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Human Kinetics
CONSENSUS STATEMENT

International Olympic Committee (IOC) Consensus Statement on Relative Energy Deficiency in Sport (RED-S): 2018 Update

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In 2014, the International Olympic Committee (IOC) published a consensus statement entitled "Beyond the Female Athlete Triad: Relative Energy Deficiency in Sport (RED-S)". The syndrome of RED-S refers to: "impaired physiological functioning caused by relative energy deficiency, and includes but is not limited to impairments of metabolic rate, menstrual function, bone health, immunity, protein synthesis, and cardiovascular health." The aetiological factor of this syndrome is low energy availability (LEA) (Mountjoy et al., 2014).

The publication of the RED-S consensus statement stimulated activity in the field of Female Athlete Triad science, including some initial controversy (De Souza, Williams, et al., 2014; Mountjoy, Sundgot-Borgen, Burke, Carter, Constantini, Lebrun, Meyer, Sherman, Steffen, Budgett, & Ljungqvist, 2015) followed by numerous scientific publications addressing:

1. The health parameters identified in the RED-S conceptual model (Figure 1) (Constantini, 2002; Mountjoy et al., 2014)

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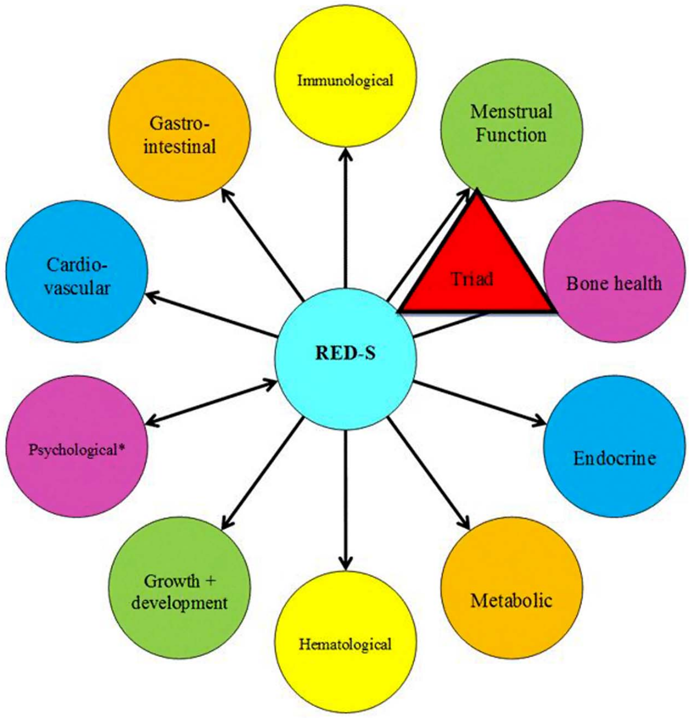

Figure 1 — Health Consequence of Relative Energy Deficiency in Sport (RED-S) showing an expanded concept of the Female Athlete Triad to acknowledge a wider range of outcomes and the application to male athletes (*Psychological consequences can either precede RED-S or be the results of RED-S).

