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THE IMPACT OF INTENSIVE SPORTS TRAINING ON THE DEVELOPMENT OF YOUNG GIRLS

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ABSTRACT

Introduction: Adolescence is a critical period for physical and mental development, during which physical activity can improve bone mineral density (BMD), reduce obesity, and enhance self-esteem. However, intense sports participation increases energy demands, potentially leading to energy deficits, particularly in female athletes. This energy imbalance can negatively impact the health of adolescent athletes.

The purpose of research: This paper explores the effect of intensive training on the health of young female athletes.

Material and methods: PubMed and Medline databases were searched. Relevant literature was selected.

Results: A persistent state of low energy availability (LEA) has been demonstrated to lead to a variety of disorders, including menstrual irregularities, impaired bone microarchitecture, and depressive and anxiety symptoms. These abnormalities pose a particularly elevated risk to young female athletes, as they can result in severe lifelong complications.

Conclusions: Every young female athlete should be screened for the symptoms of the syndrome of relative energy deficiency in sport (RED-S). Examination should be repeated at least annually. In the treatment of disorders arising from LEA, the primary objective is to enhance energy levels. In cases of low BMD, it is imperative to ensure an adequate supply of vitamin D and calcium in order to prevent fractures.

Keywords: adolescents, Female Athlete Triad, RED-S, LEA, menstrual disorders, BMD, mental state

INTRODUCTION

Physical activity in adolescents supports their physical and mental development. It has been shown to improve bone mineral density (BMD), reduce the risk of obesity, improve self-esteem and reduce risk-taking behaviors (Weiss Kelly et al. 2016; Ravi et al. 2023). However, participation in sports is associated with increased energy demands on the body. Concurrently, athletes may encounter social pressures to maintain a specific body shape or a certain body weight (Weiss Kelly et al. 2016; Wells et al. 2020). During sports, athletes typically experience a substantial energy expenditure, frequently resulting in insufficient energy intake from food sources. This results in an energy deficit and subsequent depletion of body fat stores. The prevalence of energy deficiency in female athletes is a salient concern, with 7 to 54% of adolescent female athletes experiencing menstrual cycle dysfunction. Moreover, 44% of female athletes believe that the loss of menstruation during intensive training is normal (Armento et al. 2021). Consequently, there is a necessity to promote awareness regarding harmful effects of energy deficiencies in sports.

The measure used to assess energy deficiency is energy availability (EA), which is the fraction of the difference in energy intake (EI) and energy expended for exercise (EEE) by fat-free mass (FFM). A failure to align nutrition with training intensity can result in low energy availability (LEA), which has a detrimental effect on the health of young female athletes. This is manifested by the characteristic symptoms of the female athlete triad (Brown et al. 2017, Mountjoy et al. 2018; Kelly et al. 2022, Ravi et al. 2023).

THE PURPOSE OF RESEARCH

This literature review aimed to gather information on the effects of intensive sports training and low energy availability on the developmental health of young athletes.

MATERIALS AND METHODS

We searched PubMed and Medline databases on March 11, 2025 using a formula ("amenorrhea" OR "hypogonadism") AND ("athletes" OR "sport" OR "sports") AND ("child" OR "children") and initially selected 30 results in the last 10 years. We selected literature items relevant to the topic of our study. Finally we selected 8 publications to include in our work. We decided to reject papers that did not fit the purpose of our study, particularly papers regarding different topics. In addition, we searched the database manually for articles that could not be searched by the previous method which resulted in the inclusion of additional 4 publications. Ultimately, we included 12 publications in our study.

RESULTS

Female Athlete Triad and the syndrome of RED-S

Initially, this triad was considered to consist of three disorders: disordered eating, amenorrhea and osteoporosis. Over time, this definition has undergone expansion. Currently, the triad includes: LEA, menstrual disorders and low BMD. It is noteworthy that the presence of any one of these components in a young female athlete has been associated with an elevated risk of adverse consequences in the future (Mountjoy et al. 2014, Weiss Kelly et al. 2016, Brown et al. 2017, Mountjoy et al. 2018, Kelly et al. 2022).

