Energy Availability

for Female Athletes

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Introduction

A fundamental nutrition consideration for athletes is ensuring sufficient energy for the exercise that they are undertaking. Providing the body with an adequate amount of energy is beneficial to an athlete's health and performance. On the other hand, if energy needs are consistently not met, this may have a negative impact on health and performance. The information below will explain the importance of energy, the concepts of energy balance and energy availability, as well as the consequences of inadequate energy availability. Finally, practical solutions will be shared to help female athletes consistently meet their energy needs.

Energy balance

Energy balance refers to the balance between the amount of energy (kilocalories, kcal) consumed through food and drink (i.e., energy intake) and the amount of energy expended by the body (i.e., energy expenditure). Depending on the difference between energy intake and energy expenditure, an athlete can be in an 'energy deficit' or an 'energy surplus' (Figure 1).

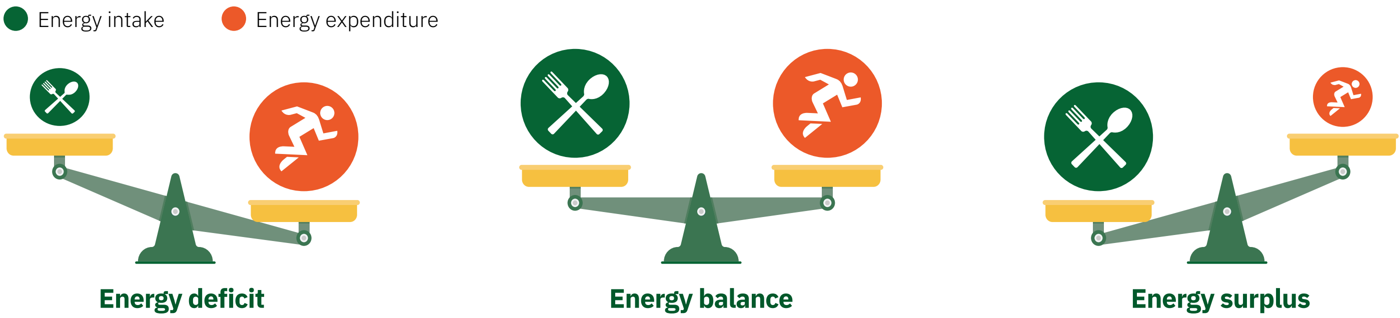

Figure 1: Energy deficit, energy balance and energy surplus

Daily energy requirements

There are three main processes which contribute to the body's total daily energy expenditure (TEE) which are basal metabolic rate, thermic effect of food, and thermic effect of activity (Figure 2). Daily energy intake requirements to ensure energy balance vary from athlete to athlete, mainly dependent on the duration and intensity of exercise.

