Impact of Dietary Management in Estrogen Regulation on the Prevention of Relative Energy Deficiency in Sport (REDs)

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Abstract

Relative Energy Deficiency in sport (REDs) is a syndrome individuals develop from lacking sufficient amounts of energy compared to the energy demanded during exercise. Similarly, significant symptoms of REDs is Low Energy Availability (LEA): a condition found more commonly in females. Sparse supplies of energy result in many harmful impacts on athletes' physiological health. Low levels of estrogen can lead to complications including low bone mineral density (BMD) and disruptions of the menstrual cycle. To reverse or prevent the effects of energy deficiency, individuals need to consume specific micro and macronutrients. These nutrients can be ingested to supply the body with more energy, raising levels of estrogen and repairing menstrual and bone function. The purpose of this paper is to review studies on consumption of essential macro and micronutrients to help athletes manage and mitigate the physiological impact of REDs.

Introduction

By definition, LEA, or Low Energy Availability, is insufficient energy intake relative to expended energy through exercise[1]. REDs, Relative Energy Deficiency in sport, is a syndrome of depleting health and performance when athletes are exposed to LEA[1]. Despite its commonality in female athletes, REDs is rarely discussed and not well known to a greater population of athletes and coaches. Athletes who are prone to developing REDs are likely to participate in high intensity sports such as running. Both REDs and LEA can leave long-lasting impacts on athletes which can stay with individuals longer than their athletic careers[2]. These impacts include lowered bone density from disrupted hormonal levels, disrupting performance and overall health. Without sufficient energy, the hypothalamic-pituitary-ovarian axis is suppressed, resulting in altered production of estrogen[3]. Menstrual and ovarian functions become dysregulated. Thus, bone mineral density is lowered, which impacts bone regeneration and increases the risk of injury[4]. Athletes are frequently told to eat "healthier" when faced with health issues; however, most athletes do not know what to eat and what best enhances their performance to keep them healthy and avoid injuries. Micronutrients such as vitamin D, calcium, and iron contribute to healthy bone cells and energy levels[5]. Furthermore, lower levels of macronutrients, including carbohydrates and protein, are associated with REDs[6]. Therefore, this literature review is to help athletes find a balanced diet with sufficient macro and micronutrients to avoid or mitigate the effects of REDs. Specifically, REDs should not occur when athletes get enough energy from certain nutrients to match the amount of energy they expend[2].

Literature Review

REDs and LEA

REDs, as stated previously, is a syndrome of declining health due to individuals being exposed to Low Energy Availability (LEA)[1]. LEA is a state in which one doesn't get a sufficient amount of energy compared to the energy being expended. The decline of health can be defined by multiple injuries mainly due to stress[4] and by the disruption of important body

functions such as the menstrual cycle and the regrowth of bone cells. To avoid overuse, overtraining, burnout, and consequently REDs, individuals can look towards nonsurgical rehabilitation or management[7]. To minimize risk, athletes can optimize energy availability and treat body system dysfunctions by moderating types and amounts of food intake[1].

Macronutrients

Dietary management plays a crucial role in preventing REDs by restoring lost energy and allowing the body to function healthily. Carbohydrate, protein, and fat consumption is vital to avoid LEA and its negative health consequences (Figure 1).

Carbohydrates are sugar molecules that are broken down into simpler compounds known as glucose. Glucose is the body's main source of energy. LCHO, or low carbohydrate intake (<3.0g/kg), is positively correlated with low energy availability. Thus, the lower the carbohydrate intake, the lower energy availability[6]. Furthermore, lower carbohydrate levels are associated with negative endocrine and metabolic responses from bodies. A study conducted by doctors of sport & health sciences in Iceland tried to find a correlation and causation between low carbohydrate intake and LEA. Individuals in this study who fell under the group LEA+LCHO (had both low energy availability and low carbohydrate intake) were deficient in other vital micro and macronutrients[6]. All aspects of a diet are important to reduce the chances of REDs. With lower levels of carbohydrates, individuals can lack essential nutrients to promote a healthy body. Women experiencing LCHO reported disruptions in their periods, conveying that menstrual cycles and endocrine systems are impacted by carbohydrate intake (Figure 2).

