Current views on relative energy deficiency in sport (REDs)

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Abstract

Relative energy deficiency in sport (REDs) is a clinical syndrome which includes the adverse effects on health and performance caused by chronic low energy availability. This article explores the current view of REDs, highlighting the recent updates from the International Olympic Committee consensus statement issued in September 2023. Psychological factors and mental health are recognised as having a reciprocal relationship with both the aetiology and outcome of the chronic low energy availability that leads to REDs. This has important implications in terms of prevention and management for individuals experiencing REDs. Unintentional or intentional unbalanced behaviours around high levels of exercise and insufficient nutrition lead to a situation of low energy availability. Low energy availability is not synonymous with REDs; rather, cumulative and sustained low energy availability, particularly low carbohydrate availability, leads to the clinical syndrome of REDs comprising a constellation of adverse consequences on all aspects of health and performance. Furthermore, REDs is not synonymous with an eating disorder (ED), although some individuals may have disordered eating or an ED. REDs can potentially arise in both biological sexes, at all ages and all levels of exercise. This is of particular concern for the young aspiring athlete or dancer, where behaviours are being established and in terms of long-term consequences on mental and physical health. The mechanism of sustained low energy availability leading to these negative health outcomes is through the adaptive down-regulation of the endocrine networks. Therefore, raising awareness of the risk of REDs and implementing effective prevention and identification strategies is a high priority.

Keywords: low energy availability, relative energy deficiency in sport (REDs), hormone, psychology, nutrition, exercise

Introduction

Relative energy deficiency in sport (REDs) is a clinical syndrome which includes the adverse effects on health and performance caused by chronic low energy availability. REDs was first described in the International Olympic Committee (IOC) consensus statement published in the British Journal of Sports and Exercise Medicine in 2014 (1). Since then, there have been updates published in 2018 (2) and, most recently, in September 2023 (3).

Seminal studies of female collegiate runners in the 1980s found that those athletes with higher weekly training load but the same food intake as those with lower training load experienced menstrual disruption, including secondary amenorrhoea and poor bone health (4). This led to the description of the female athlete triad, which comprises a clinical spectrum of eating patterns, menstrual function and bone health. This ranges from optimal fuelling, good menstrual function and good bone health to eating disorders, amenorrhoea and osteoporosis.

However, as further evidence emerged, it became apparent that the impact of under-fuelling is not confined to menstrual and bone health. Rather, the consequences of under-fuelling are multisystemic and can also affect male athletes. This led to the initial description of REDs in 2014 as a syndrome comprised of the potential adverse effects on many systems in the body with both physical and mental health implications. Crucially, unlike the female athlete triad, REDs also included the potential negative sequelae on athletic performance. Ultimately, the goal for all athletes is to perform to their best, so REDs is not something of interest just in academic or clinical circles. REDs is highly relevant to both biological sexes and exercisers of all levels and ages.

What is energy availability?

The underlying aetiology of REDs is low energy availability. The life history theory describes how biological processes compete for energy resources (5). Energy requirement for movement is prioritised from an evolutionary point of view in order to take evasive action from predators. The residual energy from food intake is described as energy availability. This is roughly equivalent to resting metabolic rate for the individual. Simply lying in bed all day, staying alive, has a high level of energy demand for humans as homeotherms. The numerical value of energy availability is expressed in kcal/kg of fat-free mass. The energy availability requirement for health will vary between individuals depending on sex, age and body composition. Although energy availability is a very useful concept, in practice it is not actually measured outside of the research setting. Rather, objective surrogates indicating energy availability can be measured, such as triiodothyronine which is used as a primary indicator of low energy availability as outlined in the updated REDs Clinical Assessment Tool, which is described in further detail below (6).

An important highlight from the updated consensus statement on REDs is that it is specifically low carbohydrate avail-

ability that is most detrimental, especially for reproductive hormone networks. Comparing isocaloric intake, where there is a low proportion of energy from carbohydrate, this has the most marked negative consequence on both hormone health and performance. The mechanism of sustained low carbohydrate availability appears to involve the hormone leptin, an adipokine, which is secreted by adipose tissue. Low levels of leptin cause suppression of the reproductive axis via the hypothalamus-pituitary axis (7).

