Consequences of Energy Deficiency in Female Athletes

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Introduction

Since the inception of Title IX the participation of women in competitive sports and recreational fitness activities has increased dramatically. Regular exercise is an integral part of a healthy lifestyle, and the benefits range from getting better grades, improving mood and self-esteem, reducing the likelihood of using alcohol or smoking, reducing the risk of certain cancers, and improving overall health. However, an imbalance between the energetic needs of the body and the energy required to participate in physical activity can have serious consequences on various systems of the body including the reproductive, skeletal, and cardiovascular systems.

Maintaining energy balance is an essential element for everyone, but even more important for athletes. Energy balance is achieved when the amount of energy intake (i.e., all foods and beverages consumed) matches the energy that is expended throughout the day. Your energy expenditure has three parts: 1) your resting energy expenditure, or the amount of energy you would use if you were to just lay quietly; 2) your energy expenditure from normal daily activities, like walking to the bus stop or doing household chores; and 3) your energy expenditure from exercise, such as going out for a run, dancing, or swimming. This last component is typically the most variable between people, and individuals who exercise regularly expend a lot of extra energy compared to a sedentary person. Therfore, being physically active and participating in sports requires that you achieve higher levels of energy intake to prevent an energy deficit.

Reproductive System

Following puberty women begin to have regular menstrual cycles generally lasting between 24 – 35 days. Women with normal menstrual cycles (eumenorrhea) will have 12 – 13 periods per year, however circumstances exist when irregular (oligomenorrhea) or absent (amenorrhea) menstrual cycles may be present. Oligomenorrhea is defined as a menstrual cycle lasting between 36 – 90 days, whereas amenorrhea is defined as having no menstrual period for at least three months and having less than three periods in the previous 12 months. These menstrual disturbances are more common in exercising women compared to the general population and are associated with low levels of estrogen (the primary female sex hormone). Suppressed estrogen in physically active women is related to bone loss, and more recently has been shown to increase the risk of cardiovascular disease in young, otherwise healthy women. Thus, maintaining regular menstrual periods and more importantly normal levels of estrogen is essential for a woman's health.

Menstrual disturbances in exercising women was originally believed to be the result of low levels of body fat, where a minimum of 22% was necessary to maintain normal reproductive function. However, some women with body fat levels below this threshold still get normal monthly periods, suggesting that other factors play a role in regulating menstrual cycles. So researchers began to look for other causes of these menstrual disturbances. It soon became evident that women who were in an energy deficit were much more likely to experience irregular or absent menstrual cycles (10). What was also discovered is that there are a host of signals from the body that get sent to a specific region of the brain (the hypothalamus) which communicate the body's energy

status. The hypothalamus is responsible for interpreting these signals and then provides instructions for how the body should respond. In addition, this region of the brain is also responsible for regulating the menstrual cycle.

Normal menstrual cycles depend on regular pulses every 60 – 90 minutes of a certain hormone called gonadotropin-releasing hormone (GnRH) from the hypothalamus; without this the menstrual cycle would become irregular or absent (6). This hormone then signals another part of the brain to release two other hormones called lutenizing hormone (LH) and follicle stimulating hormone (FSH). Lutenizing hormone also has a pulse which occurs approximately every 60 – 90 minutes. A decrease in the number of LH pulses is used by researchers to identify disturbances in the hypothalamus (because GnRH very easily).

In a series of well designed studies from Ohio University, researchers showed a decrease in LH pulses in women who had regular menstrual cycles by having them dramatically increase their energy expenditure through exercise (7). It was shown that the change in LH pulses was the result of an imbalance between energy intake and the energy expenditure from exercise. They showed that when individuals were able to consume the same amount of calories that they expended during exercise, no disruptions of LH pulses were evident, indicating that disruptions in the brain were not caused by the exercise per se, but rather the energy deficit. When signals from the body tell the brain that there is an energy deficit, the hypothalamus slows its pulses, which then slows the LH pulses and can eventually result in menstrual cycle irregularities or possibly its complete absence. This is done for a very simple reason: to conserve energy. In women, reproduction is considered non-essential, meaning it is not necessary for the survival of the individual, and it is costly from an energy perspective. Therefore, to help conserve energy when the brain senses an energy deficit, reproductive function is reduced and is casually observed with menstrual irregularities.

