Ensuring optimal energy availability

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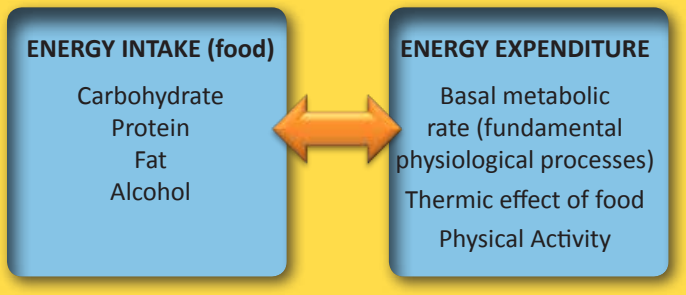
Recommendations regarding the achievement of an energy balance have always been emphasized to assist optimal training and competition performance. Energy balance is although often compromised by athletes in attempt to modify their body size and composition in attempt to achieve performance goals. Whilst compromising optimal energy balance, athletes should pay careful attention to dietary intake and exercise regimens to avoid compromising health.[1]

Moving from energy balance to energy availability….
Energy expenditure in athletes consists of much more than the energy spent during exercise. Energy obtained from dietary intake is firstly expended during several fundamental physiological processes, including cellular maintenance, thermoregulation, growth, reproduction, immunity and movement. In athletes further energy is then needed for energy expenditure during training which may be double or even more than the amount spend on day-to-day locomotion.[1]



Energy availability (EA) is the amount of dietary energy remaining to support remaining 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 (EEE) is removed from energy intake.[1,2]

EA = EI - EEE

The amount of energy remaining after accounting for the energy expenditure during exercise therefore accounts for the available energy as a source of input into the body's physiological systems.[1] 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.[2]

Compared to energy availability, **energy balance (EB)** is defined as dietary energy intake minus the total energy expenditure per day (TEE), consisting of energy used for daily physiological processes and physical exercise.[1] Energy balance is therefore an indicator of 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.[2]

EB = EI - TEE

Energy balance can therefore be positive or negative and therefore indicates the amount of dietary energy added or lost from the body's energy stores over a particular time. The energy balance therefore serves as an output measure.[1]

An energy balance of 0 kcal indicates an energy balance in healthy individuals when EA = 45 kcal/ kg fat free mass

The interference with these simple facts is although that, in times of a prolonged negative energy balance (EI < TEE), the body slows various physiological processes to achieve energy balance. Less energy will therefore be allocated to body processes to decrease TEE in order to achieve energy balance in periods of low energy intake (low EA). This adjustment may lead to a disruption in various hormonal, metabolic and functional characteristics,[1,2] leaving the prediction of energy needs unreliable.

Energy balance is therefore a questionable measure for managing an athlete's dietary intake and adequacy,[1] and low energy availability can occur even in the scenario where energy intake and total energy expenditure are balanced (i.e. there is no energy deficit),[2] but is your body functioning at an optimal level?

Relative energy deficiency in sport (RED-S)

Relative energy deficiency in sport (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 in females, bone health, immunity, protein synthesis and cardiovascular health.[2]

Various factors can contribute to an energy deficiency in athletes:

(i) Athletes can present with disordered eating or obsessive eating disorders associated with mental illnesses.(1,2) A disordered eating continuum starts with appropriate eating and exercise behaviours with short-term extreme restrictive diets (< 30 kcal/kg FFM) and progresses along the continuum towards a clinical eating disorder characterised by abnormal eating behaviours, distorted body image, weight fluctuations, medical complications and variable athletic performance. Various factors play a role in the development of eating disorders, e.g. cultural, familial, individual and genetic or biochemical factors. In athletes, sport-specific factors can also contribute for example dieting to enhance performance, personality factors, pressure to lose weight, frequent weight cycling, early start of sport-specific training, overtraining, recurrent and non-healing injuries, inappropriate coaching behaviours and regulations in some sports.[2]

(ii) Athletes can alternatively have a deliberate, rational approach to lower energy intake in attempt to reduce body size and fat percentage. This approach can although be mismanaged due to a lack of knowledge or skills.[1]

(iii) Athletes can lastly fail to increase their energy intake to compensate for energy expenditure during exercise, especially in times where training volume or intensity is increased. The failure to increase energy intake may be attributed to the suppression of appetite by prolonged exercise.[1,2]

In spite of the cause of a relative energy deficiency in athletes, low energy availability may impact on several metabolic and physiological processes and systems.

