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LOW ENERGY AVAILABILITY AS THE MAIN COMPONENT TO IDENTIFY THE FEMALE ATHLETE TRIAD OR RELATIVE ENERGY DEFICIENCY IN SPORT PREVALENCE IN BRAZILIAN ATHLETES: A SYSTEMATIC REVIEW

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ABSTRACT

Introduction and Aim: The Female Athlete Triad (FAT) and the Relative Energy Deficiency in Sports (RED-S) are known as syndromes that affect athletes' health and performance. Since 2007, the Low Energy Availability (LEA) is considered as the etiological factor of both conditions. This review aimed to identify the prevalence of FAT and RED-S, in Brazilian athletes, considering the LEA as the main component. Materials and Methods: This is a systematic review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyzes (PRISMA) guideline on reporting reviews. The following databases: Scopus, EMBASE, Web of Science, PubMed, BVS, Google Scholar and CAPES Theses and Dissertations Catalog were searched from June to August 2020. The Joanna Briggs Institute (JBI) Critical Appraisal instruments were used to evaluate the quality of studies. Results: The initial search yielded 454 studies. After applying the inclusion criteria, three studies were eligible for this review. All selected studies determined FAT prevalence, considering LEA as the main component, in Brazilian athletes, while none investigated the prevalence of RED-S. The FAT prevalence found in Brazilian athletes ranges from 4% to 4.2%, by the presence of LEA. Conclusion: Although cases of disordered eating in athletes often evolve into an energy deficiency and, consequently, FAT and RED-S, other unintentional eating behaviors can lead to a LEA. Considering disordered eating as the only risk factor to detect energy deficiency can underestimate the prevalence of FAT, since many athletes in LEA do not present eating disorder.

Key words: Female Athlete Triad. Relative Energy Deficiency in Sports. Athlete. Exercise. Nutrition.

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RESUMO

Baixa disponibilidade energética como principal componente para identificar a tríade da atleta feminina ou relativa deficiência energética na prevalência do esporte em atletas brasileiras: uma revisão sistemática

Introdução e Objetivo: A Tríade da Mulher Atleta (TMA) e a Deficiência Energética Relativa no Esporte (RED-S) são síndromes conhecidas por acometer a saúde e performance de atletas. Desde 2007, a baixa energia disponível (BED) é considerada como o fator etiológico de ambas as condições. Essa revisão tem como objetivo identificar a prevalência de TMA e RED-S, em atletas do Brasil, considerando a BED como componente principal. Materiais e Métodos: Essa é uma revisão sistemática baseada na diretriz PRISMA (Principais Itens para Relatar Revisões sistemáticas e Meta-análises). As seguintes bases de dados: Scopus, EMBASE, Web of Science, PubMed, BVS, Google Acadêmico e Catálogo de Teses e Dissertações da CAPES foram pesquisadas de Junho a Agosto de 2020. Os instrumentos de Avaliação Crítica do Instituto Joanna Briggs (JBI) foram utilizados para avaliar a qualidade dos estudos. Resultados: A busca inicial resultou em 454 estudos. Após aplicar os critérios de inclusão, três estudos foram elegíveis para essa revisão. A prevalência de TMA encontrada em atletas brasileiras varia entre 4% e 4.2%, a partir da presença de BED. Conclusão: Embora os casos de transtorno alimentar em atletas evoluam frequentemente para uma deficiência energética e, consequentemente, para TMA e RED-S, outros comportamentos alimentares não intencionais podem levar à BED. Considerar desordem alimentar como o único fator de risco para detectar deficiência energética pode subestimar a prevalência de TMA, uma vez que muitas atletas em BED não apresentam transtorno alimentar.

Palavras-chave: Tríade da Mulher Atleta. Deficiência Energética Relativa no Esporte. Atleta. Exercício. Nutrição.

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INTRODUCTION

The Female Athlete Triad (FAT) is a medical condition described since 1992 as an association of disordered eating (DE), amenorrhea and osteoporosis presented by physically active girls and women (Slater, 2015).

