RELATIVE ENERGY DEFICIENCY IN SPORT

CLINICAL APPROACH IN THE AQUATIC DISCIPLINES

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WHAT IS RED-S?

In 2014, the International Olympic Committee (IOC) convened a group of experts to address and update the topic of the female athlete triad (Triad). A critical review of the evolution of the body of science that has been published since the origin of the Triad in 1972 found that the syndrome is much broader than originally thought. In response to this discovery, the IOC introduced a broader, more comprehensive term known as 'Relative Energy Deficiency in Sport' or RED-S.

Relative Energy Deficiency in Sport: 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[1].

Like the Triad, the underlying etiology of RED-S is low energy availability. In particular, the IOC group defines the cause as 'an energy deficiency relative to the balance between energy intake in the form of food and energy expenditure required for activities of daily living, healthy bodily functions, growth and sport activities such as training and competition[2].' While the Triad links the low energy availability with menstrual dysfunction and bone pathology, RED-S identifies many more body systems that are negatively affected. Given the number of body systems affected, the term 'triad' no longer adequately or appropriately describes the syndrome. In addition, RED-S also has potential performance consequences for athletes. Both the health consequences and performance effects of relative energy deficiency are reviewed in more detail later in this article.

The review of the scientific literature on relative energy deficiency also revealed that male athletes are similarly affected by this syndrome. Until 2014, attention had not been given to male athletes by sport medicine or sport science researchers despite the fact that some male athletes also have health and performance consequences from RED-S. Aquatic sports have both male and female athletes, so it is important to address both genders in the delivery of RED-S prevention, screening, treatment and return to play programmes.

RED-S KEY DEFINITIONS

Energy balance: *energy balance is the amount of dietary energy added to or lost from the body's energy stores after all of the body's physiological systems have completed their work for the day (energy balance=energy intake–total energy expenditure).*

Energy deficit: *energy deficit is the discrepancy in energy balance when dietary energy intake is less than total energy expenditure, such that energy is lost from the body's energy stores and/or compensatory mechanisms take place to reduce total energy expenditure.*

Energy availability: *energy availability is the amount of dietary energy remaining to support metabolic systems in the body after the energy cost for a particular system has been removed. In the case of athletes, energy availability is the amount of energy remaining to support all other body functions after the energy expended in exercise and sporting activities is removed from energy intake (energy availability=energy intake–energy expended in exercise).*

Low energy availability: *low energy availability occurs when an individual's dietary energy intake is insufficient to support the energy expenditure required for health, function and daily living, once the cost of exercise and sporting activities is taken into account.*

Relative energy deficiency: *relative energy deficiency connotes that low energy availability can occur even in the scenario where energy intake and total energy expenditure are balanced (i.e. there is no overall energy deficit).*

TABLE 1

Aesthetic-judged sports
Endurance or long-distance sports
Weight category sports
Weight-dependent sports

Table 1: Sports at risk of RED-S.

HEALTH IMPLICATIONS

RED-S affects many body systems. Figure 1 shows a conceptual model that illustrates the numerous body systems that can be affected by relative energy deficiency. The arrow in the model depicts the relationship between the cause of the problem 'relative energy deficiency' and the outcome effect on the identified body system. Of particular note however, is the psychological component which is unique in that it can both precede or cause RED-S from an eating disorder or disordered eating or, independently, be the result of RED-S.

PERFORMANCE IMPLICATIONS

Likewise, relative energy deficiency can also have a negative effect on athlete performance. A similar conceptual model (Figure 2) depicts the various performance effects that have been shown to potentially result from low energy availability. In particular, the decreased training response and increased injury risk are two preventable factors that directly impact on athlete performance. In addition, the suppression of immune function caused by energy deficiency results in an increased susceptibility to viral infections. Evidence from illness surveillance at Olympic Games and FINA World Championships shows that during these events, more athletes are affected by infectious diseases than by injuries in the aquatic sports. The psychological effects of relative energy deficiency can also result in a decrease in athletic performance.

RED-S IN THE MALE ATHLETE

Although much of the research in the field has been devoted to the female athlete, there is sufficient published evidence to support the premise that male athletes are also affected by relative energy deficiency. As a result, the IOC has broadened the concept to include men. Evidence shows that male athletes at particular risk are those in sports with a high training volume and in those which demand leanness or have weight categories. Male athletes in a variety of sports including cycling, weight class and gravitational sports, have been identified with disordered eating and eating disorders. Other male athletes with relative energy deficiency have been shown to have decreased immunological function, impaired bone health, lower sex hormones and impaired reproductive function. Male cyclists in particular have been shown to have low energy availability.