Aetiology of low energy availability

Low energy availability is a situation where, once energy demand from movement has been met, the available residual energy is insufficient to support the functioning of other biological life processes.

Low energy availability could arise unintentionally or intentionally (8). Unintentional low energy availability is where an exerciser does not appreciate the energy demands of exercise and other activities with an energy demand. For example, many athletes will not consider the energy required to "commute" to a training session on foot or by bike. Unintentional low energy availability could be due to practical issues; for example, a long cycle ride over several hours will require the cyclist to take nutritional sources in the pockets of clothing and/or plan in suitable stops where it is possible to obtain nutrition. Similarly, going to a training camp, especially at altitude, will greatly increase energy demand from exercise and this needs to be factored in. Finances could also be a limiting factor.

On the other hand, intentional low energy availability is where an exerciser intentionally restricts nutrition intake in the belief that this might confer a performance advantage in terms of body weight, composition or shape. Intentional food restriction covers a range of eating behaviours, from disordered eating to a clinically diagnosed eating disorder. This is particularly associated with any exercise against gravity such as running, road cycling and climbing; weight category sports like martial arts; aesthetic forms of sport (diving, gymnastics); and dance.

For individuals with intentional low energy availability, psychology and mental health can have a reciprocal interaction (9). Personality characteristics such as self-motivation and perfectionism can be very laudable traits in terms of dedication to exercise training to achieve success. However, when these characterises impact and support rigid behaviours around training and nutrition, this can become problematic (Figure 1). Those who are able to adapt to external pressures and have a flexible approach to training and nutrition are more likely to experience positive outcomes, whereas those who have a more rigid approach, which might include disordered eating, an eating disorder and/or exercise dependence, are more likely to experience negative outcomes. This reinforces self-doubt and culminates in a vicious circle of perpetuating rigid behaviours and negative outcomes in terms of both physical and mental health.

Evidence for this interaction between psychological factors and the risk of REDs was found in our study of dancers, referenced in the updated IOC consensus statement. A significant relationship was found between psychological factors such as anxiety around body shape/weight and missing training. These psychological factors had significant associations between physical manifestations of low energy availability (low body weight) and physiological outcomes (menstrual irregularity) (10). Similarly, in more of our published research papers referenced in the IOC consensus statement focusing on male athletes, a significant association was found between cognitive nutritional restraint and negative physiological and performance outcomes (11).

Acknowledging this reciprocal interaction between internal and external factors is a systems biology approach, highlighted in the recently updated IOC consensus statement. From a physiological point of view, the brain is a high-energy-demand organ, requiring a good supply of glucose. Low carbohydrate availability will restrict this cerebral energy supply, which can impair cognitive function and, ultimately, decision making. It is interesting to reflect that the neuroendocrine gatekeeper, the hypothalamus, monitors internal and external factors, not distinguishing between the source of stressors when initiating an adaptive response (7).

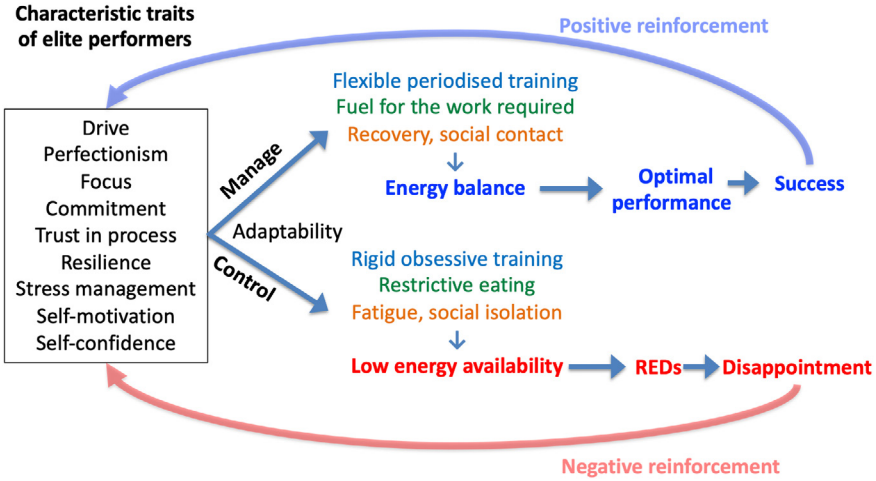

Figure 1: Psychological factors in REDs (reproduced with permission from nickykeayfitness.com)