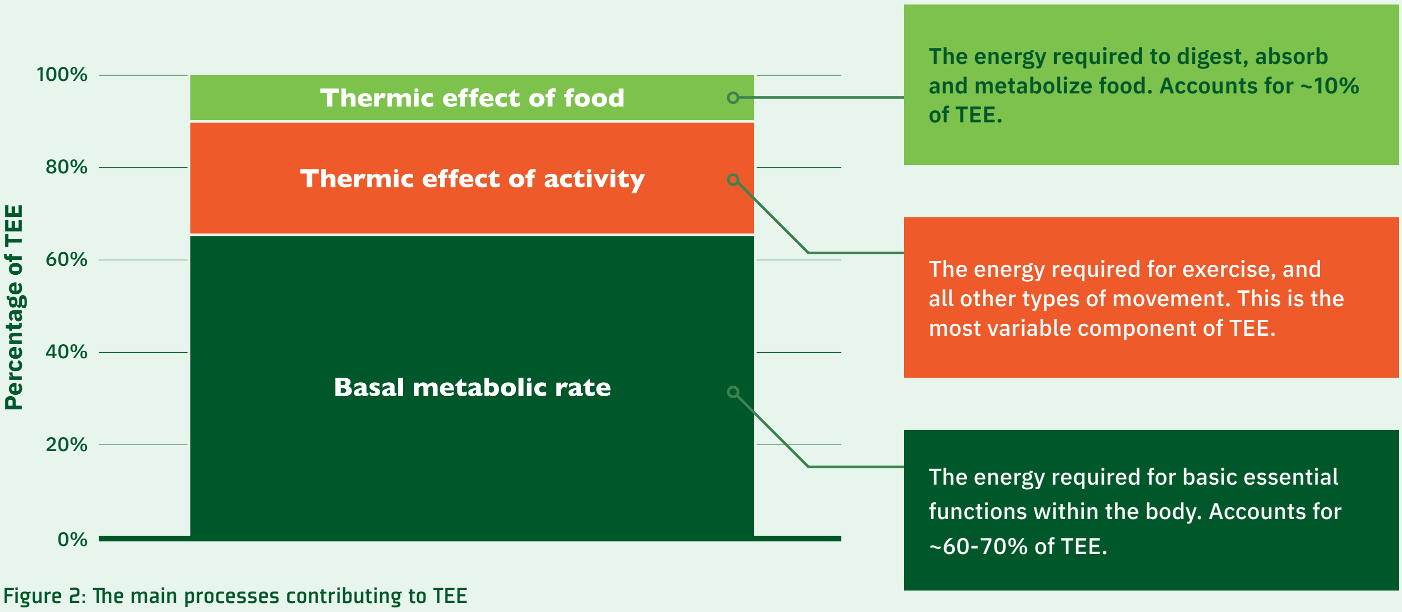

Figure 2: The main processes contributing to TEE
TEE = Total Energy Expenditure

Energy availability

Energy availability refers to the amount of energy available for bodily physiological and homeostatic processes to function properly, after accounting for the energy expended through exercise (i.e., exercise energy expenditure). Energy availability is expressed relative to fat free mass, the body's most metabolically active tissue. The calculation for energy availability is as follows:

$$\text{Energy availability (kcal/kg FFM/day)} = \frac{\text{Energy Intake (kcal)} - \text{Exercise Energy Expenditure (kcal)}}{\text{Fat Free Mass (kg)}}$$

The body requires enough energy available for important physiological functions and systems, such as:

- **Immune system**
- **Reproductive system**
- **Hematological function**
- **Neurocognitive function**
- **Cardiovascular function**

Low energy availability (LEA)

Many athletes expend large amounts of energy on a daily basis through undertaking intense training loads. It is important that athletes consistently meet their energy needs to ensure that their body has sufficient energy available to carry out fundamental physiological processes that are important for health, as well as to support their exercise demands. If an athlete's body consistently does not have enough energy left after exercise to support fundamental physiological functions, this can result in what is known as 'low energy availability' (LEA). LEA is the underlying cause of the conditions known as Relative Energy Deficiency in Sport (REDs) and the Female Athlete Triad. For more about these conditions, see the reference and resources list.

According to the IOC 2023 consensus statement (Mountjoy et al., 2023), LEA occurs as a continuum between:

1 Adaptable LEA

Exposure to reduced energy availability. Associated with benign effects which are mild and easily reversible, typically having little to no impact on long-term health, well-being or performance.

2 Problematic LEA

Exposure to low energy availability. Associated with greater disruption to body systems, which can potentially cause long-term impairments to health and performance.

Causes of LEA

The fundamental causes of LEA are inadequate energy intake and/or failure to match energy intake to training regimes. This is demonstrated in mathematical terms in the table below.

Table 1: Theoretical calculations for adequate EA and LEA

	Exercise Energy Expenditure (kcal/day)	Energy Intake (kcal/day)	Energy Availability (kcal/kg FFM/day)
Adequate EA	500	2700	45*
LEA through inadequate energy intake	500	1900 ▼	29 ▼
LEA through failure to match energy intake to high training load	1300 ▲	2700	29 ▼
LEA through a combination of inadequate energy intake and failure to match energy intake to high training load	1000 ▲	2200 ▼	24 ▼

Example: 60 kg (132 lb); 49 kg (108 lb) FFM

*In this example, 45 kcal/kg FFM/day has been used to demonstrate adequate EA, however please note that thresholds for EA are debated.

Factors contributing to the development of LEA

There are a number of factors which can contribute to the development of LEA, related to either inadequate energy intake or failure to match energy intake to high training load (Figure 3). Through education and awareness, many of these barriers can be addressed to minimize the likelihood of an athlete inadvertently experiencing low energy availability.

