Low energy availability in the female athlete

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Athletes striving for success may feel pressure from themselves and others to achieve 'optimal' physique, but reducing energy availability may compromise their health for life.

Low energy availability (EA) in women is now known to be central to the negative health consequences described in the female athlete triad. In the *2014 Female Athlete Triad Coalition Consensus Statement*,[1] this triad was defined as a medical condition involving three interrelated components – low EA, with or without disordered eating; menstrual dysfunction; and low bone mineral density (BMD) – each of which exists on a continuum of severity (Figure).[1,2] Recent research and clinical experience have shown energy deficiency to be the underlying cause of this condition, with insufficient dietary energy to support physiological function after expenditure in exercise is accounted for. There is now a substantial body of scientific literature regarding the consequences of low EA in female athletes.

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In 2014, a new term, 'relative energy deficiency in sport' (RED-S), was proposed by the International Olympic Committee (IOC) to further describe the clinical syndrome resulting from low EA that affects aspects of physiological function in addition to those components described in the female athlete triad.[3] However, the term 'female athlete triad', with low EA associated with endocrine and menstrual dysfunction and low BMD in women, is still widely used. There is a long history of published research regarding the female athlete triad,[4] which is the focus of this article.

What is energy availability?

Energy availability (EA) is the amount of dietary energy available for body functions after accounting for exercise energy expenditure (EEE). EA is reduced by decreasing energy intake (EI), increasing EEE, or both.

Daily EA calculated for athletes is defined as the difference between EI and EEE, expressed per kilogram of fat-free mass (FFM):

EA = (EI – EEE)/FFM

EA is expressed per kilogram of FFM (rather than total body weight) because more energy is expended in fat-free mass than in fat mass. A healthy adult is in energy balance with an EA of about 190 kJ/kgFFM/day (45 kcal/kgFFM/day). These values are based mostly on studies in women.

The Female Athlete Triad Coalition provides an online calculator that can be used to estimate EA (http://www.female athletetriad.org/calculators).[3] However, the field techniques available to determine EI, EEE and FFM are imprecise. A dual-energy x-ray absorptiometry (DXA) scan can give an accurate measurement of FFM.[1] Referral to a qualified sports dietitian may assist with the estimation of EA. An example is described in Box 1.

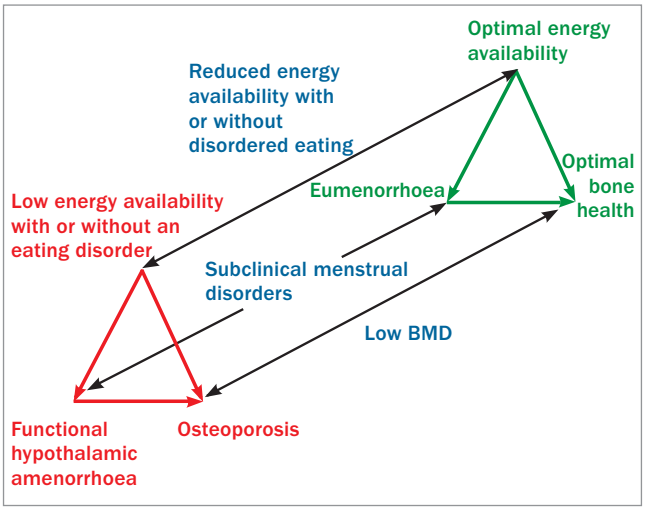

Figure. The three interrelated components of the female athlete triad. At one end of the spectrum, optimal health is indicated by optimal energy availability, eumenorrhoea, and optimal bone health. At the other end, the most severe presentation of the triad is characterised by low energy availability with or without an eating disorder, functional hypothalamic amenorrhoea and osteoporosis. An athlete's condition moves along each continuum at different rates depending on her diet and exercise behaviours.

Reproduced from: De Souza MJ, Nattiv A, Joy E, et al; Female Athlete Triad Coalition; American College of Sports Medicine; American Medical Society for Sports Medicine; American Bone Health Alliance. 2014 Female Athlete Triad Coalition consensus statement on treatment and return to play of the female athlete triad: 1st International Conference held in San Francisco, CA, May 2012, and 2nd International Conference held in Indianapolis, IN, May 2013. Clin J Sport Med 2014; 24: 96-119 (reference 1). © Wolters Kluwer Health, Inc.

Consequences of low EA

The endocrine linkages between elements within the triad are described in the *2007 American College of Sports Medicine Position Stand*.[5] EA is linked to bone strength by metabolic hormones such as insulin, triiodothyronine (T3) and insulin-like growth factor 1 (IGF-1) that regulate bone formation. EA affects gonadotrophin-releasing hormone and has an impact on the pulsatile release of luteinising hormone, which links EA to the menstrual cycle and bone health. Oestrogen links the menstrual cycle to bone health by inhibiting osteoclast activity, so a low oestrogen level may lead to an increase in bone breakdown. Thus, EA affects BMD both directly (via metabolic hormones) and indirectly (via effects on menstrual function).