Consequences of cumulative low energy availability

Low energy availability is not synonymous with REDs. Indeed, short-term low energy availability might initially help performance. Low energy availability can become problematic, depending on the time scale, which, in turn, determines the degree of adaptive response, described in the clinical physiological model of REDs (12). The first system to adapt to low energy availability is bone, as bone turnover moves in favour of resorption over formation. This is why bone stress responses, specifically bone stress fractures, can be an early warning sign of REDs and is designated a primary indicator in the updated IOC consensus statement. There will follow sequential down-regulation of metabolic rate, mediated via the thyroid axis, followed by the reproductive axis. In women, primary amenorrhoea or sustained functional hypothalamic amenorrhoea (FHA) lasting 6 months or more is a severe primary indicator of REDs. In men, low-range testosterone is a severe primary indicator. Ultimately, body composition will be adversely affected, with the only endocrine system to be up-regulated being that of the hypothalamic-pituitary-adrenal axis (13).

Health

Cumulative low energy availability causes the syndrome of REDs, which produces progressive adverse effects on all aspects of health and physical, mental and social wellbeing, as described in the REDs conceptual model. Poor sleep will compound these negative health effects (7).

Performance

Although there may be some initial good performances, chronic low energy availability will result in adverse performance consequences of REDs, described in the REDs performance conceptual model. In our referenced papers in the consensus statement, we found that in male athletes, short-term low energy availability negatively impacted performance (14). In another of our referenced studies, we showed that male cyclists in sustained low energy availability over 6 months not only experienced bone loss commensurate with that experienced by astronauts in space, but these cyclists also underperformed compared with their energy-replete fellow cyclists (15). On a positive note, explaining to athletes and dancers that improving energy availability will improve their performance can help in overcoming problematic behaviours.

Identification of those at risk

In view of the potential adverse health and performance effects of REDs, it is a priority to raise awareness of this risk to affect prevention. To this end the British Association of Sports and Exercise Medicine (BASEM) has produced a website, health4performance.basem.co.uk, dedicated to providing reliable information on REDs for athletes, parents, coaches and healthcare professionals, together with BASEM-endorsed online courses. Targeting and identifying those at increased risk is very important. Young athletes and dancers can be most severely affected as down-regulation of hormone function due to low energy availability can cause delays in growth and development. In particular, delayed puberty and menarche dampens the accrual of peak bone mass, with implications for bone health (16). Furthermore, there is evidence that these adverse effects on bone health might not be fully reversible (17).

From a psychological point of view, the young aspiring athlete and dancer is also at heightened risk. This was explored and viewed by many dancers in the BBC *Panorama* episode, "The Dark Side of Ballet Schools" (season 33, episode 28). Selection for specialised training will inevitably favour those who are self-motivated and dedicated. In a group of individuals sharing similar psychological traits this could act as a "breeding ground" for reinforcing these characteristics in ways that could lead to behaviours which are not conducive to positive outcomes, rather reinforcing the negative interpretation of external and internal factors, leading to a vicious circle of reinforcing attitudes and behaviours leading to REDs, as described in Figure 1.

Risk stratification

Early identification of those at risk of developing REDs is an important preventative strategy, especially for young aspiring athletes and dancers in whom behaviours around eating and exercise are being established and developed. A step-by-step approach to identify and risk-stratify individuals is provided in the second version of the Relative Energy Deficiency in sport Clinical Assessment Tool (REDsCat v2) (6). Initial low-cost screening questionnaires can be helpful, particularly if tailored to a specific sport/activity or dance, for example, the sports-specific energy availability questionnaire (18) and the dance energy availability energy questionnaire (10). These can be helpful in identifying those individuals for whom further investigation is clinically indicated. As REDs is a diagnosis of exclusion, targeted blood testing excludes medical conditions per se and provides objective quantification in the stratification of risk. Severe primary indicators of REDs are issues in the reproductive axis, namely a long duration of amenorrhoea in females and low-range testosterone in males.