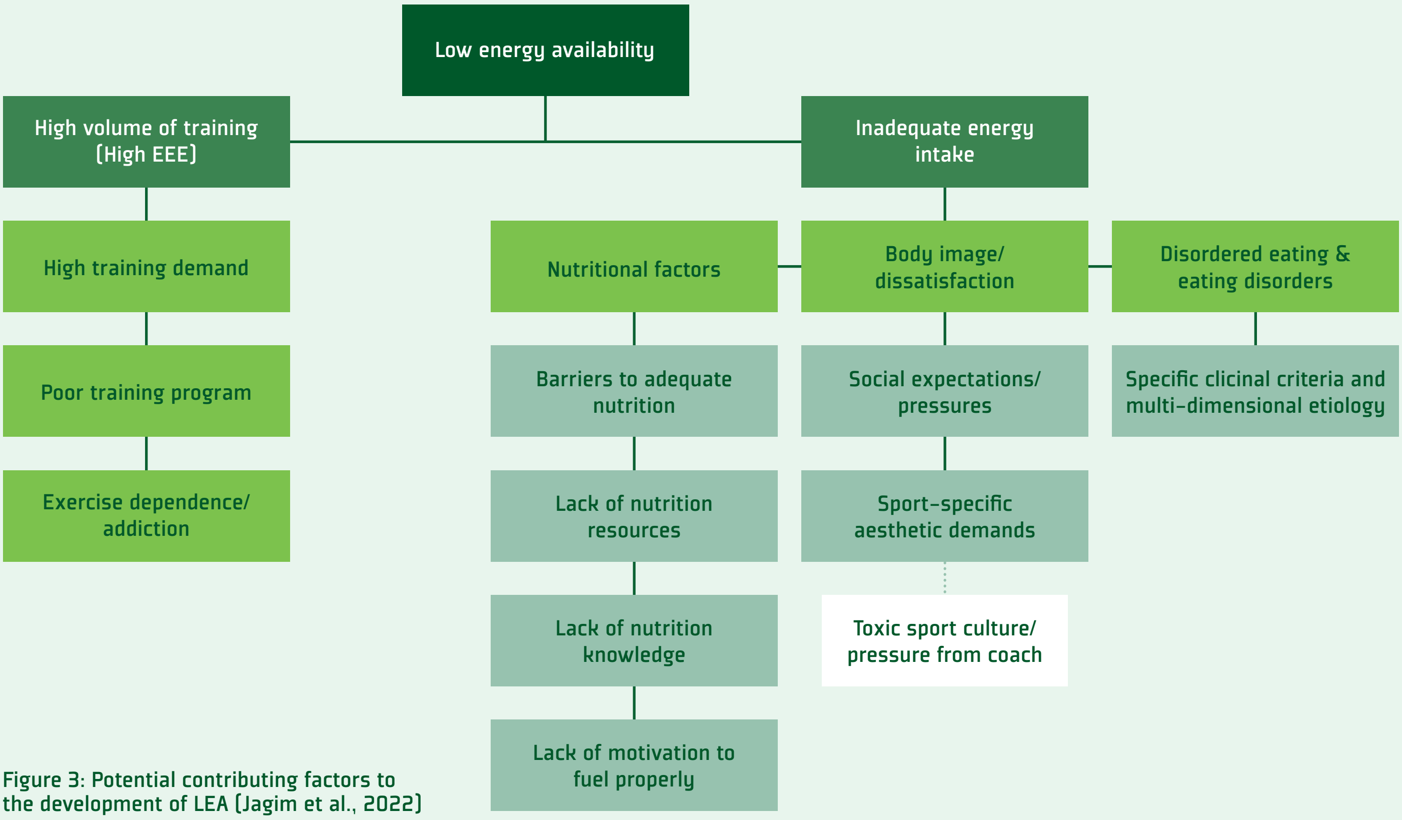

Figure 3: Potential contributing factors to the development of LEA (Jagim et al., 2022)

Assessing LEA

It is challenging for practitioners to accurately measure all components of energy availability (i.e., energy intake, exercise energy expenditure and fat free mass), in particular energy intake and exercise energy expenditure. In turn, this makes it difficult to identify LEA, particularly in the field. Alternatively, there are several screening tools which have been produced to assess LEA and its associated outcomes. These include:

Low Energy Availability in Females Questionnaire (LEAF-Q)	RED-S Specific Screening Tool (RST)	Eating Disorder Examination Questionnaire (EDE-Q)
Exercise Addiction Inventory (EAI)	Exercise Dependence Scale (EDS)	IOC Relative Energy Deficiency in Sport Clinical Assessment Tool-2 (IOC REDs CAT2)

Signs, risk factors and consequences of LEA

It is important for coaches, support staff and athletes to be aware of potential signs and risk factors of LEA in female athletes (Figure 4). It is important to note that the signs and risk factors shown below are not an exhaustive list. In addition, an athlete does not need to show all of these symptoms to be experiencing LEA.

