ENERGY AVAILABILITY IN FEMALE ATHLETES WITH DISABILITIES: A NARRATIVE REVIEW

DISPONIBILIDADE ENERGÉTICA EM ATLETAS MULHERES COM DEFICIÊNCIA: REVISÃO NARRATIVA

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Abstract. Research on female athletes has increased, with the main focus on Low Energy Availability (LEA) and Female Athlete Triad (TRIAD), however there is a gap in knowledge about LEA and related conditions such as eating disorder, menstrual dysfunction and bone health in athletes with disabilities. The literature suggests that those athletes, depending on the type of disability, have a higher risk of developing LEA. In this way, the objective of this review is to describe the impact of LEA on health and performance of female athletes, with special focus on athletes with disabilities. A narrative review of the literature was conducted using as search terms LEA and TRIAD components - bone health and menstrual dysfunction - in female athletes. The narrative review yielded 24 studies on the subject, of those, 10 original studies, in which LEA was diagnosed in female athletes, only one referring to athletes with disabilities. Literature indicates the complexity in estimating EA, since the methods used to determine its components may present inaccuracies, especially for athletes with disabilities. Further researched is needed to assess EA in female athletes, especially with disabilities, as well as the improvement of EA's assessment and screening methods.

Keywords: low energy availability; female athletes; athletes with disabilities.

Resumo. A pesquisa sobre mulheres atletas aumentou, com o foco principal na baixa energia disponível (LEA) e na tríade da mulher atleta (TRIAD), no entanto, há uma lacuna no conhecimento sobre LEA e condições relacionadas, como distúrbios alimentares, disfunção menstrual e saúde óssea em atletas com deficiências. A literatura sugere que esses atletas, dependendo do tipo de deficiência, tenham maior risco de desenvolver LEA. Desta forma, o objetivo desta revisão é descrever o impacto da LEA na saúde e desempenho das atletas mulheres, com foco especial em atletas com deficiência. Uma revisão narrativa da literatura foi conduzida usando como termos de busca os componentes LEA e TRIAD - saúde óssea e disfunção menstrual - em atletas mulheres. A revisão narrativa produziu 24 estudos sobre o assunto, desses, 10 estudos originais, nos quais LEA foi diagnosticada em atletas mulheres, apenas um referente a atletas com deficiência. A literatura indica a complexidade na estimativa de EA, uma vez que os métodos utilizados para determinar seus componentes podem apresentar imprecisões, especialmente para os atletas com deficiência. Pesquisas adicionais são necessárias para avaliar EA em atletas mulheres, especialmente com deficiências, bem como a melhoria dos métodos de avaliação e seleção da EA.

Palavras-chave: baixa energia disponível; atletas do sexo feminino; atletas com deficiência.

INTRODUCTION

In the last decades, the idea about women being less capable of engaging in sports at all levels has changed (Slater et al., 2016), with an increase in their participation in Olympic and Paralympic sports (Matzkin, Curry & Whitlok, 2015; Blauwet, 2015). For instance, in London 2012 Olympics, there was an increase of 44% in women's participation in comparison with the last two decades (IOC, 2017). In the Paralympic Games, only two females participated in archery in their first edition in 1948, while in London 2012, there were 1501 female athletes representing eighteen of the twenty sports of the summer games program (Blauwet, 2015). For the Paralympic Games in Rio de Janeiro 2016, the number of female athletes increased by 9.9% when compared to London, 2012 (IPC, 2016).

With the greater participation of female in sports, especially athletes with disabilities, there is a growing need for a deeper understanding and attention to minimize athletes' health problems and injury risk. In the case of athletes with disabilities, there may be specific problems related to the different types of impairments that should be taken into consideration (Blauwet, 2015; Slater et al., 2016).

In recent years, research on female athletes has emerged with a focus on low energy availability (LEA), and its relationship to the Female Athlete Triad (TRIAD), and more recently, to the Relative Energy Deficiency in Sport (RED-S): LEA has been considered as the prime factor in both syndromes (Souza et al., 2014; Mountjoy et al., 2015; Slater et al., 2016). However, it is important to recognize that studies on LEA and people with disabilities are scant (Broad & Burke, 2013).

The consequences of the energy deficiency in athletes, mainly female, has been discussed by the International Olympic Committee since 1993 (Loucks, Kiens & Wright, 2011; Slater et al., 2016). The TRIAD was initially described as a set of symptoms that consisted of eating disorder, amenorrhea, and osteoporosis (ACSM, 2007; Matzkin, Curry & Whitlok, 2015). In 2007, the American College of Sports Medicine (ACSM) reviewed the concept of TRIAD and described it as the interrelationship of three components: LEA with or without eating disorder, low bone density and dysfunction of the menstrual cycle (Souza et al., 2014; Mountjoy et al., 2015). In 2014 a new position on the subject was published, with a proposal of risk assessment to assist professionals in the identification and follow-up of TRIAD (Mountjoy et al., 2014; Souza et al., 2014).