Proteins also impact systemic functions in the body due to the macronutrient's role in hormonal regulation, enzyme functions, and being the main building blocks of cells. As a result of the importance of protein for the menstrual cycle, a higher intake of protein should be prioritized[2]. Consumption of proteins allows muscle mass to grow and repair. Recommended protein levels are 1.2-2.0 g/kg BW[6]. The LEA+LCHO group displayed <1.0 g/kg BW of protein, expressing that protein deficiency is also related to low energy availability.

Similarly, fats sustain metabolic and hormonal systems. Fats should be about 20 to 35% of an individual's total energy consumption or intake[2]. Women burn more macronutrients when exercising than men, as found in a study conducted by Hausswirth et al, emphasizing the significance of LEA in active females who cannot get an adequate amount of macronutrients. In addition, the connection between LEA and the lack of macronutrients expresses a correlation between the two factors. Although there are many aspects that play into the lack of energy, consuming vital macronutrients – such as carbohydrates, proteins, and fats – ensures an increase in energy availability and will decrease the chances of having LEA. Some foods high in protein are red meat, fish, and eggs. Carbohydrates consist of wheat or grain products such as pasta noodles, bread, and rice. Fats are found in avocados, nuts, and oils.

Micronutrients

Similar to macronutrients, micronutrient consumption is vital to ensure energy availability is optimal (Figure 1). Despite the variety of micronutrients, vitamin D, calcium, iron and ferritin, and magnesium are essential due to their positive impact on bone mineral density (BMD). Having a healthy BMD ensures that future breakage or fracturing of bones – which is a symptom of REDs – is less likely to occur.

Vitamin D, a crucial micronutrient, helps improve bone health and reduce the risk of bone stress injuries. Vitamin D also helps maintain normal neuromuscular functions in individuals[2].

According to the IOC, sufficient Vitamin D intake is >30ng/mL ~ 80 nmol/L. Vitamin D deficiency is defined as <50 nmol/L[6]. Furthermore, athletes with LEA and LCHO had lower levels of vitamin D. In other words, low vitamin D intake is associated with low carbohydrate intake and low energy availability. To raise vitamin D levels, foods, and supplements should be consumed. Eggs, dairy products (milk and cheese), salmon, herring, and mackerel have abundant amounts of vitamin D[2].

Calcium, more commonly associated with bone growth, is crucial for maintaining optimal BMD. In support of this statement, a study shows that 85% of female runners with low bone density didn't meet the recommended intake for calcium[2]. Athletes with nutritional disorders, or menstrual disruptions, are recommended to take about 1500 to 2000 mg/day of calcium. Higher dietary calcium intakes protect athletes from stress fractures. Two studies concluded that low calcium intake increased the risk of stress fractures[5]. Furthermore, the main dietary sources of calcium include dairy and milk products. Spinach, kale, and beans are plant products high in calcium. Both lactose and vitamin D augment calcium absorption. Only 500mg of calcium can be ingested at one time, so it is crucial to spread calcium intake throughout the day.

Ferritin, a protein that stores iron (Fe) is important for oxygen transport as hemoglobins in the bloodstream. If iron levels are suppressed, LEA can develop due to the diminishment of energy efficiency, lowering of maximal oxygen consumption, and the athlete's lack of ability to work at an optimal level[2]. The recommended Fe consumption per day is about 18 mg/day. In addition, it is recommended that females increase the estimated average requirement by 70% due to the menstrual cycle[2]. Iron is lost through menstruation, sweat, and the gastrointestinal tract. Therefore, females in demanding and high-impact sports (such as distance running) need to consume iron to avoid fatigue and decreased performances[4]. Meat products have high iron content and can be consumed to raise iron levels. Supplementation, particularly in pill, liquid, drops, or capsule form, is another way to increase iron consumption. Intestinal absorption of ferrous sulfate, citrate, and gluconate can substitute for consuming foods such as meat. By supplementing or consuming more foods rich in iron, athletes can improve their athletic capabilities and fight against LEA.

Magnesium, another vital micronutrient, helps ensure electrolyte balance and keeps the endocrine system in check. This micronutrient also ensures the body takes in oxygen at a proper level. Women in sports with high LEA rates express that they have low magnesium intake[2]. Moreover, athletes need about 20% more magnesium than standard individuals. Magnesium aids other micronutrients to support bone health as well[9]. According to a book on dietary reference intakes, magnesium's Recommended Dietary Allowances (RDAs) are based on personal size and weight rather than a universal amount of magnesium. For instance, females in the 14 to 18-year-old range should take 300 mg (12.5 mmol)/day of magnesium with a reference weight of 57 kg[10]. Foods high in magnesium include bananas, potatoes, nuts, legumes, dark chocolate, and cereal. Supplementation of magnesium is important if individuals can't reach recommended magnesium levels.