But the definition of FAT was revised in 2007, when the low energy availability (LEA) was first implicated as its main component, replacing DE (Nattiv et al., 2007).

Since then, the FAT has been described as the interrelation of LEA, with or without DE, menstrual dysfunction, and low bone mineral density (BMD) (Nattiv et al., 2007).

This current definition places LEA as the FAT etiological factor, given that its presence can cause menstrual irregularities (MI) and bone health impairments (Nattiv et al., 2007).

In 2014, the new concept of RED-S was proposed also considering LEA as its main component (Mountjoy et al., 2014).

From this concept, LEA has been put as the main reason for triggering not only menstrual dysfunction and bone health impairments, but also other dysfunctions, with impact on metabolic rate, immunity, protein synthesis, cardiovascular health and many other aspects of physiological function, health and athletic performance (Mountjoy et al., 2014).

In addition to a wider range of symptoms associated with LEA, RED-S can impact both females and males (Mountjoy et al., 2014).

EA is defined as the remaining available energy to support athlete's body function, after the exercise energy expenditure (EEE) is deducted from energy intake (EI) (Loucks, 2004). EA can be estimated through algebraic calculation: dietary EI minus EEE, corrected for fat-free mass (FFM) (Loucks, Kiens, Wright, 2011).

LEA is considered a state in which the body does not have sufficient energy to maintain all physiological functions required to support optimal health (Wasserfurth et al., 2020).

In females, an EA of 45kcal/kg FFM/day has been considered optimal and healthy for physiological functions, while EA below 30kcal/kg FFM/day has been defined as a threshold for LEA, as this level of EA can cause substantial perturbation in body systems (Mountjoy et al., 2018).

In males, EA cut-off points remain unclear (Mountjoy et al., 2018), although Koehler et al., (2013) suggested the cut-off point of 40 kcal/kg/FFM.

LEA may occur due to DE, clinical eating disorder (ED), or to unintentional or deliberate unbalance between food intake and exercise expenditure, without DE, resulting from failure to adjust energy intake to training load due.

This unbalance may happen due to lack of nutrition knowledge, to exercise-induced appetite suppression, by the adoption an inadequate program of weight control, or even unawareness of the need to match EEE (Souza et al., 2014; Burke et al., 2018; Juzwiak, Joaquim, 2019).

Given the severity of FAT and RED-S consequences on health and performance, it is important to monitor the status of these conditions in athletic population around the world, following their current definition which puts LEA as its main component.

The objective of this review was to investigate the prevalence of FAT and RED-S in Brazilian athletes in studies published from 2007, in which LEA came to be considered the main component of both syndromes.

MATERIALS AND METHODS

This review was conducted according to the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines (Moher et al., 2009).

The study protocol was registered on PROSPERO International Prospective Register of Systematic Reviews on 19th May 2020 (registration number CRD42020187192).

In order to determine the review question and search terms, the Patient, Intervention, Comparison, Outcome (PICO) model was followed as a search strategy.

Review question

The purpose of the present review was to answer the question: "What is the prevalence of Female Athlete Triad or Relative Energy Deficiency in Sport, in Brazilian athletes, considering the low energy availability as their main component?"

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Literature search

A systematic electronic search was performed from June to August 2020 on the following databases: Scopus, EMBASE, Web of Science, PubMed, BVS, Google Scholar and CAPES Theses and Dissertations Catalog. MeSH (Medical Subject Headings) terms, keywords and Boolean operators applied to combine the keywords used in each database are presented in Table 1.

Table 1 - Search strategy.