When BMD is reduced, it is mainly the trabecular bone that is affected; therefore, the structural integrity of the bone is ultimately impacted when BMD has decreased during periods of low EA. The ratio of cortical to total cross-sectional area and bone strength may also be reduced in amenorrhoeic athletes.[6] The loss of BMD may not be fully recovered.[7,8] The risk of bone stress injury may increase, from approximately 15 or 20% for significant single risk factors as defined by the triad, to 30 or 50% for significant combined risk factors related to the triad.[9]

1. Calculating energy availability: an example

Jane is 18 years old and a keen hockey player. She plays two games and has four training sessions (drills and skills) each week. She has been amenorrhoeic for six months.

Jane's sports dietitian calculates her EA. She uses a seven-day food diary and specialised dietary analysis software to estimate Jane's average daily EI to be approximately 5972 kJ/day. She uses an accelerometer to estimate her EEE to be approximately 2605 kJ. Jane's FFM is measured by DXA and estimated to be 38.4 kg.

Jane's EA is calculated as follows:

EA = (EI – EEE)/FFM

EA = (5972 – 2605)/38.4

= 87.7 kJ/kgFFM/day (20 kcal/kgFFM/day)

Jane has low EA. When EA is below about 126 kJ/kgFFM/day (30 kcal/kgFFM/day), reproductive and bone health are likely to be disrupted. By restoring her EA above 126 kJ/kgFFM/day, Jane is likely to restore menstruation and prevent decline in her BMD. She would need to aim for an EI of at least 7443 kJ/day to achieve this, but is likely to need more than 10,000 kJ/day for optimal health and performance.

Abbreviations: BMD = bone mineral density; DXA = dual-energy x-ray absorptiometry; EA = energy availability; EEE = exercise energy expenditure; EI = energy intake; FFM = fat-free mass.

It has been suggested that low EA could have an impact on cardiovascular health, particularly endothelial function.[10,11] Women who have experienced previous oestrogen deficiency or menstrual dysfunction may have an increased risk of cardiovascular disease (CVD),[12,13] and endothelial dysfunction has been associated with menstrual irregularities in premenopausal athletes.[14,15] Older female athletes who have a previous history of menstrual dysfunction or who have participated in sports where low body weight or dietary restriction was encouraged could be screened for CVD.[16]

Assessment and management

The *2014 Consensus Statement*[1] identified the following risk factors for the female athlete triad, which should be considered in all female athletes:

- history of menstrual irregularities and amenorrhoea[5,17]
- history of stress fractures[5,17]
- history of critical comments about eating or weight from parent, coach, or teammate[18,19]
- a history of depression[20-22]
- a history of dieting[22,23]
- personality factors (such as perfectionism, obsessiveness)[24-26]
- pressure to lose weight and/or frequent weight cycling[23]
- early start of sport-specific training[23]

- overtraining[23]
- recurrent and nonhealing injuries[27]
- inappropriate coaching behaviour.[23,25]

Early detection of women at risk is important in the prevention of the female athlete triad. Use of a screening questionnaire is recommended for athletes at the time of the pre-participation evaluation and also annually – see the Triad Consensus Panel Screening Questions at http://journals.lww.com/cjsportsmed/Fulltext/2014/03000/2014_Female_Athlete_Triad_Coalition_Consensus.2.aspx (Table 1 of the statement).[1] The LEAF questionnaire, published in 2014, is another screening tool for identifying athletes at risk for the female athlete triad. Early intervention is particularly important in adolescent girls who are yet to achieve peak bone mass.[28]

Further evaluation should be undertaken if any indication of the triad is present. Athletes may present with one, two or three of the components in the triad; an athlete presenting with any of these components should be assessed for the others.[5] Athletes presenting with physical signs suggestive of low EA, such as low body mass index, weight loss, orthostatic hypotension, presence of lanugo hair, hypercarotenaemia, bradycardia or other signs of an eating disorder should be investigated further.[1] If low BMD is suspected, a DXA scan can be undertaken to investigate. Diagnostic DXA is listed on the MBS; the details of criteria for subsidy for hypogonadism in women are available online (http://www.mbsonline.gov.au).

Advice on diagnosing low EA, evaluating amenorrhoea, prolonged oligomenorrhoea and BMD, and taking steps for treatment and return to play is presented in the previously mentioned *2014 Consensus Statement*.[1] An athlete with low EA should be referred to a qualified sports dietitian for advice about increasing EA, and a sports physician should oversee the care of an athlete with the triad. If an eating disorder or body image issue is present then a psychologist should be involved. An endocrinologist or gynaecologist could be consulted for advice regarding hormonal and reproductive issues.

Conclusion

Low EA in women is associated with endocrine and menstrual dysfunction and low BMD. There is now a substantial body of literature on the female athlete triad, and understanding of this complex area is still evolving. Clinicians may find it helpful to regularly consult the latest guidelines for the current recommendations. The *2014 Female Athlete Triad Coalition Consensus Statement* and *2007 American College of Sports Medicine Position Stand* provide up to date information.[1,5] Early detection and treatment of patients at risk of the female athlete triad is essential to prevent progression along each of the continuums of EA, menstrual dysfunction and BMD, and also the long-term negative health consequences. MT

References

A list of references is included in the website version (www.medicinetoday.com.au) and the iPad app version of this article.

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