The syndrome of relative energy deficiency in sport (RED-S) was defined by the International Olympic Committee (IOC) in 2014. It is an extension of the Female Athlete Triad concept. The syndrome of RED-S encompasses not only the elements of the triad, but also other consequences of relative energy deficiency, such as reduced metabolic rate, stunted growth, increased risk of cardiovascular events, impaired immunity, gastrointestinal symptoms, and psychological problems. Low energy availability (LEA) is thought to be the etiological factor in all these disorders (Mountjoy et. al. 2018).

A substantial proportion of the LEA can be attributed to the presence of undiagnosed eating disorders (Mountjoy et al. 2014). The most common reasons given by athletes for developing an eating disorder were long periods of dieting, changes in coaching staff, injuries and casual remarks from coaches, parents, and friends regarding weight (Weiss Kelly et al. 2016, Kelly et

al. 2022). Nevertheless, other scenarios may also result in LEA. These include a suboptimal management of a rapid weight/fat loss programme, as well as an individual's inability to track their EI in the context of intense physical exertion (Mountjoy et al. 2014). It is interesting to note that Ravi et al. observed no differences between the athletes and the controls in eating behaviours at any age. Nevertheless, the prevalence of menstrual dysfunction and delayed puberty was found to be elevated among the cohort of athletes when compared to that of the control group (Ravi et al. 2023).

The syndrome of RED-S is not only associated with impaired functioning of many systems in the body, but also has a negative impact on sports performance. LEA exerts a marked effect on the reduction of glycogen stores within the organism, the impairment of protein synthesis and, moreover, an overall reduction in basal metabolism. Neuromuscular performance is defective, resulting in a reduction of muscle strength and a decline in endurance. The response to training is diminished and the risk of injury is increased. The effects of LEA on the human organism include depression and irritability, impaired judgement, and a negative impact on concentration and coordination, resulting in a decline in sports performance (Mountjoy et al. 2018).

Menstrual Dysfunction

The menstrual dysfunction experienced by young female athletes is mostly of hypothalamic origin and is referred to as functional hypothalamic amenorrhoea (FHA). It has been demonstrated that LEA exerts a suppressive influence on the hypothalamus-pituitary-gonadal axis. The prevalence of menstrual disorders is contingent upon the extent of the energy deficit (Weiss Kelly et al. 2016, Brown et al. 2017, Mountjoy et. al. 2018, Kelly et al. 2022).

Menstrual irregularities are a common occurrence in adolescent girls; however, it is significantly more frequent among adolescent female athletes (Weiss Kelly et al. 2016). Distinguishing between normal and abnormal menstruation can present a challenge in the adolescent population, due to the fact that their hormonal systems are still undergoing development (Brown et al. 2017). It is important to note that the anovulation or luteal phase defects are asymptomatic, and therefore difficult to identify (Weiss Kelly et al. 2016, Kelly et. al. 2022). Consequently, particular attention should be paid to symptoms of delayed puberty and to menstrual periods that are scanty or irregular. It was found that female athletes were

more likely to have amenorrhoea (both primary and secondary) than the control group, in addition to having later menarche and regular periods at a later age (Ravi et al. 2023).