Due to its importance, the objective of this review is to describe studies on LEA in female athletes, especially female athletes with disabilities, and their impact on health and performance, allowing a greater understanding of the subject to the professionals that work with this population, as well as to encourage further research.

METHOD

A literature review was conducted from February to March 2017, using PubMed and Virtual Health Library databases, to identify articles focused on LEA in female athletes with and without disabilities, conducted in the last 10 years. The TRIAD components - bone health and menstrual dysfunction - were also researched in association with LEA in female athletes, with a primary focus on female athletes with disabilities. We included in the scope of the research original articles, reviews, book chapters and thesis (master/doctoral) using the following terms: "low energy availability", "bone mineral density" "menstrual dysfunction", "eating disorder", "female" and "athletes" or "para athletes" (focusing on four major groups of "visual impairment", "cerebral palsy", "spinal cord injury" and "limb deficient or amputee"). The initial search resulted in a total of 99 search results. Three book chapters identified in the references of the articles and a master's thesis were also included, totaling 103 results. The references were than selected according to the following inclusion criteria: studies published in English, Spanish and Portuguese, and conducted with female athletes. Results with animal studies, clinical studies, studies with intervention (i.e. dietary supplements), non-athlete population, and male subjects were excluded, totaling 79 results. After deleting the duplicated articles, the final selection resulted in 24 search results (20 articles, three book chapters and a master's thesis) as demonstrated in Figure 1.

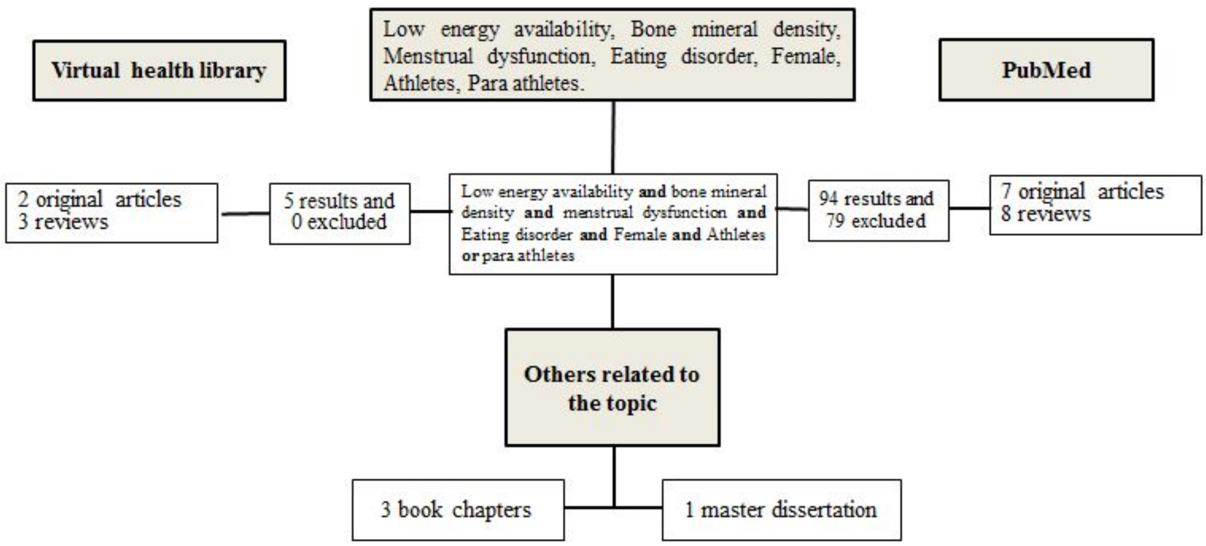

Figure 1. Review organization.

RESULTS

Energy Availability

Energy Availability (EA) is defined as the energy intake (EI in kcal) minus the energy expenditure with exercise (EEex in kcal), divided by Fat Free Mass (FFM in kg), with values equal and above 45kcal/kgFFM/day considered as adequate (Broad & Burke, 2013; Souza et al., 2014), while values below 30kcal/kgFFM/day are considered as LEA (Broad & Burke, 2013).