Menstrual irregularities or complete loss of menstrual cycle	Chronic dietary restriction and/or extreme dieting	History of bone stress injuries
Low bone mineral density	Poor recovery between training sessions	Clinically diagnosed depression and/or anxiety
Lack of ovulation	Urinary incontinence	Gastrointestinal symptoms at rest/during exercise
Reduced or low resting metabolic rate	Sleep disturbances	Increased stress or anxiety
Exercise dependence/ addiction	Difficulty concentrating	Perfectionist tendencies
Frequent injuries	Training inconsistencies	Constant fatigue

Figure 4: Potential indictors of LEA in female athletes

Health and performance impacts of LEA

The REDs Health/Performance conceptual models (Mountjoy et al., 2023) outline the range of impacts that LEA can cause. The outcomes shown will occur over different time periods, and with differing severities. In addition, the outcomes experienced may differ between individuals. Please also note that the impacts captured within the conceptual models can occur due to etiologies other than problematic LEA.

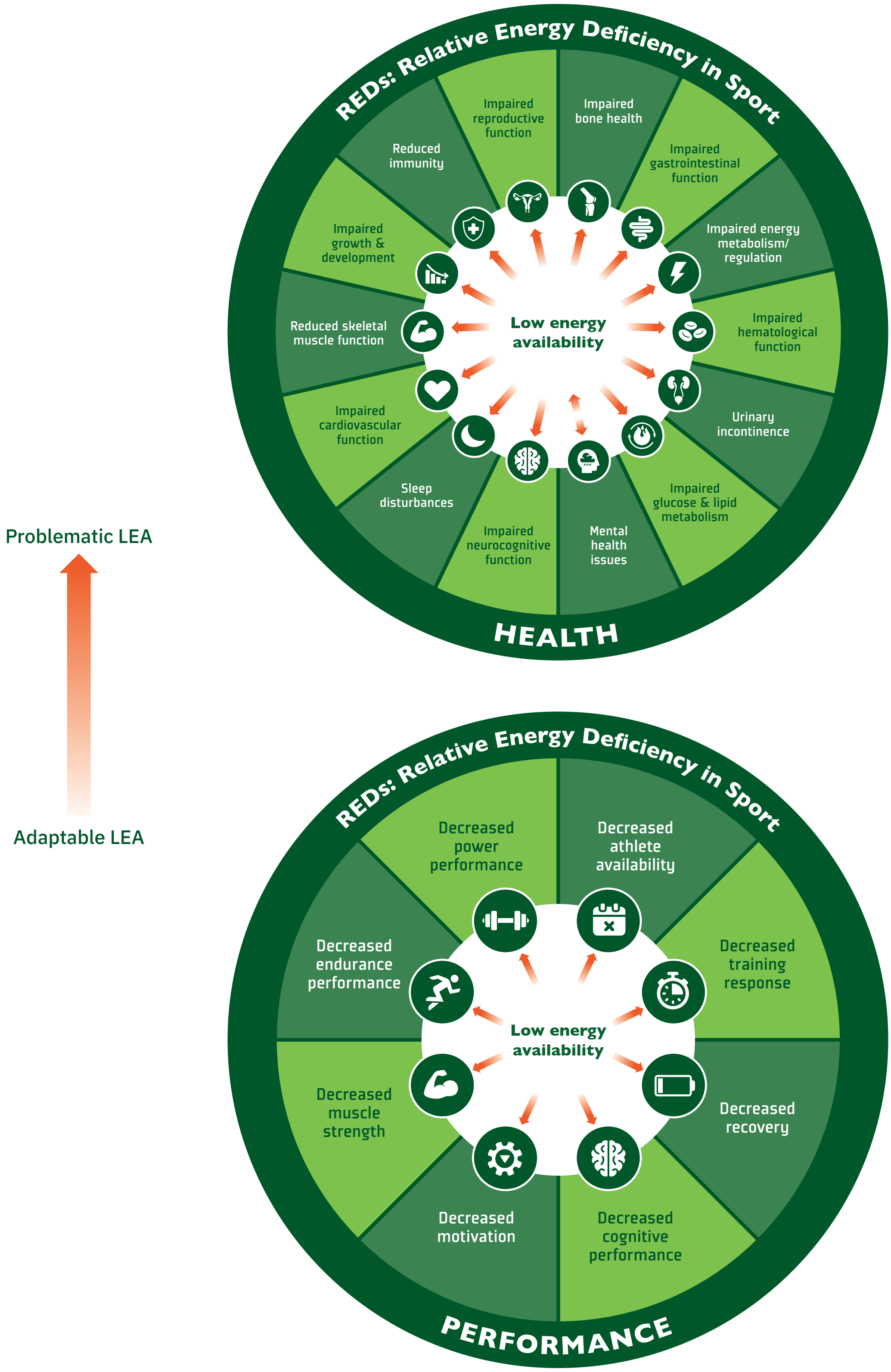

Figure 5: REDs Health and Performance conceptual models (Mountjoy et al., 2023)