LEA and BMD

The decline in BMD observed in female athletes can be attributed to two independent factors: reduced energy availability and a hypoestrogenic state (Kelly et. al. 2022). It is vital to acknowledge the significance of bone mass accrual during the developmental stages of childhood and adolescence. These periods are pivotal in determining the maximum potential for bone mass accumulation, which in turn is essential for the subsequent prevention of osteoporosis in adulthood (Weiss Kelly et al. 2016). It is important to note that the vast majority, approximately 90%, of adult bone mass is typically acquired by the age of 18. A substantial proportion, amounting to 25% of bone mass, is accumulated during the two years preceding menarche (Brown et al. 2017, Kelly et. al. 2022). The potential for BMD to stabilise or even improve is contingent upon the duration of triad-specific disorders; however, it is possible that a return to the optimal levels of BMD may never be achieved. To acquire age-appropriate BMD, there is a need for nutrition appropriate to energy requirements. Furthermore, it is necessary to engage in physical activity that is of a moderate intensity and involves weight-bearing exercise. The association between weight-bearing athletic activity and increased total trabecular area, as well as greater cortical perimeter in the tibia, has been demonstrated. In contrast, amenorrhoea and oligomenorrhoea resulting from excessive physical training leading to LEA have been shown to be associated with impaired bone microarchitecture. This is characterised by diminished trabecular number, augmented inter-trabecular space, and reduced total density of the tibia. Moreover, the duration of amenorrhoea in athletes was positively associated with a higher level of marrow adiposity, which was inversely proportional to BMD. Consequently, the bones may become more fragile and vulnerable to injury and the risk of fracture (Singhal et al. 2015, Weiss Kelly et al. 2016). Such injuries can have profound and lasting consequences for individuals, often impacting their quality of life. In the early stages of life, articular cartilage injuries have the potential to result in limb deformity and discrepancy in leg length. Furthermore, the weight-bearing joints of former athletes, such as the hips, knees and ankles, are susceptible to osteoarthritis following injury (Maffulli et al. 2011).

LEA and mental state

In addition to its detrimental effects on the skeletal system, low energy availability has also been shown to have significant impacts on the nervous system and mental state of athletes. A study by Armento et al. found that athletes with menstrual dysfunction exhibited statistically significantly higher levels of anxiety and fatigue. The disruption of the hypothalamic-pituitary-gonadal axis, consequent to low energy availability, results in hypogonadotropic hypogonadism. There is a simultaneous disruption of the hypothalamic-pituitary-adrenal axis with an increase in blood cortisol levels, which contributes to the development of anxiety. In addition, chronic stress, including that caused by energy deficiency and high cortisol levels, is associated with fatigue. The authors hypothesize that the heightened pain sensitivity associated with amenorrhea may be attributable to an anxious approach to pain perception, excessive focus on it, or inadequate coping mechanisms for pain-related stress (Armento et al. 2021).

It is not known whether anxious personality is primary to relative energy deficiency in sports, or whether anxiety and depression are secondary to functional and morphological changes caused by energy deficiency. In a study of female athletes with oligomenorrhea, depressive and anxiety symptoms were found to be statistically significantly more prevalent compared to women with normal menstruation (Baskaran et al. 2023).

Estrogens affect the nervous system, showing anxiolytic and antidepressant effects. When estrogen is deficient, its supplementation reduces the severity of anxiety symptoms in adolescent girls (adolescents) with anorexia (Misra et al. 2013).

Baskaran et al. suppose that estrogen concentrations may impact brain development during adolescence. A notable finding was that adolescent athletes exhibited increased caudate nucleus volume compared to the control group. The authors observed a reduced activation of the caudal body in the reward/punishment system, suggesting that estrogen deficiency impairs the reward system's response to stimuli, thereby reducing brain function in anticipation of reward (Baskaran et al. 2023).

Assessment

Early screening and identification of athletes who are at risk of developing RED-S is important to avoid long term complications. The screening assessment should be performed at the initial evaluation for sports participation and optimally at least once a year. The Female Athlete Triad Coalition has created a screening test consisting of 12 questions (Weiss Kelly et al. 2016). However, it is important to remember that athletes may attempt to conceal their health concerns during the evaluation process (Mountjoy et al. 2018). Special attention should be paid to individuals who self-report any history of symptoms associated with the triad, particularly instances of fatigue, fractures, multiple pathological fractures, or menstrual cycle disorders (Weiss Kelly et al. 2016). American College of Sports Medicine (ACSM) guidelines stipulate that female athletes should be screened for the female athlete triad, as well as other underlying medical conditions, if they have experienced a total of six months of oligomenorrhoea or amenorrhoea (Brown et al. 2017). It is essential to exclude any other potential causes of menstrual disorders in these girls (Kelly et. al. 2022).