From a combination of all these results, the individual can be placed in an appropriate risk category. The updated REDsCAT v2 includes a more fine-grained approach, with four categories of green, yellow, amber and red. This assessment also provides the background on which to base the appropriate level of support. For all, management will be directed at restoring energy availability and include modification of training schedules and nutritional intake. However, the details will vary according to the severity of REDs. Individuals with intentional REDs, especially when formally diag-

nosed with an eating disorder, will need more intensive input than a person with transient unintentional low energy availability.

Management

A nuanced approach is required for individual athletes, depending on their risk stratification and biopsychosocial factors. In all cases, some degree of psychological support will be helpful. Involvement of the extended multidisciplinary team is ideal, including the physician, dietitian, coach and parent (where appropriate), with the athlete/dancer at the centre.

Restoring energy availability will require careful discussion around nutrition in terms of the consistency of eating patterns and composition of food groups consumed. This starts with regular meals containing good portions of complex carbohydrate and protein. Studies show that inconsistent intake of carbohydrate (e.g., "backloading" eating to the evening) produces an unfavourable hormone profile. Fuelling around training is also a high priority for hormone health and driving positive adaptations to exercise. Pre-training consumption of carbohydrate, together with post-training refuelling with both complex carbohydrate and protein within 20 minutes of stopping, are important behaviours for favourable hormone response to exercise (7).

In terms of pharmacological intervention, National Institute for Health and Care Excellence (NICE) guidelines, updated in 2022, recommend body-identical hormone replacement therapy (HRT) over the combined oral contraceptive pill for bone protection in those with evidence of bone poor health due to FHA as a consequence of REDs (19). Poor bone health is defined as an age-matched Z score less than −1 of the lumbar spine (trabecular bone is particularly sensitive to low oestradiol) and/or two or more stress fractures at a site of concern (trabecular-rich bone). For male athletes/dancers, external testosterone is not appropriate, as this supresses internal hormone production. Furthermore, testosterone is on the World Anti-Doping Agency banned list and it is not possible to obtain a therapeutic use exemption as REDs is a functional condition, not a medical condition.

Prevention

Prevention is always the ultimate goal. In order to achieve this, a cultural shift in sport and dance is required. The emphasis should be on the fact that health is a prerequisite for performance. Pursuing a lighter body weight or leaner body composition will not automatically lead to improved performance. Each individual will have a personal "tipping point". As we are all different, there is no such thing as a generic "ideal" weight, shape or body composition.

In practical terms, prevention can be considered as primary, secondary and tertiary (20). Primary prevention consists of providing and disseminating reliable educational resources. Secondary prevention includes early identification of those at risk of developing REDs, together with prompt and correct diagnosis. For example, regardless of whether the individual is an athlete or dancer, amenorrhoea in a woman of reproductive age (apart from physiological amenorrhoea of pregnancy) is never "normal", whether blood tests are in range or not. The tertiary level of prevention encompasses evidence-based treatments. As mentioned above, NICE guidelines are now in line with those of the Endocrine Society and the IOC in advising HRT for bone protection in FHA, rather than the oral contraceptive which masks underlying hormone dysfunction and is not bone-protective. Similarly, thyroxine is not advised where there is down-regulation of this axis as a consequence of REDs. This is not the same as the medical condition of a primary underactive thyroid indicated by raised thyroid-stimulating hormone (7).

Conclusion

Ultimately, we all have a role to play in supporting exercisers, athletes and dancers in avoiding "the REDs card" (21). This involves the extended multidisciplinary team, starting with the individual exerciser, and extending to their family, friends and coaches, and then bringing in healthcare professionals from medicine, dietetics and physiotherapy.

Imbalances in behaviours around exercise and nutrition can have potential negative consequences on all aspects of health and performance. On a positive note, exercise, supported with appropriate nutrition, is an excellent way to achieve and maintain optimal physical, mental and social health, and support performance. This is applicable for exercisers of all ages and levels, from the recreational to the amateur to the elite athlete.

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