SCREENING AND RETURN TO PLAY

As the signs and symptoms of RED-S are often subtle, the sports medicine clinician must have a high index of suspicion when assessing athletes at risk. Screening is beneficial as early detection and appropriate intervention is important to prevent health consequences and to improve athlete performance. As low energy availability is the cause of RED-S, screening should focus on identifying the presence and causes of the low energy availability. Screening should occur as part of a Periodic Health Examination or if an athlete presents with disordered eating/eating disorders, menstrual dysfunction, stress fracture, weight loss, lack of growth,

decreased performance or mood disorders. An increased vigilance for RED-S by the team physician is warranted when working with athletes in high-risk sports of (Table 1).

If there is a suspicion of disordered eating or an eating disorder, standardised screening questionnaires can be used to aid the diagnosis. In addition to the history and physical examination, laboratory examinations may be helpful including blood work (hormonal profiles, blood chemistry) and assessment of bone mineral density, body composition and resting metabolic rate.

In an attempt to facilitate knowledge translation of the science on RED-S, in 2015 the IOC developed a Clinical Assessment Tool (RED-S CAT). The RED-S CAT was created to assist clinical sports medicine professionals with the screening and management of the RED-S in a practical, usable format that is both evidence-based and effective[3]. In the RED-S CAT , the RED-S 'Red Light – Yellow Light – Green Light' Risk Assessment Model is introduced. This conceptual model is designed to take a complex clinical assessment and integrate it into an easy-to-implement model that is simple to understand for athletes and clinicians. The model was developed with flexibility to allow the treating clinician some latitude to adapt the model to the particular athlete scenario.

After medical assessment, athletes who are found to be classified in the Red Light (high risk) category, should not be cleared to participate in sport due to the health risk of practicing their sport. These athletes should receive treatment in either an inpatient or outpatient setting as medically required. Athletes identified through screening to be in the Green Light (low risk) category can train and compete without any limitations. Athletes who are found to be in the Yellow Light (moderate risk) category should only be cleared for sport participation with medical supervision. Health monitoring at regular intervals (e.g. every 1 to 3 months) is recommended.

Following treatment for RED-S, the athlete is then re-assessed and classified once again into the appropriate 'Red Light – Yellow Light – Green Light' risk category. Likewise, an athlete in the green zone can enjoy full sport participation, while the athlete in the

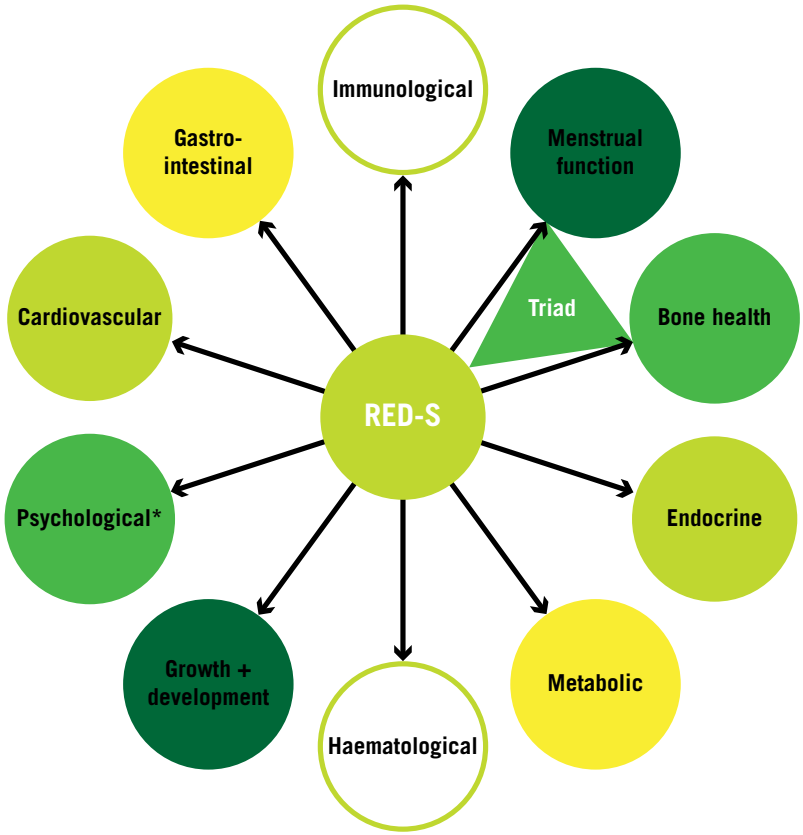

Figure 1: Health consequences of relative energy deficiency[1].