A balanced diet comprising of macronutrients and food rich in micronutrients, or vitamins, is essential to maintain a sufficient EA and reduce the development of LEA or further REDs.

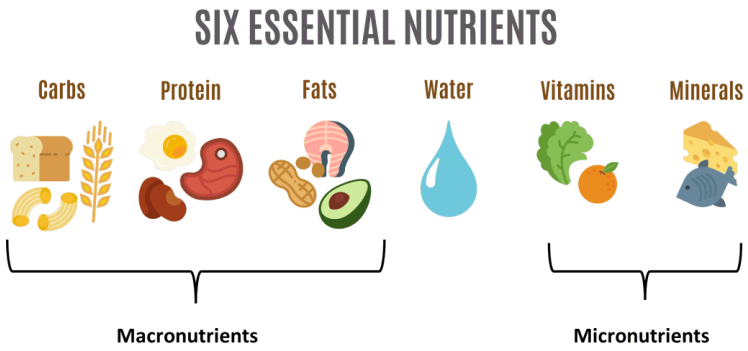

Figure 1 — Essential nutrients comprise macro and micronutrients[11]. Carbohydrates, proteins, and fats are macronutrients while micronutrients consist of vitamins and minerals. Vitamin D is a well known micronutrient which promotes bone health. All of these nutrients are proven to be helpful when raising Energy levels if they are consumed at a recommended level.

REDs Impact on Estrogen and the HPG Axis

As seen in the macronutrient section, women and men are different when it comes to how each gender expends energy. Women secrete sex-specific hormones from glands such as ovaries. Controlling the ovaries, the hypothalamic-pituitary-gonadal axis (HPG) is a system of endocrine glands controlling reproductive processes. The ovaries produce estrogen which is a hormone vital for reproductive and bone health (Figure 2). As found in female athletes, long-term LEA can lead to low bone mineral density. In addition, these athletes with low BMD have menstrual dysfunction[8]. Osteoblasts and osteoclasts exist in balance in bones. Both of these cells are important to maintain bone health. Osteoblasts build bones while osteoclasts break down bones. Estrogen reduces the number of osteoclasts. When estrogen is low, osteoclasts increase in numbers, offsetting the balance of bone remodeling towards more bone destruction (Figure 2). About 28% of females in a low BMD study reported having no menstrual bleeding despite having gone through puberty and having a cycle in the past[8]. Therefore, there is a clear connection between LEA and menstrual cycles. The more LEA is present, the more strain on the menstrual cycle and overall bodily health.

Due to the HPG axis and estrogen's regulation of the menstrual cycle, these systems are also impaired by low energy availability and REDs[4]. The macro and micronutrient segment highlights that without proper nutrition, individuals will most likely develop LEA. Females with low levels of essential nutrients have an inhibited HPG axis. Due to this impairment, there is an inhibition of the release of gonadotropin-releasing hormone (GnRH), and consequently, low production of luteinizing hormone[9], follicle-stimulating hormone, and estrogen[3] (Figure 2). Inhibition of these systems causes females to have a higher risk of anovulation. Estrogen deficiency is linked to menstrual irregularities and the development of stress fractures[5]. Disruption of the menstrual cycle can lead to severe health complications and impede athletic abilities. Therefore, by avoiding dietary deficiencies, female athletes can avoid LEA and disruptions of menstrual processes[3] and reduce bone breakdown.

