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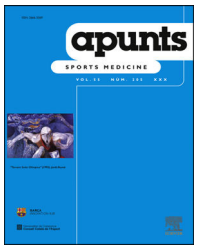

EDITORIAL

Women's football: towards gaining a deeper understanding

The practice of women's sports has been clearly increasing in recent years, with a higher number of athletes, higher standard of play, and greater professionalism. The differences in sports performance between the best men and women ranges from 8% to 12% depending on the sports discipline, and appears to be clearly linked to hormonal profiles related to gender. However, it this gap has been seen to decrease with increasing professionalism in female athletes and growing knowledge about their physiology.[1] The most important factor identified to date that could explain the differences in performance between the two genders is the concentration of circulating testosterone, which is 10 to 15 times higher in males.[2]

Most research in recent years has focused on the fragile profile of women, and their predisposition to pathologies associated with energy deficit and endocrine disorders. Although things are starting to change, to date less than 40% of papers have focused on female athletes, probably due to the complexity of understanding the effects of menstrual cycle on sports performance.[1] This trend has resulted in a very limited and uniform vision of the woman athlete and her hormonal metabolic profile, and little knowledge of any differences between sports disciplines, or of metabolic endocrine phenotypes and their etiology.

Athletes require energy to develop multiple bodily functions beyond simply performing physical exercise. Functions such as maintaining cellular structure, reproduction, immunity, and thermoregulation have daily energy needs that are reflected as energy availability, and if not met, there can be repercussions for health and physical performance[3]. Meeting these energy needs to avoid energy deficits that decrease performance and endanger health has been a subject of increasing study. ?[4]These findings challenge the contemporary concept of the female athlete triad, which postulates that reproductive dysfunction in athletic women is typically a consequence of chronic energy deficiency resulting from eating disorders.[5]

The concept of the 'female athlete triad' was first described in 1993 as the association of eating disorder (ED), amenorrhea, and osteoporosis. In 2007, the American College of Sports Medicine (ACMS) redefined the concept of the triad as a series of pathophysiological mechanisms that link energy availability, menstrual function, and bone density. This revised definition also considers the possibility of a series of subclinical alterations in different physiological systems associated with low energy availability (LEA) that is more common in female athletes, but that can also occur in male athletes.[6] LEA can have serious repercussions for the athlete.

For more than a decade, LEA has been considered as the basis and cause of the triad, and more broadly of RED-S (relative energy deficiency related to sports), as described by Mountjoy and colleagues in 2014.[7] However, there is **growing concern** regarding the methodology used to determine LEA. Diagnosis is typically based on various numerical values and cut-off points, but to date there are **no consensuated and standardized protocols**. The burden of LEA can be determined using mathematical formulae based on self-reported food intake data, but recent publications reveal that there may be a host of inaccuracies and errors in these formula-based estimations of energy availability, as described by Burke *et al*. in their article ''Pitfalls of Conducting and Interpreting Estimates of Energy Availability in Free-Living Athletes''.[8] Similarly, poor estimates can also result from estimating caloric expenditure from exercise daily or during the previous 24 hours using subjective questionnaires and conversion to metabolic equivalent (METS).[3] In general, a more precise diagnosis of LEA is needed in order to correctly decide on treatment pathways.

The problems of diagnosing LEA using imprecise formulae and estimated intake and expenditure led to the proposal of **more quantitative** assessments, such as needing to meet a threshold of 30 kcal/kg FFM (Fat Free Mass)of energy availability to avoid energy deficit.[9] In addition, based on the results of recent studies, and also from our own experience, there is a clear need for better methods to describe the physiological profile of athletes. One option is to use biomarkers[7], such as quantifiable biochemical, hormonal, or metabolic parameters, or muscle and bone mass measurements (Dxa). These precise methods provide a detailed

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description of sports performance-related phenotypes, and would allow us to rely less on formulae and thresholds as the basis for diagnosing LEA.[9]

Other researchers have revisited the concept of the Female Athlete Triad, such as De Souza *et al*. in their article, ''Rethinking the concept of an energy availability threshold and its role in the Female Athlete Triad'', in which they discuss the need to find better methods to measure adequate energy availability and its variability between individuals. [4] In fact, current publications go beyond the concept of the female athlete triad, and have discovered **that endocrine disorders and reproductive dysfunction in female athletes are not always due to chronic energy deficiency**.[10]

Menstrual disturbances specific to female athletes can be mistakenly identified as hypoestrogenism or pituitary hypogonadism. Instead, these disturbances may actually be due to an opposing condition, hyperandrogenism with or without polycystic ovary syndrome (PCOS).[11] PCOS may be accompanied by bone or muscle anabolism, and a hormonal profile associated with a series of advantages and protective effects in the context of sports.[5] Interestingly, PCOS diagnosis in some of football players is consistent with a similar increase in cases observed in other sports, which may explain a certain performance advantage associated with higher levels of androgens. PCOS can also sometimes be the cause of amenorrhea, with very different consequences from those in athletes with hypogonadism, along with a different metabolic endocrine profile. It is clear that not all female athletes experience the triad.[6]

Indeed, disorders that were once described as triad, like low bone mass or catabolic profile and then more fully defined as RED-S, are in contrast with the metabolic, hormonal, and structural profiles of some female soccer players who present with high muscle and bone mass and a clear anabolic profile.[10]. It is possible that years of consistent structured training, and the consequent adaptation to these stresses, may actually protect female atheletes from triad-associated symptoms, perhaps more than in the general population.[11]

High values of dehydroepiandrosterone (DHEA) and testosterone are compatible with **hyperandrogenism** of adrenal origin[12], which is responsible for many sports-relevant advantages such as increased strength, speed, oxygen consumption, bone and muscle mass, and stimulated erythropoiesis. These traits, which are typical among football players, have been described previously by researchers such as Hirschberg in her recent work ''Female Hyperandrogenism and Elite Sport''.[5] Football is a team sport with characteristics that are clearly favoured by anabolic hormones and an endocrine-metabolic profile that, far from being catabolic and oestrogen-deficient, is androgenic and characterised by high levels of insulin, IGF-1, and thyroid hormone. However, DHEA and testosterone are factors that confer an anabolic phenotype and clearly improve performance capacity among these players.[13]

Finally, the anabolic profile of these athletes rules out the incidence of LEA, triad, or RED-S. On the contrary, our findings encourage us to continue investigating how performance can be optimized, and in so doing, highlight and utilise the favourable characteristics of our selected and gifted players.

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