Database	MeSH terms and boleean operators used
Scopus	("female athlete triad" OR "female athlete triad syndrome" OR "relative energy deficiency in sport") AND (brazil* OR brasil*) AND female
EMBASE	("female athlete triad" OR "female athlete triad syndrome" OR "relative energy deficiency in sport") AND (brazil* OR brasil*) AND female
Web of Science	("female athlete triad" OR "female athlete triad syndrome" OR "relative energy deficiency in sport") AND (brazil* OR brasil*) AND female
PubMed	("female athlete triad" OR "female athlete triad syndrome" OR "relative energy deficiency in sport") AND (brazil* OR brasil*) AND female
BVS	("female athlete triad" OR "female athlete triad syndrome" OR "relative energy deficiency in sport") AND (brazil* OR brasil*) AND female
Google Scholar	("female athlete triad" OR "female athlete triad syndrome" OR "relative energy deficiency in sport") AND (brazil* OR brasil*) AND female
CAPES Theses and Dissertations Catalog	"female athlete triad" OR "relative energy deficiency in sport" (in Portuguese)

Study selection

To be included, studies met the following criteria: 1) FAT or RED-S prevalence or frequency studies; 2) studies conducted with Brazilian female athletes; 3) studies published in Portuguese, English or Spanish, and; 4) publications from 2007 to August 2020. In addition to prevalence studies, systematic reviews and meta-analyzes were scrutinized to identify prevalence studies not revealed in the searches.

As exclusion criteria studies in which FAT or RED-S risk prevalence were measured using questionnaires, case studies, opinion studies, book chapters and conference abstracts were not considered.

The first step was the removal of duplicates of the initial articles retrieved. After that, titles and abstracts of the remaining articles were screened (by UPM) for eligibility. The full texts of potentially eligible articles were examined independently by both authors (UPM and CRJ), and any disagreement regarding eligibility of the studies inclusion were resolved via consensus-based discussion between the researchers.

Data extraction

Data extracted (UPM) from the studies selected for inclusion were: first author, year of publication, sports discipline, range age/mean age (SD), country, sample size, methods used to identify FAT or RED-S and prevalence of FAT or RED-S. The authors of included studies were not contacted for further information.

Quality assessment

The methodological quality of studies was evaluated using the validated tool developed by the Joanna Briggs Institute to assess quality within prevalence studies (Munn et al., 2014). Both authors (UPM and CRJ) used the standardized form to conduct the quality assessment independently, and discrepancies were resolved by consensus.

The studies that obtained five or more “yes” ratings out of nine were included in the

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review and studies with a minimum of five “yes” scores were excluded (Munn et al., 2014).

Synthesis of study findings

A formal narrative synthesis was used to describe the studies. The variability of the available data, including the screening measures used were explored.

The studies were discussed, mainly, according to the syndrome trigger component reported and its relationship with the current description of the condition.

RESULTS

Figure 1 presents the PRISMA flow diagram with the selection procedures and the reason for exclusion. A total of 454 records were initially identified. After removing duplicates and screening titles and abstracts, 45 studies remained to be fully read.

Forty-two studies were removed because they did not meet the inclusion criteria, of which three FAT prevalence studies were not eligible because LEA was not described as the main component of the syndrome.

One excluded study determined risk for the FAT prevalence by the Low Energy Availability in Females Questionnaire (LEAF-Q), which is a screening tool. The search strategy and study selection process resulted in three studies for inclusion in the present review.

During the search phase, no study investigating RED-S in Brazilian athletes was found. All studies that met the inclusion criteria obtained more than five “yes” ratings out of nine in JBI criteria.