During the physical examination, the BMI (which may, however, be normal) and body weight according to percentile grids, as well as an evaluation of symptoms typical of patients with eating disorders (e.g., bradycardia, lanugo, cold extremities, salivary gland enlargement) should be assessed first and foremost. In the preliminary evaluation, it is also beneficial to conduct a complete blood count (anemia), as well as biochemical tests, TSH, fT3, and fT4, and an urinalysis (Brown et al. 2017). A pregnancy test should also be performed to exclude the possibility that the absence of menstruation is due to pregnancy. It may be useful, especially at a more advanced stage of evaluation, to assess sex hormones, FSH and LH for differential diagnosis. Nutritional deficiencies may also be a contributing factor; therefore, an evaluation of iron metabolism (ferritin, transferrin, serum iron concentration) may be indicated (Kelly et. al. 2022).

Dual energy X-ray absorptiometry (DXA) using Z-score is a method of assessing bone complications. Low BMD is characterized by a Z-score between -1 and -2, while osteoporosis is defined as a Z-score below -2 (Brown et al. 2017). According to AAP guidelines, DXA is recommended for female athletes with weight <85% of expected, recent weight loss of at least 10%, menstrual disorders, LEA for longer than 6 months, or a history of fatigue fractures (Weiss Kelly et al. 2016).

Treatment

The most important component of RED-S treatment is to increase energy availability. This can be accomplished through a reduction in the frequency and intensity of physical activity or by increasing caloric intake. If LEA is caused by unintentional under-eating, a limited intervention with simple nutrition education may suffice. The optimal energy availability for treatment is >45 kcal/kg lean body mass (Weiss Kelly et al. 2016).

However, controlling caloric intake, as well as energy expended for exercise, is difficult and prone to falsification by inaccurate data from athletes. Therefore, other indicators, such as regaining recently lost weight, achieving a BMI >18.5, or regaining menstruation, can be used to assess the effects of treatment. However, it is important to keep in mind that the return of normal menstruation can occur even more than a year after the recovery of normal energy availability (Weiss Kelly et al. 2016). Individuals affected by RED-S should undergo evaluation for the presence of eating disorders and potential psychiatric disorders. If any are present, they should be treated by a mental health specialist. Cognitive behavioral therapy (CBT) has been demonstrated to be an effective treatment for eating disorders, with studies showing that it can reduce the pursuit of thinness and enhance body satisfaction in patients (Kelly et. al. 2022).

To treat low bone density and prevent fractures, vitamin D should be used in prophylactic doses and calcium intake of 1,300 mg/day should be ensured for children and adolescents between the ages of 9 and 18. The use of oral hormonal contraception is not recommended for both restoring menstruation and improving BMD. Oral contraception can mask the symptoms of RED-S by providing reproductive tract bleeding without achieving adequate energy management. The usage of estrogen transdermal systems to improve BMD can be considered. This method has been shown to yield clinically significant improvements in BMD in patients with anorexia, but there is a paucity of studies in a group of women affected by RED-S, so the administration of transdermal estrogens needs to be done with extreme caution (Mountjoy et. al. 2018). The use of bisphosphonates is not recommended for the treatment of RED-S. In addition, there are concerns about the potential teratogenicity of bisphosphonates, so they should be avoided in women of childbearing age (Mountjoy et. al. 2018).

CONCLUSIONS

Although physical activity is generally beneficial for young female athletes, it can cause many disorders. If intensive sports training is not balanced with adequate energy intake, it can lead to the syndrome of relative energy deficiency in sport. The most characteristic symptoms of the syndrome of RED-S are irregular menstruation, abnormal bone microarchitecture, and depressive and anxiety symptoms. These conditions carry a heightened risk for young girls, as they can lead to distant complications that will impair the quality of life of the affected individual. Therefore, it is strongly recommended that every young female athlete undergoes a screening for the symptoms of RED-S on at least an annual basis. In the therapeutic management of conditions stemming from LEA, the overarching aim is to elevate energy levels. In instances of low BMD, there is a need to assure sufficient levels of vitamin D and calcium to prevent the onset of fractures. It is crucial to raise awareness among general practitioners, sports coaches, athletes, and their parents about the potential dangers of inadequate energy availability in sport.

DISCLOSURE

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