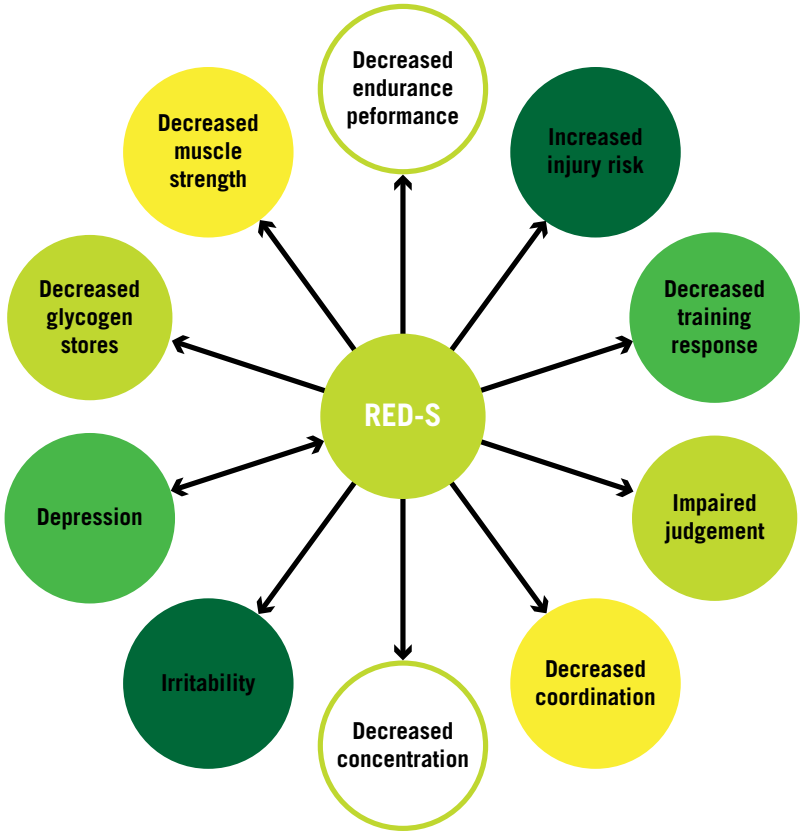

Figure 2: Performance consequences of relative energy deficiency[1].

HIGH RISK: NO START RED LIGHT	MODERATE RISK: CAUTION YELLOW LIGHT	LOW RISK: GREEN LIGHT
Anorexia nervosa and other serious eating disorders *Other serious medical (psychological and physiological) conditions related to low energy availability* *Extreme weight loss techniques leading to dehydration-induced haemodynamic instability and other life-threatening conditions.*	*Prolonged abnormally low percentage body fat measured by DXA or anthropometry using ISAK or non-ISAK approaches* *Substantial weight loss (5-10% body mass in 1 month)* *Attenuation of expected growth and development in adolescent athlete*	*Healthy eating habits with appropriate energy availability*
	Abnormal menstrual cycle: FHA >6 months *Menarche >16 yrs* *Abnormal hormonal profile in males*	*Normal hormonal and metabolic function*
	Reduced BMD (either from last measurement or Z-score <-1 SD). *History of one or more stress fractures associated with hormonal /menstrual dysfunction and/or LEA*	*Healthy BMD as expected for sport, age and ethnicity* *Healthy musculoskeletal system*
	Athletes with physical/psychological complications related to LEA/disordered eating; *- ECG abnormalities* *- Laboratory abnormalities* *Prolonged relative energy deficiency* *Disordered eating behaviour negatively affecting other team members* *Lack of progress in treatment and/or non-compliance*	

Figure 3: RED-S risk assessment screening model[1]. DXA=dual X-ray absorptiometry, ISAK=International Society for the Advancement of Kimanthrometry, FHA=functional hypothalamic amenorrhoea, BMD=bone mineral density, LEA=low energy availability, ECG=electrocardiogram, SD=standard deviation.

red zone should not be cleared for sport participation while undergoing supervised treatment. The athlete categorised in the yellow zone may train if compliant with treatment and can compete if medically cleared and under medical supervision.

TREATMENT

The treatment programme for RED-S should focus on reversing the underlying cause – low energy availability. Treatment includes increasing dietary intake of energy and/or decreasing energy expenditure through limiting exercise intensity and quantity. A practical approach is to commence by increasing energy intake by 300 to 600 kcal/day. Attention should be given to ensure that the energy intake is spread throughout the day and around periods of exercise. Underlying psychological or other health issues must also be addressed.