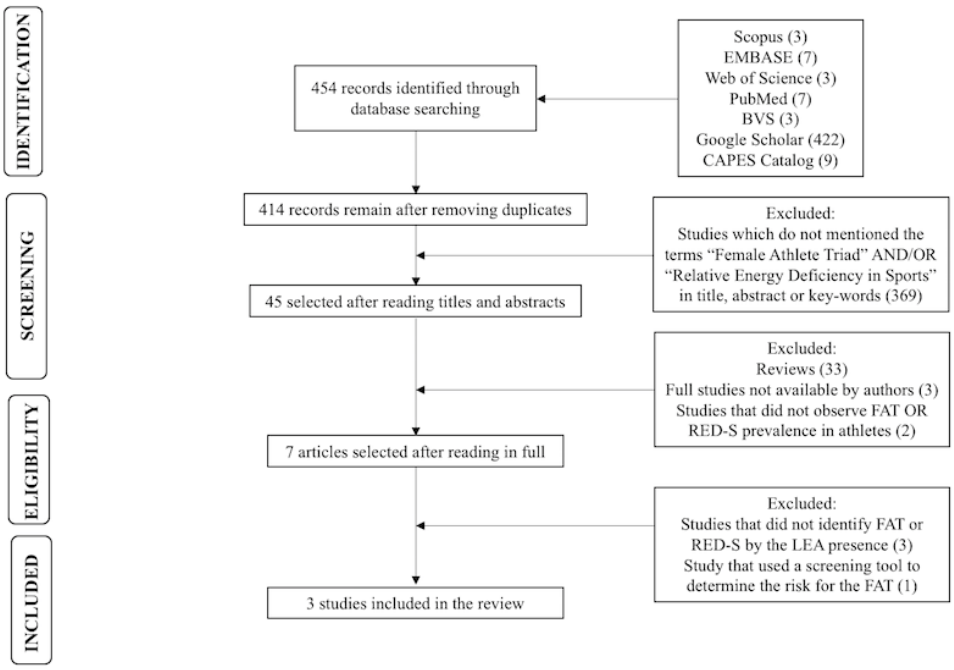

Figure 1 - PRISMA flow diagram.

Characteristics of studies included

All the three studies (Coelho et al., 2013; Coelho, 2015; Miranda, 2018) are cross-sectional studies and were conducted in Rio de Janeiro - Brazil.

The studies examined female athlete teenagers to determine the presence of FAT. The characteristics of each study are described in Table 2.

The three studies that met the inclusion criteria and showed a high level of quality were conducted between 2013 and 2018.

Two included studies (Coelho et al., 2013; Coelho, 2015) used the same inclusion criteria: female athletes competing in tennis events, who had to be associated with the Federation, to have trained in the sport for at least 6 months and to train for a minimum of 9 hours/week.

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As exclusion criteria of these two studies, adolescents could not be pregnant or breastfeeding, smokers, with history of polycystic ovary syndrome or hyperprolactinemia and/or users of oral contraceptive, illicit drugs, corticoids and/or thyroid hormones.

One of these studies also excluded subjects with diabetes mellitus.

In the third study (Miranda, 2018), participants should be female adolescents in the 9th year of elementary school and enrolled in a sport vocational school.

Subjects excluded were those who did not participate in any sports discipline, were unable to train, used contraceptive pills, were in the first year of menarche or/and were pregnant.

Components to determine the Female Athlete Triad

The studies included in the present review considered the presence of FAT by the occurrence of concomitant LEA and/or (ED), MI and low BMD (Coelho et al., 2013; Coelho, 2015; Miranda, 2018).

Two studies (Coelho et al., 2013; Miranda, 2018) classified participants as having moderately severe FAT if they presented LEA, MI (primary amenorrhea, secondary amenorrhea or oligomenorrhea) and low BMD (Z-score < -1.0 standard deviation - SD).

Table 2 - Summarized overview of the included studies.

Author, year	Country	Sports discipline	Age	Sample Size	Methods						LEA Prevalence	FAT Prevalence
					EI	EEE	FFM	ED/DE	MI	BMD		
Coelho e colaboradores, 2013	Brazil	Tennis	14.7 (2.1)	24*	mean energy intake from 3-day food record of non-consecutive days	estimated by activity logs, reported by athletes, and calculated using METs	DXA	EAT-26, BITE and/or BSQ	Self-report of primary amenorrhea, secondary amenorrhea or oligomenorrhea	DXA	87,5%	4.2%
Coelho, 2015	Brazil	Tennis	15 (2.3)	25*	mean energy intake from 3-day food record of non-consecutive days	estimated by activity logs, reported by athletes, and calculated using METs	DXA	EAT-26, BITE and/or BSQ	Self-report of primary amenorrhea, secondary amenorrhea or oligomenorrhea	DXA	88%	4%
Miranda, 2018	Brazil	Badminton, soccer, handball, table tennis, volleyball, chess, swimming, athletics and judo	**	45	one day 24-hour recall	calculated using METs considering diary 100 minute-training for swimmers and 90 minute-training for other athletes	DXA	EAT-26, BITE and/or BSQ	Self-report of primary amenorrhea, secondary amenorrhea or oligomenorrhea	DXA	62%	4%