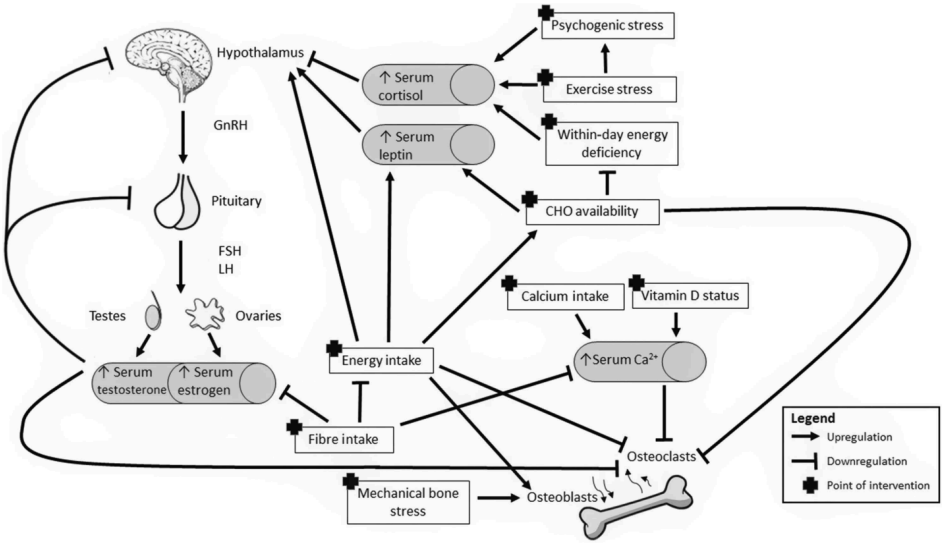

Figure 2 — This image depicts the function of the HPG axis and how hormones affect bodily processes[9]. The HPG axis consists of the hypothalamus, the pituitary gland, and the ovaries/testes, which produces estrogen. Furthermore, this image expresses how calcium and Vitamin D (micronutrients) intake can affect osteoclasts and osteoblasts, affecting BMD and the HPG axis as a result.

Alternative Perspective

Dietary management has a minimal effect on the prevention of REDs. Some factors other than lack of sufficient nutrition can cause REDs. There are many different approaches to mitigating the effects of REDs, causing an emphasis on nutritional balance to be diminished.

Conclusion

Biases

As a review paper, this text contains and utilizes information from published medical articles and studies conducted by credible sources. These studies note that all athletes and individuals, used as study subjects, are different and have differing nutritional necessities. For instance, everyone has varying EA levels which affects the amount of nutritional intake (of macro/micronutrients) to ensure that LEA isn't developed. Despite the recommended amounts of intake of macro and micronutrients, the amount of energy expended by each person differs. Furthermore, many studies, such as the LCHO study, used self-reporting surveys to get an accurate idea of how much food participants consume each day. Surveys can lead to small forms of bias as the participants can fill out surveys knowing how to answer certain questions to appear different than their true selves. Accordingly, nutritional intake was subject to error in memory when asked to be recorded. Measuring EA was another process that could involve some bias as there are portion estimates needed to figure out how much energy is being consumed and how much is being expended. Finally, despite REDs and LEA being the main

causes of stress fractures and disruptions of the menstrual cycle, individuals struggling with these issues may have other health problems that can't be solved with just nutritional changes.

Summary

As individuals are exposed to LEA, REDs can develop, causing many vital bodily functions to be disrupted. In order to minimize the risk of REDs, individuals, specifically female athletes, can manage the types or amount of food intake to optimize energy availability. Macronutrients with the ability to reduce the chances of developing LEA include carbohydrates, proteins, and fats. All of these macronutrients play a key role in raising energy availability and keeping systems and glands, such as the endocrine system, in check. Furthermore, micronutrients are also crucial for keeping energy availability at a healthy level. Vitamin D and calcium ensure healthy bones and a healthy BMD, while iron sustains a high aerobic capacity. Magnesium supports energy uptake and metabolic processes. These micronutrients keeps the bodily processes in good condition and reduce risk of LEA. Supplementation of micronutrients is important if the consumption of foods rich in these nutrients isn't meeting the daily consumption requirements. Furthermore, without sufficient amounts of macro and micronutrients, suppression of the hypothalamic-pituitary-ovarian axis occurs, causing menstrual dysfunction. If consumption of the previously listed macro and micronutrients is increased to reach optimal levels, LEA and REDs will occur less in female athletes.

Further Implication

Athletes can be more aware of what needs to be consumed for their bodies to stay healthy. Furthermore, athletes should know the dangers of REDs and LEA and how sufficient nutrition is vital to maintain healthy bodily functions. Parents and coaches can be more vigilant of REDs in female athletes, helping them develop good nutrition to avoid menstrual disturbances and bone fractures. Overall, this literature review ensures that REDs is acknowledged in athletic communities to help athletes mitigate the impacts and development of LEA.

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