The treatment of menstrual dysfunction is best managed by increasing body weight while ensuring an adequate intake of protein and carbohydrate. The use of the oral contraceptive pill for the treatment of RED-S is NOT recommended as it may have a negative effect on bone health and may mask amenorrhoea caused by RED-S. A diet with adequate intake of calcium and vitamin D is recommended for athletes with osteopenia and osteoporosis. Any underlying bone pathology should be addressed. Other medical therapies to maximise bone density exist and are currently in the process of being validated. Finally and very importantly, a treatment plan for any psychological sequelae is critical to athlete health and recovery from RED-S. Any eating disorders or disordered eating behaviours require psychological and medical support. This may include psychotherapy, medical therapy in the inpatient or outpatient setting depending on the clinical scenario.

RED-S IN AQUATIC SPORTS

FINA is the international federation that governs the aquatic disciplines of swimming, diving, water polo, synchronised

HIGH RISK RED LIGHT	MODERATE RISK YELLOW LIGHT	LOW RISK GREEN LIGHT
No competition *No training* *Use of written contract*	*May train as long as he/she is following the treatment plan* *May compete once medically cleared under supervision*	*Full sport participation*

Figure 4: RED-S return to play model[3].

swimming and open water (marathon) swimming. The physiological demands of training and competition are quite diverse among the various disciplines. In addition to the varying physiological demands, the sport structure and culture also varies significantly. A review of FINA's sport risk for RED-S-related health issues shows that four of the five aquatic disciplines are identified as being high risk.

For example, the disciplines of swimming and open water swimming are both speed-dependent sports which occur in water. To maximise speed, the training emphasis is therefore placed on decreasing active drag and increasing stroke efficiency. Coaching strategies which focus on attaining an ideal body composition to maximise swimming efficiency may inadvertently result in an energy deficient state, even in the absence of the psychological overlay seen in disordered eating or eating disorders. Well-intentioned and even justified endeavours to lower body fat or mass, if misinformed or mismanaged, may result in health and performance consequences from energy deficient states.

Another common scenario which can lead to relative energy deficiency in athletes who train and compete in middle- and long-distance swimming events and all events in open water swimming is from inadvertent over-expenditure of energy during training. For example, these athletes may unintentionally expend more energy during long distance training relative to their energy intake in the form of food, leaving them in a relative energy deficient state.

Of particular importance when reviewing the scientific literature on swimming and energy availability is one pivotal study investigating the effects of energy deficiency on athlete performance. This study examines performance following a controlled training programme in two groups of female teenage swimmers:

One cohort of swimmers with low energy availability as defined by ovarian suppression

A comparison group in energy balance with a normal ovarian/hormonal cycle.

This pivotal study by Van Heest[4] shows a negative response to a controlled training programme in the ovarian suppressed (energy deficient) cohort of adolescent swimmers in comparison with a control group in energy balance who showed a positive response to the same training stimulus in the pool. Those athletes who had relative energy deficiency did not swim as fast as those in energy balance following the same training regime. This is a powerful study that shows the importance of energy balance in swimming performance.

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The other two FINA disciplines at risk of RED-S are diving and synchronised swimming. These are classified as aesthetic sports, which are awarded marks and subsequently ranked by judges. Often in these sports, emphasis is erroneously placed on reaching an unrealistic body composition. Acknowledging that there are other sociocultural, behavioural and psychological factors involved in the development of disordered eating/eating disorders, sport pressures such as overtraining, weight and injuries, as well as certain coaching behaviours are also sport risk factors. While there exists prevalence data on disordered eating and eating disorders in females in swimming, diving and synchronised swimming, there are no prevalence data published in water polo or for male athletes in any of the aquatic sports.

Taking these factors into account, athletes in the aquatic disciplines are vulnerable to the health and performance

consequences of RED-S. Attention should be paid by team physicians, sport physiologists, coaches and athletes to ensure adequate energy balance, preserve athlete health and promote performance in the pool and open water. Prevention of RED-S should be accomplished by ensuring adequate nutrition to fuel bodily function and to accommodate the energy expenditures incurred by training and competition for those athletes at particular risk in diving, synchronised swimming, swimming and open water swimming. Early identification of athletes in difficulty with appropriate screening and intervention should prevent health complications and performance deficits.

By ensuring energy balance in the aquatic sports, athletes can enjoy good health both during and after their competitive career and television audiences worldwide can enjoy watching spectacular performances in the pool and open water.

References

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