Skeletal System

So what is the big deal that an energy deficiency can lead to menstrual irregularities? Some women involved in competitive athletics might be convinced that not having a menstrual cycle is a good thing. Despite the positive impact sport and physical activity has on increasing bone mass, menstrual disturbances and the associated low levels of estrogen can result in bone loss, even in young apparently healthy women (1, 2, 5, 8). Bone loss creates weak bones and could predispose a physically active woman to stress fractures, resulting in lost training time and decrements in performance. Reduced levels of estrogen could also prevent the attainment of peak bone mass, thereby increasing the likelihood of low bone mass or osteoporosis later in life. Several studies have reported a decrease of 7 – 30% in bone mineral density (BMD) in the spine and legs in athletes who were amenorrheic (no menstrual periods) compared with athletes who were eumenorrheic (regular menstrual periods) (2,5). The longer women remain amenorrheic, the greater the amount of bone loss. This is especially important considering that only partial restoration of bone mass is achieved when women regain regular menstrual periods (and normal levels of estrogen). In other words, simply regaining regular menstrual periods does not guarantee a return of all the lost bone. Therefore, maintaining regular menstrual cycles is important for bone health.

In addition to the indirect effects an energy deficit can have on bone (i.e., initiating menstrual irregularities), there are also direct effects. It has repeatedly been shown that certain factors responsible for stimulating bone formation are suppressed as a result of an energy deficiency. Reduced bone formation will lead to incomplete refilling of resorption cavities that are a normal part of the bone remodeling process. So a woman's nutritional status can also independently affect bone health even without overt menstrual disturbances.

Cardiovascular System

Estrogen is also known to have protective effects on the cardiovascular system and so menstrual disturbances resulting in low levels of estrogen can have negative consequences on the cardiovascular health, which is one reason we see an increase in cardiovascular disease in postmenopausal women. Cholesterol has a wide range of beneficial physiological functions and is often categorized as either high density lipoproteins (HDL) or low density lipoproteins (LDL). Within this classification scheme LDL is known as 'bad cholesterol' because of the association between elevated LDL and cardiovascular disease, whereas HDL is known as 'good cholesterol' due to the correlation with lower risk of cardiovascular disease. Research has shown that amenorrheic athletes have higher levels of total cholesterol, triglycerides,

and LDL compared to eumenorrheic athletes (3, 9), however these women are not considered to be in the high risk category since the levels do not exceed national recommendations. In addition, physically active women with amenorrhea also present with higher levels of HDL compared to their eumenorrheic counterparts, which may help to counteract any potential risk associated with the higher levels of cholesterol, triglycerides, and LDL.

Brachial artery flow-mediated dilation is another measure of cardiovascular disease risk, which evaluates how well an artery (in this case the brachial artery in the arm) dilates in response to an increase in blood flow, where a reduced response is suggestive of an impairment of cardiovascular function. Several studies have reported a reduction in flow mediated dilation in amenorrheic athletes compared to athletes with regular menstrual cycles, which was also associated with unfavorable cholesterol profiles (9). More research is needed in this area because the long term implications on cardiovascular health in amenorrheic athletes remain unclear. In the meantime the unfavorable changes in cholesterol, triglycerides, and cardiovascular function should not be ignored, and recommendations to achieve energy balance and either maintain or regain normal menstrual function should be strongly encouraged to physically active women.

Conclusion

An energy deficit can induce disruptions in the menstrual cycle, which is associated with low levels of estrogen. Consequently, low levels of estrogen are related to bone loss and unfavorable alterations in factors associated with cardiovascular disease. Unfortunately, in a survey of physicians, physical therapists and athletic trainers, less than half were able to identify these interrelated components and astoundingly only 9% of the physicians felt comfortable discussing treatment for these conditions (4). Education of individuals working with female athletes as well as the athletes themselves is the cornerstone to prevention. In the meantime, women should continue to lead physically active lives, participate in sport, and consume adequate calories so as to remain healthy and competitive.

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