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THE ROLE OF ESTRADIOL IN REGULATING BODY COMPOSITION AND ENERGY EXPENDITURE IN FEMALE ATHLETES

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Abstract

Background: Hormonal regulation, particularly estrogen, is crucial for female athletes› performance. Low energy availability (LEA) is a prevalent issue, linked to health complications like menstrual irregularities and diminished metabolic efficiency.

Aim of Study: This study aims to explore the relationship between estradiol, body composition, and energy expenditure in female athletes, with a particular focus on elite female athletes in Albania. It seeks to clarify the potential connections between variations in estradiol levels and energy availability, as well as athletic performance.

Methods: A literature review explored estradiol›s physiological roles, energy availability, and athletic performance implications, focusing on female athletes and cultural contexts like Albania.

Results: The findings indicate that estradiol significantly influences body composition, promoting lean mass and fat distribution, regulating resting energy expenditure, metabolic efficiency, appetite regulation, and managing energy intake. Low estradiol levels can cause menstrual irregularities and decreased bone mineral density.

Discussion: The results underscore the essential role of estradiol in regulating body composition and energy expenditure in female athletes, but negative LEA impacts can cause health issues like menstrual irregularities and reduced bone density. Strategies like nutritional interventions are recommended.

Conclusion: Estradiol regulates body composition, energy expenditure, and athletic performance in female athletes. Understanding challenges in LEA and RED-S is crucial for developing strategies for improved health and performance.

Keywords: *Low Energy Availability (LEA), Estradiol, Hormonal Profiles, Athletic Performance, Cortisol, Female Athletes*

Introduction

The intricate relationship between hormonal regulation, energy availability, and athletic performance has garnered significant attention in sports science, particularly among female athletes. The estrogen hormone estradiol is crucial for regulating body composition, energy levels, and physical activity. Studies show its levels change throughout the menstrual cycle, impacting fat and carbohydrate use during workouts (Willett, H. N., Koltun, K. J., & Hackney, A. C., 2021). Elite athletes are especially susceptible to these physiological effects, as even small changes in energy balance significantly impact their health and performance.

Low energy availability (LEA) occurs when dietary energy intake fails to satisfy the energy requirements for both exercise and essential physiological functions, and it is a significant issue among female athletes. LEA is associated with various health complications, such as menstrual irregularities, compromised bone health, and diminished metabolic efficiency, which are collectively known as the Female Athlete Triad (Raj M. A., Creech J. A., Rogol A. D., 2023). Recently, the more comprehensive concept of Relative Energy Deficiency in Sport (RED-S) has broadened the scope to include additional physiological and psychological repercussions (Mountjoy M., Sundgot-Borgen J., Burke L., et al., 2014). In this context, the role of estradiol in energy regulation is particularly important. Studies indicate that estradiol influences energy expenditure by enhancing lipolysis and affecting fat distribution, which may aid in maintaining lean body mass during periods of energy shortfall (Gavin, K. M., Kohrt, W. M., Klemm, D. J., & Melanson, E. L., 2018). Nevertheless, fluctuations in estradiol levels, commonly seen in athletes experiencing LEA, can worsen metabolic and hormonal disruptions, negatively impacting performance and recovery (Wasserfurth, P., Palmowski, J., Hahn, A., & Krüger, K., 2020).

The cyclic hormonal connections that affect metabolism and performance, especially in high-stress training conditions, are highlighted by recent advancements in sports endocrinology. Improved training plans and injury prevention techniques can be influenced by an understanding of these cycles. New research has also shown how environmental variables, like training in hot or high-altitude environments, might exacerbate symptoms of LEA by interacting with hormonal changes. Particular attention should be paid to these connections in understudied populations, such as Albanian athletes.

It is critical to comprehend the relationship between body composition, levels of physical activity, and estradiol in Albania, where there is currently a lack of sports science study on female athletes. Special cultural, dietary, and training challenges faced by elite female athletes in this nation may make them more susceptible to LEA and its associated risks (Torstveit, M. K., & Sundgot-Borgen, J., 2005; Slater, J., Brown, R., McLay-Cooke, R., & Black, K., 2017). The purpose of this paper is to investigate these factors to elucidate any possible relationships between differences in estradiol and energy availability and athletic performance among Albanian elite female athletes.

Methodology

The methodology for this study involved a comprehensive literature review and analysis of existing research related to estradiol and its effects on body composition and energy expenditure among female athletes. Key databases were searched for studies published in peer-reviewed journals that examined the physiological roles of estradiol, energy availability, and the implications for athletic performance. The focus was primarily on studies relevant to female athletes, with particular attention given to those from Albania and similar cultural contexts. Keyword combinations including “estradiol AND energy expenditure,” “female athlete triad AND performance,” and “low energy availability AND sports health” were used in the review to find the most pertinent literature. Peer-reviewed journal articles written in English, published between 2005 and 2025, and concentrating on female athletes or hormonal

influences in sports environments were the requirements for inclusion. Excluded studies were those that only examined non-athlete populations or male athletes without a female comparison.