Notes: *sample number composed only by athletes. It does not refer to the total sample number of the study (athletes+controls). **the age mean (SD) of the total sample number was not reported. BITE = Bulimic Investigatory Test Edinburgh; BMD = bone mass density; BSQ = Body Shape Questionnaire; DE = disordered eating; DXA = dual-energy X-ray absorptiometry; EAT-26 = Eating Attitudes Test-26; ED = eating disorder; EEE = exercise energy expenditure; EI = energy intake; FAT = Female Athlete Triad; FFM = fat-free mass; MET = Metabolic Equivalent of Task; MI = menstrual irregularities

However, the most severe manifestation of the syndrome was defined as the presence of ED, amenorrhea and low BMD (Z-score < -2.0 SD).

The third study (Coelho, 2015) identified FAT by the occurrence of concomitant LEA and/or ED, MI and low BMD (Z-score < -1.0 SD).

LEA was identified by the assessment of energy intake, exercise energy expenditure (EEE) and FFM. In two studies (Coelho et al., 2013; Coelho, 2015), participants completed 3-day food records in alternating days. In the third study (Miranda, 2018), food intake was estimated using 24-hour recall.

All studies calculated the EEE using the compendium of energy expenditure for youth which contains a list of activities and their associated Metabolic Equivalent Task (MET) intensity levels (Ridley, Ainsworth, Olds, 2008).

The EEE calculation considered exercise duration, training intensity, body weight and age. Studies whose participants were only tennis players (Coelho et al., 2013; Coelho, 2015) used the exercise duration reported by athletes to estimate the energy expenditure during training.

The study which recruited several sports disciplines athletes (Miranda, 2018) considered 100 minutes of training per day for individuals who practice swimming and 90 minutes for other sports disciplines participants.

All the studies (Coelho et al., 2013; Coelho, 2015; Miranda, 2018) used dual-energy X-ray absorptiometry (DXA) to estimate FFM as well as defined LEA as an energy availability below 45 kcal/kg FFM/day.

In the revised studies (Coelho et al., 2013; Coelho, 2015; Miranda, 2018), menstrual status was evaluated based on athletes'

information about age at menarche, oral contraceptive use and changes in menstrual cycle using a questionnaire (Oliveira et al., 2003).

Studies also used the same definition of oligomenorrhea, primary and secondary amenorrhea (Practice Committee, 2008).

Primary amenorrhea was considered as the lack of menstrual periods in adolescents aged up to 15 years. Secondary amenorrhea was determined when menstruation was interrupted for three or more consecutive cycles after having normal menarche or when athlete presented less than nine menstrual cycles in one year.

Oligomenorrhea was characterized by intervals greater than 35 days between cycles. Regular menstrual cycles were defined as menstrual periods occurring every 28-30 days.

Three studies (Coelho et al., 2013; Coelho, 2015; Miranda, 2018) used DXA to assess bone mass.

FAT Prevalence

Overall FAT prevalence in the included studies ranged from 4% to 4.2%. Coelho et al., (2013) observed only one tennis player presenting concomitant EA<45kcal/kg FFM/day, MI and low BMD.

However, among the 24 athletes studied, 23 presented one of the three FAT components. In Coelho et al., (2013) study, the mean energy availability calculated for the athletes was 31.17kcal/kg FFM/day.

Coelho (2015) identified the presence of FAT in only one female tennis athlete, but there is not a register if this adolescent presented LEA and/or ED as this condition trigger. The mean energy availability calculated for the tennis players was of 31kcal/kg FFM/day.

In a study with several sports discipline athletes, Miranda (2018) identified two athletes presenting all the components of FAT (EA<45kcal/kg FFM/day, MI and low BMD). In this study, Miranda (2018) divided athletes into two groups according to the 1) risk for ED sports discipline and 2) competition level.

Both teenagers with FAT were athletes of no risk for ED sports disciplines (badminton, soccer, handball, volleyball, chess and table tennis) and lower competition level (school and regional competition).