LEA is described as an energy deficit, in which the body does not have enough energy to meet the physiological process' energy demands after the energy necessary to exercise is discounted from the equation (Melin et al., 2014; Mountjoy et al., 2015). This concept distinguishes itself from the energy balance (EB) concept, since athletes can be in negative energy balance due to suppression of physiological functions, in an attempt to restore the energy balance (EB = 0 kcal) and/or the stability of the body mass (Souza et al., 2014; Slater et al., 2016).

LEA can be a consequence of an inadequate manipulation of the EI, whether intentional or not, and can happen when there is an eating disorder, when the athlete is trying to reduce body mass and fat percentage, or when the athlete is incapable of adjusting EI to an increase in EEex (Broad & Burke, 2013; Souza et al., 2104). LEA may trigger changes in basal metabolic rate, menstrual function, bone health, protein synthesis, immunity and cardiovascular health, with a consequent decrease in performance (Broad & Burke, 2013; Souza et al., 2014; Mountjoy et al., 2015).

Low Energy Availability

LEA is particularly common in sports that require body mass control (e.g. combat sports, running), in sports in which the aesthetic component is an important factor (e.g. rhythmic gymnastics, ballet, skating and synchronized swimming), and gravitational sports, in which a high body mass restricts movement against gravity (e.g. artistic gymnastics, cross-country skiing, mountain-biking and jumping in athletics) (Mountjoy et al., 2014; Matzkin, Curry & Whitlok, 2015; Muia et al., 2016).

There are few studies in which all LEA components (EI, EEex and FFM) were evaluated. Table 1 summarizes the findings of studies conducted in female athletes.

Reed, Souza & Williams (2013) investigating the prevalence of EA during one season of a female soccer team of the first division, observed a prevalence of LEA of 26%, 33% and 12% of the athletes, respectively in pre, during and post-competition periods. The authors reported that LEA in pre-competitive and competitive periods occurred due to the decrease in food intake, while the increase of the EA in the post-competitive period was due to the reduction in the EEex.

Melin et al. (2015) evaluated the effects of LEA and menstrual dysfunction in female endurance athletes on energy metabolism. Athletes who presented low/reduced EA demonstrated a lower resting metabolic rate, besides the reduction of pulses of luteinizing hormone (LH) values in comparison to the athletes with adequate EA. Muia et al. (2016) evaluated Kenyan adolescent runners and observed that 17.9% of athletes presented LEA associated with eating disorder, 8.9% had LEA associated with menstrual dysfunction, and 3.3% of athletes presented clinical signs of eating disorder and menstrual dysfunction.

Koehler et al. (2013), evaluated EA in 185 female young athletes and its relationship with leptin, insulin, insulin-like growth factor 1 (IGF-1), and triiodothyronine (T3). The authors observed a high concentration of leptin in athletes with LEA. In contrast, insulin, IGF-1 and T3 did not differ between athletes with LEA and adequate EA.

Joaquim (2016) assessed eight track & field female Paralympic athletes with visual impairment, all runners, during four days and found two athletes with LEA, two with adequate energy intake and four, in a vulnerable range (between 30 and 45 kcal/kg FFM). In this unprecedented study with Paralympic athletes, food intake was assessed using 24-hour photographic register (conducted by the researcher), exercise energy expenditure was measured using actigraphy, and FFM was estimated using skinfolds and Jackson & Pollock equations.

It is important to emphasize the complexity of estimating EA, since the methods used to determine its components may present inaccuracies (Souza et al., 2014). The FFM (kg) estimate is the most challenging in athletes with disabilities because of the types of impairment and their specificities, and the absence of a gold standard for measurements (Blauwet et al., 2017). Therefore, to date there is little information about LEA and its consequences on athletes with disabilities.

Table 1. Review about Energy Availability.