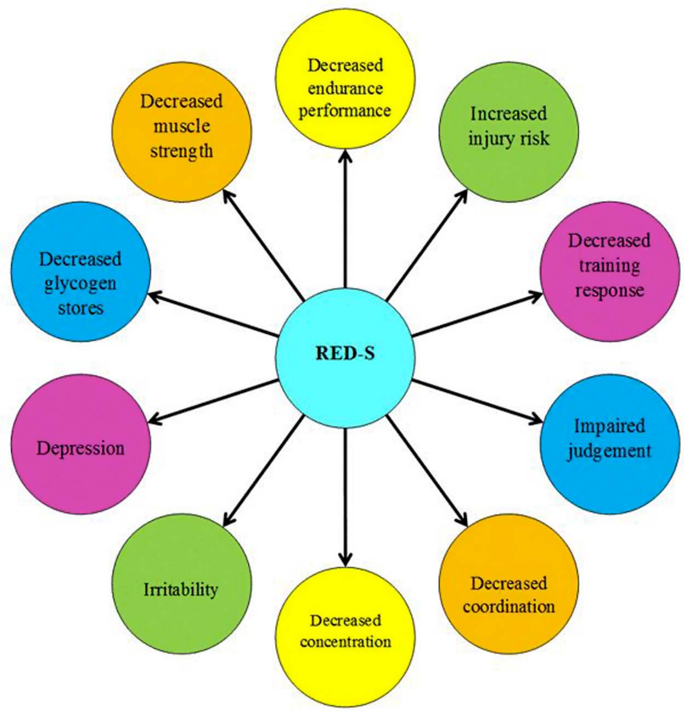

Figure 2 — Potential Performance Effects of Relative Energy Deficiency in Sport (RED-S) (*Aerobic and anaerobic performance) Adapted from Constantini.

2. Relative energy deficiency in male athletes
3. The measurement of LEA
4. The performance parameters identified in the RED-S conceptual model (Figure 2) (Constantini, 2002; Mountjoy et al., 2014)

The IOC RED-S consensus authors have reconvened to provide an update summary of the interim scientific progress in the field of relative energy deficiency with the ultimate goal of stimulating advances in RED-S awareness, clinical application, and scientific research to address current gaps in knowledge.

Low Energy Availability

LEA, which underpins the concept of RED-S, is a mismatch between an athlete's energy intake (diet) and the energy expended in exercise, leaving inadequate energy to support the functions required by the body to maintain optimal health and performance. Operationally, energy availability (EA) is defined as:

$$\text{Energy Availability (EA)} = [\text{Energy intake (EI) (kcal)} - \text{Exercise Energy Expenditure (EEE) (kcal)}] / \text{Fat-free mass (FFM) (kg)};$$

where exercise energy expenditure is calculated as the additional energy expended above that of daily living during the exercise bout, and the overall result is expressed relative to FFM, reflecting the body's most metabolically active tissues (Loucks et al., 2011; Melin & Lundy, 2015). Rigorously controlled laboratory trials in women have shown that optimal EA for healthy physiological function is typically achieved at an EA of 45 kcal/kg FFM/day (188 kJ/kg FFM/day) (Loucks & Heath, 1994; Loucks & Thuma, 2003). Meanwhile, although some caveats are noted in relation to differential responses of various body systems (Burke & Deakin, 2015), many of these systems are substantially perturbed at an EA < 30 kcal/kg FFM/day (125 kJ/kg FFM/day), making it historically a targeted threshold for LEA. However, recent evidence suggests that this cutoff does not predict amenorrhea in all women (Lieberman et al., 2018; Williams et al., 2015). In addition, and not withstanding differences across body sizes and pubertal age, it is noted that an EA of 30 kcal/kg/FFM roughly equates to the average resting metabolic rate (RMR) (Loucks et al., 2011). Because LEA has proven robust in explaining markers of sub-optimal health and function in both laboratory (Loucks & Heath, 1994; Loucks & Thuma, 2003) and field settings (Melin et al., 2014; Vanheest et al., 2014), it seems logical that an EA assessment could serve as a diagnostic tool in the prevention or management of RED-S.

Measurement of EA

Despite the primary importance of determining whether an athlete has adequate EA, several barriers prohibit the direct measurement of EA from being a practical and reliable option. First, there is no standardised or reference protocol for undertaking an EA assessment (e.g., the number of collection days, methodologies for assessing energy intake, exercise energy expenditure, or FFM). Furthermore, there are significant concerns over the reliability and validity of each of these metrics. The greatest challenge is to gain an accurate record of usual energy intake from self-reported sources (Burke, Melin, et al., 2018; Burke & Deakin, 2015). Other