DISCUSSION

This is the first systematic review that has searched and synthesized studies reporting the prevalence of Female Athlete Triad and Relative Energy Deficiency in Sports, considering low energy availability as their main component, in Brazilian athletes.

This systematic review found three studies that observed FAT prevalence ranging from 4% to 4.2%, by the presence of LEA. The studies included in this review evaluated the same age group females and assessed FAT components by similar methods.

Also considering LEA as the main FAT component, Hoch et al., (2009) found a prevalence of 1.2% among varsity female athletes from a private high school in the Midwest of the USA. However, Melin et al., (2015) identified 23% of endurance Danish and Swedish athletes with FAT, assessed through 7-consecutive-day food records and training logs (associated with heart rate data), DXA for estimation of FFM, and transvaginal ultrasound examination associated with self-report menstrual information for menstrual dysfunction.

Athletes evaluated in studies included in this review (Coelho et al., 2013; Coelho, 2015; Miranda, 2018) and by Hoch et al., (2009) were adolescents, while the Scandinavian sample (Melin et al., 2015) was composed of females from 18-38 years old.

The adolescence is a transition period when food choices become a more autonomous and independent practice (Bittar, Soares, 2020).

However, depending on the autonomy degree, adolescents' food choices may be related to obesity, with the consume of high energy and poor nutrient-dense foods, and disordered eating, with the adoption of inappropriate eating behaviors such as skipping meals and tendency to food restrictions (Ziegler et al., 2021).

Moreover, adolescents face a period of life full of changes, frailties and emotional instability, while they go through the construction of their body identity and body image in an era in which the media is so influential and propagates a certain model of ideal body that produces a feeling of body dissatisfaction (Bittar, Soares, 2020).

Athletes still must cope with the ideal sports body demand which could be difficult to attain and therefore may encourage inappropriate eating practices and abnormal

exercise patterns (Greydanus, Omar, Pratt, 2010).

This environment in which adolescent athletes are inserted can result in energy deficiency and other FAT components (Nattiv et al., 2007).

Although the FAT has been described, since 2007, as a syndrome composed by LEA (with or without the DE presence), amenorrhea and osteoporosis (Nattiv et al., 2007), most studies reported the FAT triggered only by the presence of DE, excluding the fact that energy deficiency can also happen due to an unintentional inadequate energy intake (Burke et al., 2018).

During the eligibility phase of this systematic review, three studies (Parmigiano et al., 2014; Perini et al., 2009; Schtscherbyna et al., 2009) were excluded because DE, instead of LEA, was considered the main component of the FAT.

Parmigiano et al., (2014) reported that none of the 148 Brazilian female athletes assessed presented FAT, characterized as concomitant Eating Attitudes Test (EAT-26) ≥20 (Bighetti, 2003), menstrual irregularity or amenorrhea, and stress fractures. This study considered that athletes who scored above 20 in EAT-26 were at greater risk of eating disorder (Parmigiano et al., 2014).

Perini et al., (2009) also defined FAT as a combination of DE (EAT-26 ≥21), amenorrhea and osteoporosis and did not find Brazilian rhythmic gymnastics athletes with FAT.

Similarly, Schtscherbyna et al., (2009) reported the prevalence of FAT by the presence of DE, amenorrhea, and osteopenia or osteoporosis, but DE was diagnosed when athletes scored positive for at least one of the tests: 1) EAT-26 ≥20 (Garner et al., 1982); 2) Bulimic Investigatory Test Edinburgh (BITE) ≥10 (Henderson, Freeman, 1987); or 3) Body Shape Questionnaire (BSQ) ≥80 (Cooper et al., 1987).

Despite 44.9% of athletes presented positive status in at least one of the tests, only 1.3% were identified with FAT (Schtscherbyna et al., 2009).

The EAT-26 questionnaire, used in all excluded studies, is a valid instrument which may identify symptoms of anorexia nervosa, indicating the risk of a disordered eating patterns (Garner et al., 1982).