Low energy availability influences hormone levels. It may contribute to menstrual disorders in female athletes attributed to an oestrogen deficiency. It may also alter levels of other metabolic hormones and substrates, for example insulin, cortisol, anabolic and thyroid hormones.[2]

The influence of low energy availability on oestrogen and progesterone levels impacts on bone formation. Oestrogen plays a role in the increased uptake of calcium into the blood and eventual deposition into bone, while

progesterone facilitates the actions of oestrogen. Low EA may cause oestrogen/progesterone imbalance that result in negative change in bone. In males and females, testosterone has anabolic effects on bone through an increased bone formation and calcium absorption. Low testosterone levels have been associated with low bone mineral density in male athletes. Low energy availability further increases stress hormones can negatively influence bone mineral density. Changes in bone structure contribute to an increased risk of stress fractures. Dietary insufficiencies further increase the risk of stress fractures. Additional risk factors include menstrual dysfunction, compulsive exercise, underlying poor bone health, low body mass index, prior fractures and eating psychopathology.[1,2]

Muscle protein synthesis is dependent on energy availability and may be reduced even at an EA of 30 kcal/kg FFM.[2] Low energy availability can contribute to a lowered insulin secretion which can decrease amino acid uptake resulting in impaired anabolic processes, including muscle mass increase.[1]

Low energy availability may further have a negative on the immune system of the athlete, making them more vulnerable for viral attacks. The intake of sufficient energy and nutrients is vital to support immune function.[1,2]

Low energy availability further causes an unfavourable lipid profile and endothelial dysfunction that may contribute to cardiovascular risk. Hormonal and metabolic abnormalities associated with relative energy deficiency combined with carbohydrate deficiency can result in impairment of glucose utilisation, mobilisation of fat stores, reduction of metabolic rate and a decreased production of growth hormone.[2]

Athletic Performance

RED-S can potentially affect athletic performance. Functional impairments associated with a low energy availability include a greater prevalence of viral illnesses, injuries and most critically reduced responsiveness to training and subsequent performance.[2]

Practical Implication

Advice to athletes

- Appetite may be an unreliable indicator of energy requirements of athletes partaking in prolonged exercise training. Athletes should therefore aim to eat by discipline instead of hunger. They should eat specific amounts of particular foods at planned times. Periodization of training may require the athlete to periodize energy availability to support training efforts.[1]

- Athletes should attempt to achieve an energy availability of at least 30 -45 kcal/kg FFM while training to reduce body size or fatness.[1] Adequate energy availability can be achieved through an increased energy intake or decreased energy expenditure or a combination of both. Energy intake can be increased through the additional intake of an energy-rich supplement to achieve an initial increase in energy intake of ~300 – 600 kcal/day. Energy intake should be distributed throughout the day with emphasis on intake around exercise sessions.[2]

Calorie Content of Food

Food	Serving Size	Calorie Content (kcal)
Low fat milk	1 cup (250 ml)	102
Fresh Fruit	1 medium (150 g)	72
Bread	1 slice	67
Rice	½ cup	102
Pasta	½ cup	110
Chicken drumstick	1 average	105
Peanut butter	1 Tbsp	94
Egg	1	74
Jam	1 Tbsp	56
Orange juice	1 cup (250 ml)	112

- Athletes should aim to optimise calcium intake to achieve an intake of 1500 mg of calcium per day. This can be achieved through the intake of food sources, especially milk and milk products (4 servings per day). Supplemental intake can be used if necessary due to inadequate intake of dietary sources.[2]

Calcium Content of Food

Food	Serving Size (g)	Calcium Content (mg)
Milk	240	300
Red Beans	172	40.5
White Beans	110	113
Broccoli	71	71
Spinach	85	85
Sweet Potato	164	44
Rhubarb	120	172
Tofu with calcium	126	258
Sardines with bones	56	217
Salmon with bones	56	135

- Athletes should develop realistic and health-promoting goals related to weight and body composition.[2]

Advice to coaching and support staff

- Less emphasis should be placed on weight. Rather emphasise optimal nutrition and health as means to enhance exercise performance.[2]
- Avoid critical comments about an athlete's body shape/weight.[2]
- There should be awareness that good performance is not necessarily synonym with health.[2]

1. *Loucks AB, Kiens B, Wright HH. Energy availability in athletes. J Sports Sci. 2011;29(S1):S1-S15.*
2. *Mountjoy M, Sundgot-Borgen J, Burke L, Carter S, Constantini N et al. The IOC consensus statement: beyond the Female Athlete Triad – Relative Energy Deficiency in Sport (RED-S).Br J Sports Med. 2014;48:491-7.*