Authors	Age	Public	Body composition	EEex (kcal/hour)	EI (kcal/day)	EA (kcal/kgFFM/day)
Hoch et al	2009	80 female athletes of varied sports	DXA	PA record converted in MET	3-days food diary	36% of the athletes presented reduced EA*, 6% of which presented LEA$^{\alpha}$
Koehler et al	2013	185 female athletes of different modalities	BIA	PA record converted in MET	6-days food registry	EA Mean value: 20.5 kcal/kgFFM/d
Reed, Souza & Williams	2013	19 soccer players	DXA	Heart rate monitor and PA record	3-days diet logs	EA mean value 35.2 kcal/kgFFM/d - middle of the season and 44.2 kcal/kgFFM/d - end of the season
Coelho et al	2014	24 tennis players	DXA	PA record converted in MET	3-day food record	87.5% of the athletes presented reduced EA*, 33.3% of which presented LEA$^{\alpha}$
Melin et al	2014	84 female endurance athletes	DXA	Heart rate monitor	7-days food record	63% of the athletes presented reduced EA*.
Melin et al	2015	40 female athletes endurance sports	DXA	Heart rate monitor and PA record	7-days food record	17 athletes presented reduced EA (mean values: 38.5kcal/kgFFM/d) and 8 presented LEA (mean values 19.1kcal/kgFFM/d)
Viner et al	2015	4 female cyclists	DXA	Heart rate monitor and PA record	3-days dietary records	EA mean values: pre-season 26.2kcal/kgFFM/d, competition 24.5kcal/kgFFM/d off-season 23.8kcal/kgFFM/d
Muia et al	2016	61 female athletes and 49 female non-athletes	Skinfold	PA diary	5-days weighed dietary record	EA mean values: 36.5kcal/kgFFM/d for athletes and 39.5kcal/kgFFM/d for non-athletes
Silva & Paiva	2016	67 rhythmic gymnasts	BIA	PA record	24-hour food recall	29.7kcal/kgFFM/d for gymnasts 16-18 year sold and 32.2kcal/kgFFM/d for gymnasts 19- 26 years old
Joaquim	2016	8 female Paralympic sprinters	Skinfold	PA monitor	4-days photographic register	EA median values: 32.5 kcal/kgFFM/d

DXA: dual-energy X-ray absorptiometry; BIA: Bioelectrical Impedance Analysis; PA: Physical activity

*<45kcal/kg/FFM/day; α <30 kcal/kg/FFM

Blauwet et al. (2007) alert to the fact that some athletes with disabilities may present a higher risk of developing LEA due to type of impairment (Broad & Burke, 2013; Mountjoy et al., 2014). In a pioneering review on LEA and its consequences on athletes with disabilities, these authors indicated that athletes with cerebral palsy have increased energy expenditure due to the presence of athetosis, spasticity, or ataxia, while motor alterations in the oral functionality, can reduce food intake and consequently energy, increasing risk of LEA. Athletes who are limb deficient, especially those bipedal, have a higher energy expenditure due to the inefficacy of walking, which increases EEex and may increase the risk of LEA if intake is not properly adjusted.

LEA and Menstrual Dysfunction

Menstrual function is an important health aspect of female athletes (Blauwet et al., 2017). The desired status – eumenorrhea - is defined as the regular menstrual cycle, which occurs between 21 and 35 days (Mountjoy et al., 2014; Matzkin, Curry & Whitlok, 2015). The absence of menstruation is known as amenorrhea. Primary amenorrhea occurs when menarche is not present up to 15 years of age and secondary amenorrhea is the absence of three menstrual cycles after menarche, while oligomenorrhea is considered when less than nine menstrual cycles occur in one year (Márquez & Molinero, 2013; Matzkin, Curry & Whitlok, 2015).

LEA, associated with low body fat stores and intense exercise, can lead to menstrual disorder. This is due to the reduction in the levels of hormones such as gonadotrophin releasing hormone (GnRH) and LH, which suppresses the hypothalamic-pituitary-ovary axis causing reduction in estradiol levels and menstrual dysfunction (Nazem & Ackerman, 2012; Márquez & Molinero, 2013; Mountjoy et al., 2014; Matzkin, Curry & Whitlok, 2015). A fast reduction of body fat can also compromise menstrual function, as the consequent alteration in leptin has a positive effect on GnRH production, regulating the release of gonadotrophins, and contributing to amenorrhea (Nazem & Ackerman, 2012; Mountjoy et al, 2014).

The prevalence of menstrual dysfunction in athletes varies among different sports groups, however it is higher than in non-athletes (Dadgostar et al., 2009; Mountjoy et al., 2014). Dadgostar et al. (2009) evaluated the prevalence of amenorrhea and oligomenorrhea in Iranian athletes of different sports and observed that a higher prevalence of menstrual dysfunction in athletes who seek a lean body and a low body fat percentage. The authors highlighted the need to develop a constant work of nutritional education with athletes.

Data on menstrual function of para athletes is lacking (Blauwet et al., 2017). Blauwet et al (2017) reported that non-athletes with spinal cord injury did not show significant impact of the injury on menstrual function, which resumed months after the injury. The authors also reported that no study examined the decrease in fertility as a result of LEA.