This self-report questionnaire was translated and validated in Brazilian female adolescents by Biguetti (2003) to help pre-diagnose possible cases of eating disorder from questions that identify behaviors related to pathologic high-calorie food refusal, intense fitness concern, binge eating followed by vomiting and other behaviors to prevent weight gain, self-control over food and recognition of other people forcing food intake.

The BITE and BSQ questionnaires, administered in Coelho et al., (2013) study, also indicate disordered behaviors as bulimic episodes and concerns about body shape, respectively.

In a large proportion of LEA cases, DE seems to be an important cause that affect mainly weight-sensitive sports female athletes who chase performance improvement or/and aesthetic (Gibbs, Williams, Souza, 2013; Sundgot-Borgen, Torstveit, 2004).

But using only eating behavior instruments to detect energy deficiency can underestimate the prevalence of FAT, since many athletes in LEA do not present eating disorder or DE risk, as observed by Torres-McGehee et al., (2020) who identified 81% of females with EA ≤30kcal/ kg FFM/day, but 76% with eating disorder risk.

Similarly, some studies reported that disordered eating itself is not an independent predictor of increased FAT risk symptoms such as stress fracture (Duckham et al., 2012; Field et al., 2011; Sosa, Eriksen, 2016).

Questionnaires are not able to identify or diagnose LEA and should be used as a primary screening tool to identify subjects at risk of presenting energy deficiency and consequently FAT (Sim, Burns, 2021).

The screening tools can be important in early detection of athletes at risk which is very important to prevent the FAT (Souza et al., 2014).

According to Souza et al., (2014), history of menstrual irregularities, stress fractures, depression, dieting, weight cycling, overtraining, perfectionism and obsessiveness traits, presence of critical comments about eating and weight loss from parents, coaches and peers and early start of sport-specific training should be assessed and the existence of any FAT component, or its risk, should motivate the investigation of others.

Although there is no gold standard list of risk factors for FAT, a narrative review limited to papers from 2010 to 2020 (Sim, Burns, 2021), observed that the most frequently used validated questionnaires to determine LEA and its consequences, as menstrual dysfunction,

and injuries, is the Low Energy Availability in Females Questionnaire (LEAF-Q) (Melin et al., 2014) and the Eating Disorder Examination Questionnaire (EDE-Q) (Fairburn, Beglin, 1994).

LEAF-Q was developed to identify risk for the FAT from the presence of injuries, gastrointestinal and menstrual irregularities, which are symptoms caused by LEA (Melin et al., 2014). EDE-Q measures disordered eating psychopathology based on factors as dietary restraint, shape concern, eating concern and weight concern.

Maria, Juzwiak (2021a) translated and validated the LEAF-Q in Brazilian athletes involved in several sports disciplines and found that 34% of them were at risk for the FAT (Maria, Juzwiak, 2021b).

EDE-Q has already been translated into Brazilian Portuguese (Moser et al., 2020), but it has not yet been validated for Brazilian athletes.

As LEAF-Q and EDE-Q assessed symptoms and behaviors, respectively, the application of these may act in a complementary way to identify possible FAT cases (Sim, Burns, 2021).

Moreover, using questionnaires presents the convenience, speed of assessment and cost advantage to investigate FAT risk (Burke et al., 2018).

As FAT represents the interrelationship among LEA, reproductive dysfunction and impaired bone health (Nattiv et al., 2007), its diagnostic must be based on the evaluation of each of the three components.

Coelho et al., (2013), Coelho (2015), Miranda (2018) assessed all three FAT components using similar methods.

EA can be estimated by calculation from EI, EEE and FFM data (Heikura, Stellingwerff, Areta, 2021). There are many ways to estimate EI, such as food records, interviews and food frequency questionnaires (Capling et al., 2017).

However, the errors of self-reported intakes seem to be significant (~600kcal/day) (Burke et al., 2018).

In this review, two of the included studies (Coelho et al., 2013; Coelho, 2015) estimated EI from 3-day food records in alternating days, and Miranda (2018) used the 24-hour recall.