Prevalence of LEA

It is suggested that LEA is more likely to occur in certain types of sports:

Aesthetic sports (e.g., gymnastics) and weight sensitive sports (e.g., wrestling, jockeys): potentially due to eating disorders and/or disordered eating* being more prevalent in these sports, which impacts energy intake, thus increasing the risk for LEA. In weight sensitive sports, adaptable LEA may be more common during periods of weight loss in preparation for competition.

Endurance based sports (e.g., running, cycling): potentially due to high volumes of training resulting in increased exercise energy expenditure, which in turn increases the risk for LEA.

*It should be noted that LEA can occur both with and without an eating disorder/disordered eating

Estimated prevalence of LEA in female athletes according to research:

Ballet dancing

Prevalence of LEA: 22%
Mean age: 18
Sample size: 20
Civil et al. (2018)

Soccer

Prevalence of LEA: 23%
Mean age: 24
Sample size: 13
Moss et al. (2021)

Endurance running

Prevalence of LEA: 31%
Mean age: 26
Sample size: 35
Heikura et al. (2018)

Basketball

Prevalence of LEA: 40%
Mean age: 20
Sample size: 15
Çetiner-Okşin et al. (2023)

Rowing

Prevalence of LEA: 64%
Mean age: 25
Sample size: 25
Scheffer et al. (2023)

Swimming

Prevalence of LEA: 40%
Mean age: 20
Sample size: 15
Klein et al. (2023)

Volleyball

Prevalence of LEA: 20%
Mean age: 21
Sample size: 10
Woodruff et al. (2013)

Rugby union

Prevalence of LEA: 52%
Mean age: 21
Sample size: 15
Traversa et al. (2022)

Gymnastics

Prevalence of LEA: 100%
Mean age: 16
Sample size: 13
Villa et al. (2021)

Lacrosse

Prevalence of LEA: 50-75%
Mean age: 20
Sample size: 20
Zabriskie et al. (2019)

Synchronized swimming

Prevalence of LEA: 100%
Mean age: 20
Sample size: 11
Schaal et al. (2017)

Softball

Prevalence of LEA: 100%
Mean age: 20
Sample size: 17
Torres-McGehee et al. (2021)

The value of < 30 kcal/kg FFM/day, which is commonly utilized in research, has been used as a cut-off value for LEA. It should be noted that it is difficult to determine the exact prevalence of LEA due to variability in the methods used to assess energy availability. The prevalence of LEA may also be dependent on other contextual factors such as level of competition, age, phase of the season, etc.

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LEA: Females vs. males

Both females and males can experience LEA, however research suggests that the prevalence of LEA is higher in female athletes vs. male athletes. Research into the endocrine and bone metabolism responses to LEA suggest that **females are less resilient to the effects of LEA in comparison to males.** One explanation for this is that the energetic cost of maintaining the reproductive system, as well as gestation, are significantly higher for females in comparison to males. This means that females may be more sensitive to reductions in energy availability, due to the body preserving energy to ensure successful gestation can still occur during periods of LEA.

Practical tips to prevent the development of LEA

- Ensure an athlete's diet provides enough energy to support the demands of both their training and daily life
- Teach athletes flexible eating behaviours: encourage them to acknowledge the importance of a nutrient-dense diet while not putting labels such as 'good' or 'bad' on single food groups or macronutrients
- Make athletes, coaches and support staff aware of the signs and symptoms of LEA
- Create a safe environment for athletes in communal eating spaces
- If there is an increase in an athlete's training volume and/or intensity, ensure that energy intake increases accordingly
- Encourage athletes to be cautious of misinformation and trends on social media
- Consider whether body composition management is essential, and if so, ensure it is carried out by a qualified professional
- Report toxic training environments where athletes are shamed for the size and/or shape of their bodies

ENERGY AVAILABILITY

Energy availability is "the amount of energy available to the body for physiologic and homeostatic processes, after accounting for energy expended through exercise".

