employed by dietitians working with DE/ED include cognitive-behavioral therapy (CBT), dialectical behavioral therapy (DBT), motivational interviewing (MI), family-based therapy (FBT), and acceptance and commitment therapy (ACT). The use of these differing techniques may depend on the eating behaviors that are present and the athlete's stage of change[43]. Nutrition counseling and guidance is provided in conjunction with psychotherapy and possibly pharmacotherapy, and therefore consistent communication among members of the interdisciplinary team is recommended to ensure the athlete with DE/ED is supported while working towards normative eating behaviors and attitudes that will support adequate EA[49].

Therapeutic nutrition interventions for RED-S require an individualized approach and an assessment that indicates the contributors to LEA for an athlete. Nutritional interventions may require an increase in dietary intake, a decrease in exercise expenditure, or both to support adequate EA[3,6,9]. Athletes may need to adjust their dietary patterns by shifting their macronutrient intake or changing their nutrition timing. The provider should inform the athlete that improvement in RED-S signs and symptoms, including FHA and low BMD, can take months to years to improve, even once adequate EA is achieved[3]. For female athletes presenting with FHA, weight gain and fat mass gain may be warranted in order to support hormonal function, and improvement in EA does not ensure immediate resumption of menses[50]. In those who have achieved weight stabilization, it can take 6 to 12 months to resume menses[51].

In many cases, weight gain is necessary in order to address LEA and promote optimal physiological function. Weight gain at a rate of 0.23 kg per week is manageable for most individuals and may require an increase in EI, and decrease in EEE, or both[52,53]. The amount of weight gain needed varies and research suggests that females may need to gain 2 kg more than the weight at which menses was lost in order to support menstrual restoration[51,54]. When low body fat is present as a result

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of LEA, increasing fat mass to essential levels is required to support the role of fat in metabolism, including bone health[55,56]. Weight gain in the form of fat mass gain is associated with proper hormonal functioning in those with FHA[57]. Observation of body fat distribution in females with anorexia nervosa has described the initial increase in fat mass distribution in the central region of the body and a subsequent redistribution of body fat once weight restoration has been maintained[58,59]. It is important to explain this phenomenon to those restoring body weight, as this initial increase in central mass can be psychologically distressing.

Due to the systemic effects of LEA, certain nutrients – namely calcium and vitamin D – become particularly critical when addressing RED-S. Calcium and vitamin D are both important for bone health, therefore nutrition treatment should ensure that intake is adequate[60]. Adults and children need 1,000mg/day of calcium, while pre-adolescents and adolescents require 1,300mg/day. While dietary intake of calcium is preferred, due to its increased bioavailability, supplementation with calcium citrate or calcium carbonate is also appropriate. Because calcium is most bioavailable at or below 500 mg, calcium should be ingested multiple times per day to achieve daily requirements[40]. The United States Department of Agriculture (USDA) recommends 600-800 international units (IUs) of vitamin D daily to support bone health, but research suggests that higher doses are needed to support vitamin D levels >30 ng/mL, which is what is recommended for adequate vitamin D in athletes[61,62]. Vitamin D needs can be met through 15-30 minutes of sun exposure/day, fortified foods, and supplementation[40]. Vitamin D3 supplements are more bioavailable than vitamin D2[63].

Athletes with RED-S may present with suboptimal iron stores as well, which can become inadequate due to restricted intake of iron-containing foods[64]. A high amount of repetitive weight-bearing contact – like that seen with running – can also compromise iron levels through foot-strike hemolysis[65]. Exercise can also impair iron absorption through the upregulation of hepcidin[66,67] Dietary interventions for iron include consuming sources of heme iron and pairing sources of non-heme iron with vitamin C-rich foods for optimal absorption[68]. Supplementation is recommended for athletes with iron depletion in order to prevent anemia[40].

CONCLUSION

RED-S has varying impacts on individual athletes but can have a profound effect on health and performance. Nutrition plays a key role in correcting LEA and treating RED-S. Further research is needed to determine the best strategies for assessing EA in the clinical setting. Understanding the nutritional, psychological, and physiological contributors of RED-S can determine the most appropriate treatment approach.

References

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