LEA and bone mineral density (BMD)

Bone is a living tissue composed of connective tissue, protein and deposits of calcium and phosphorus, having as main characteristic the strength and resistance (Constantini & Lebrun, 2015). Healthy bones are key to injury prevention and performance optimization (Blauwet, 2015). The literature reviewed shows that low bone mineral density varies according to the method used to assess it (Matzkin, Curry & Whitlok, 2015; Slater et al., 2016). The gold-standard method for assessing bone mineral density is the dual-energy X-ray absorptiometry (DXA) of the lumbar spine and femur (Mountjoy et al., 2014; ISCD, 2015). The International Society for Clinical Densitometry (ISCD) (2015) indicates a Z-score below -2.5 or less in the femoral neck as abnormal for osteoporosis, while low bone mineral density (osteopenia) can be defined as a Z-score between -1.0 and -2.0 associated with low levels of estrogen, stress fractures and nutritional deficiencies, mainly consumption of inadequate energy, calcium and vitamin D (Márquez & Molinero, 2013).

Healthy athletes may have 5 to 15% higher bone density mass than non-athletes, because exercise plays an important role in the accretion and increase of bone density. However, it is known that athletes with amenorrhea have lower bone density (Márquez & Molinero, 2013; Mountjoy et al., 2014). For non-ambulatory athletes, BMD decrease may be due to low body mass, aggravated by age, and in association with TRIAD (Blauwet, 2015).

In a review by Blauwet et al. (2017), the authors found only one study that evaluated BMD of track & field athletes with hemiplegic cerebral palsy, finding no difference between BMD on the affected side and the unaffected side. Although few information is available on visually impaired athletes' bone health, there is a relationship between lack of vision and a higher incidence of fractures by falls. The authors also reported that no studies on bone mineral density and amputees and short stature were found.

Female athletes with spinal cord injury may present reduced BMD, especially below the injury level (Blauwet, 2015). This lower bone mineral density has been associated with the reduction of estrogen in comparison to athletes without disability and there is a relationship between time after injury and a significant loss of bone mineral density (Blauwet et al., 2017).

DISCUSSION

The results demonstrate the dearth of information regarding LEA, as well as its association with bone mineral density and menstrual dysfunction in athletes with disabilities. However, LEA is a condition that athletes with disabilities and the professional team working with them should be fully aware of, both because it may be present due to factors common to all athletes, but also due to specificities related to some disabilities.

One of the main reasons for the lack of studies is the complexity of EA assessment. The methods used for assessment are highly complex or may present a bias in the in athletic population with disabilities (Souza et al., 2014), and are difficult to apply in the everyday practice. Determining the components of EA in athletes with disabilities has its own challenge, due to the lack of data available on the different impairments and exercise modalities.

EI can be assessed by different methods, such as food registers or the 24-hour food recall, however, for any population, both methods can often generate underestimated intake values due to intentionally or unintentionally underreporting.

The use of available MET values and equations to determine EEex can be inaccurate due to the difference in the amount of functional muscle mass in athletes with disabilities and/or other factors related to the disability, which can influence energy expenditure, such as: level of injury in spinal cord injury athletes, asymmetry of movements due to gait imbalance due to amputation or type of cerebral palsy (Broad & Burke, 2013). It has been suggested that the use of technological tools, such as the physical activity monitors (pedometers and the accelerometers), may assist in EEex assessment, although they are not yet able to accurately assess (Broad & Burke, 2013) EEex in athletes with disabilities as those devices have internal programming softwares based on populations without disability, which may not be appropriated.

Furthermore, the FFM (kg) estimate is most challenging in athletes with disabilities because of the types of deficiency. The assumption of most methods may not be appropriate to those athletes and there is no gold standard for measurement in this population (Blauwet et al., 2017).

In search of a tool to evaluate LEA, as well as to identify the TRIAD, Melin et al. (2014), sought to validate the reliability of the "Low Energy Availability in Female Questionnaire (LEAF-Q)" in female athletes. The authors concluded the LEAF-Q is an instrument with acceptable sensibility (78%) and specificity (90%) to assessing/screening the EA in female athletes who may be at risk of TRIAD. Folscher et al (2015) sought to assess the risk of developing TRIAD in South African marathoners using LEAF-Q. The authors observed that 44.1% of the athletes presented a risk of developing TRIAD and that one-third of the athletes were in LEA due to eating disorder. No data were found for LEAF-Q in para athletes. Further studies validating this instrument in the population of athletes with disabilities should be stimulated.

CONCLUSION

Although in female athletes without disabilities LEA, menstrual dysfunction and low bone mineral density have been fairly studied, this review has demonstrated the gap in information regarding female athletes with disabilities. Further research is necessary to elucidate these conditions in this population, as well as to assess their knowledge on EA.

It is essential to improve the methods used to evaluate EA components in athletes with disabilities. In addition, it is important for the interdisciplinary team to be aware of the consequences of LEA related to health and performance and to promote awareness among athletes on the importance of a healthy diet.

Although this review focused the female athletes, research on male athletes, both with and without should also be stimulated as they can also be at risk of developing RED-S.

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