Research suggests that the prevalence of low energy availability (LEA) is higher in female athletes than male athletes.

Adequate energy is important for physiological functions and systems

- Immune system
- Reproductive system
- Hematological function
- Neurocognitive function
- Cardiovascular function

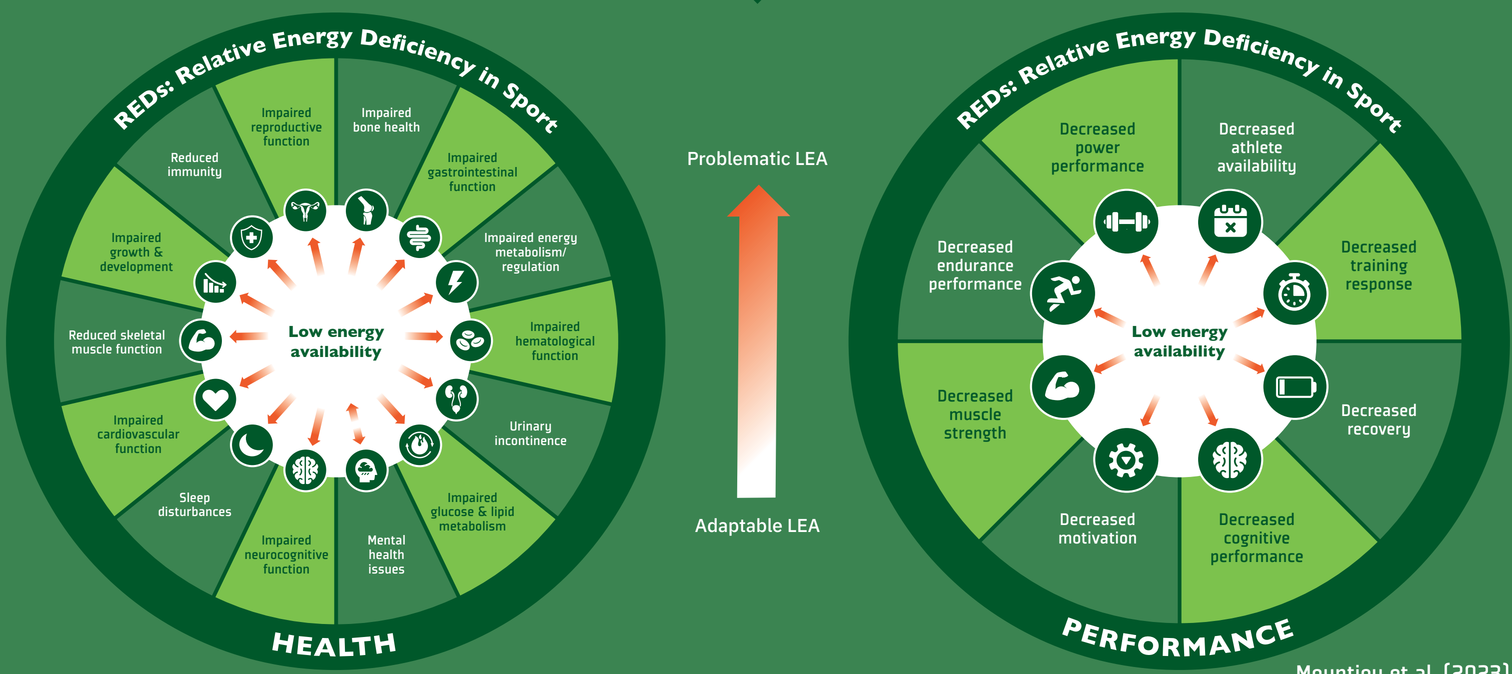
Potential contributing factors to the development of low energy availability

Low energy availability

- High volume of training (High EEE)
  - High training demand
  - Poor training program
  - Exercise dependence/ addiction
- Inadequate energy intake
  - Nutritional factors
    - Barriers to adequate nutrition
    - Lack of nutrition resources
    - Lack of nutrition knowledge
    - Lack of motivation to fuel properly
  - Body image/ dissatisfaction
    - Social expectations/ pressures
    - Sport-specific aesthetic demands
    - Toxic sport culture/ pressure from coach
  - Disordered eating & eating disorders
    - Specific clicinal criteria and multi-dimensional etiology

Jagim et al. (2022)

Potential impacts of low energy availability



Mountjoy et al. (2023)

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