Results

1. **Estradiol and Lean Body Mass**: Estradiol plays a critical role in determining body composition by influencing the balance between lean body mass (LBM) and fat mass. It promotes a fat distribution pattern, which is advantageous for athletic performance due to its association with greater lower-body strength and endurance (Tsukahara, Y., Torii, S., Yamasawa, F., Iwamoto, J., Otsuka, T., Goto, H., Kusakabe, T., Matsumoto, H., & Akama, T., 2020).
2. **Impact on Resting Energy Expenditure (REE)**: Estradiol modulates REE in premenopausal women, enhancing metabolic efficiency and promoting muscle protein synthesis via estrogen receptors. A reduction in estradiol levels has been linked to decreased REE and β-adrenergic activity, which negatively impacts energy expenditure (Gavin, K. M., Kohrt, W. M., Klemm, D. J., & Melanson, E. L., 2018).
3. **Appetite Regulation:** Estradiol may help athletes manage their energy intake in relation to their expenditures by controlling hunger through its effects on the central nervous system (Tsukahara, Y., Torii, S., Yamasawa, F., Iwamoto, J., Otsuka, T., Goto, H., Kusakabe, T., Matsumoto, H., & Akama, T., 2020). However, disparities may result in LEA during intense training times, impacting menstrual health and performance (Castanier, C., Bougault, V., Teulier, C., Jaffré, C., Schiano-Lomoriello, S., Vibarel-Rebot, N., Villemain, A., Rieth, N., Le-Scanff, C., Buisson, C., & Collomp, K., 2021; Logue, D., Madigan, S. M., Delahunt, E., Heinen, M., Mc Donnell, S. J., & Corish, C. A., 2018; Manore, M. M., Kam, L. C., Loucks, A. B., & International Association of Athletics Federations. 2007).
4. **Menstrual Function and Bone Health:** Estradiol is essential for healthy bones and menstruation. Low estradiol levels might cause irregular menstruation and a decrease in bone mineral density (Ihalainen, J. K., Mikkonen, R. S., Ackerman, K. E. et al., 2024). Tracking athletes' estrogen levels is essential for spotting LEA early (Tenforde, A. S., Barrack, M. T., Nattiv, A., & Fredericson, M., 2016).

Furthermore, several studies showed that estradiol interacts with the ghrelin and leptin pathways, which may have an impact on energy intake and satiety signaling that differs according on exercise volume and menstrual cycle phase (Vigil, P., Meléndez, J., Petkovic, G., & Del Río, J. P., 2022; Smith, A., Woodside, B., & Abizaid, A., 2022). Consistent decreases in estradiol were associated with longer recovery periods and a higher incidence of soft-tissue injuries in elite endurance athletes (Chidi-Ogbolu, N., & Baar, K., 2019; Larson, A. A., Baumann, C. W., Kyba, M., & Lowe, D. A., 2020), indicating an underestimated function of this hormone in neuromuscular adaptation and resilience.

Discussion

In female athletes, the results emphasize the critical function of estradiol in controlling energy expenditure and body composition. The way that estradiol affects fat distribution and the maintenance of lean mass is crucial for peak performance, especially in demanding sports. Menstrual irregularities and decreased bone density are among the serious health problems that can result from LEA's detrimental effects on estradiol synthesis (De Souza, M. J., Nattiv, A., Joy, E., Misra, M., Williams, N. I., Mallinson, R. J., Gibbs, J. C., Olmsted, M., Goolsby, M., Matheson, G., & Expert Panel. 2014; Lieberman, J. L., DE Souza, M. J., Wagstaff, D. A., & Williams, N. I., 2018). These risks are especially concerning for female athletes in Albania, where cultural and dietary factors may make them worse.

The findings imply that preventing LEA and the health issues that are linked to it requires maintaining appropriate levels of estradiol. It is advised to promote the health and performance of female athletes by im-

plementing strategies to improve energy availability, such as nutritional interventions and hormonal profile monitoring (Ackerman K. E., Holtzman B., Cooper K. M., et al., 2019; Melin, A., Tornberg, Å. B., Skouby, S., Møller, S. S., Sundgot-Borgen, J., Faber, J., Sidelmann, J. J., Aziz, M., & Sjödin, A., 2015). Regular hormone monitoring could be used as a performance-enhancing technique and preventative health measure, particularly in teenage and young adult female sports programs (Warrier, A. A., Azua, E. N., Kasson, L. B., Allahabadi, S., Khan, Z. A., Mameri, E. S., Swindell, H. W., Tokish, J. M., & Chahla, J., 2024). A more thorough understanding of how estradiol promotes both immediate performance and long-term athletic development would be possible with longitudinal studies that concentrate on hormone-energy interactions during many competitive seasons.

Conclusion

This article emphasizes the importance of estradiol in regulating body composition, energy expenditure, and performance in female athletes, particularly focusing on Albanian elite athletes. By recognizing the specific challenges encountered by this group, including the risks of Low Energy Availability (LEA) and Relative Energy Deficiency in Sport (RED-S), effective strategies can be formulated to enhance both health and performance outcomes. Future research should continue to explore the complex interplay between hormonal regulation and athletic performance, particularly in culturally specific contexts.

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