Given that there is no standardized guideline on EI and EEE estimation, it is common research and practitioners to observe the dietary and training practice over periods of 3-7 days in order to analyze the athletes' habitual practices (Burke et al., 2018) and obtain more accurate information.

Studies in literature have used training records, heart rate monitors, accelerometers, or a combination of these methods (Burke et al., 2018).

Training records are frequently used to calculate EEE from using Metabolic Equivalent of Task (Ainsworth et al., 2011), heart rate monitors estimate EEE by relationship between heart rate and O_2 consumption/respiratory exchange ratio determined during laboratory testing and accelerometers monitor body movements (Burke et al., 2018).

The three included studies (Coelho et al., 2013; Coelho, 2015; Miranda, 2018) estimated EEE using the compendium of energy expenditure for youth (Ridley, Ainsworth, Olds, 2008) and considering the exercise duration, the training intensity, body weight and age. However, two of these studies used training logs provided by athletes (Coelho et al., 2013; Coelho, 2015), while another study determined diary 100 minute-training for swimmers and 90 minute-training for other athletes (Miranda, 2018), which may increase inaccuracy.

In addition to the fact that the use of activity logs is less precise than other methods to estimate EEE, the use of different parameters in the same population can still result in a non-reliable EA calculation and make interpretation difficult in practical conduct (Guebels et al., 2014).

DXA, the gold standard method to assess FFM and BMD, was used in studies included in this systematic review (Coelho et al., 2013; Coelho, 2015; Miranda, 2018).

But anthropometric measurements (subcutaneous fat and girths) can also be taken using standardized, accredited and more affordable techniques, such as protocols developed by the International Society for the Advancement of Kinanthropometry (Burke et al., 2018).

In the Position Stand by Nattiv et al., (2007), menstrual dysfunction is defined as the presence of oligomenorrhea, primary amenorrhea or secondary amenorrhea.

Oligomenorrhea is recognized as menstrual cycles greater than 35 days, primary amenorrhea occurs when menarche delays and happens only after 15 years of age and secondary amenorrhea is the absence of

menstruation for longer than 3 months (Nattiv et al., 2007).

Coelho et al., (2013), Coelho (2015), Miranda (2018) investigated menstrual status using the same definition of menstrual irregularities recommended by Nattiv et al., (2007).

There are many issues regarding LEA that still must be better understood. For example, as highlighted by Burke et al., (2018), there is a lack of a single, universal protocol for the calculation of EA and the use of different methods with distinct accuracies to estimate ED components may lead to imprecise LEA diagnosis, rendering comparisons between studies difficult. Furthermore, the cut-off value of 30 kcal/kg/FFM/d was obtained from studies on reproductive hormones of eumenorrheic, non-athlete women, using a sophisticated method, but also imprecise, and therefore, does not provide a universal threshold value for all athletes.

However, even with those caveats, LEA is the main etiological factor of FAT and once present it can lead to menstrual dysfunction, and contribute to bone loss, resulting in osteoporosis and stress fractures (Mountjoy et al., 2018).

LEA can cause other functional outcomes, involving different body systems and impairing physical and mental health as well as performance (Burke et al., 2018).

As LEA may occur without the presence of DE/ED, when athletes fail inadvertently to consume enough energy to meet energy expenditure needs (Williams, Statuta, Austin, 2017), and considering the important consequences of FAT, the investigation of LEA, as its primary component, is of utmost importance, especially when not associated with DE/ED, due to difficulties in detecting it.

CONCLUSION

This systematic review found a prevalence of FAT, considering LEA as its trigger component, between 4% and 4.2% in Brazilian adolescent athletes.

The aim of this review was to find FAT prevalence in Brazilian female athletes in general, however the only studies which reported FAT, as a condition with etiology in LEA, were those conducted in adolescents. No studies on RED-S were identified.

Since 2007, FAT has been described as an interrelationship among LEA, MI and low BMD, therefore the presence of a psychopathological factor is not mandatory in the occurrence of LEA.

However, when screening the studies of this revision for eligibility, many of them, published after 2007, were excluded because they considered only DE/ED as the energy deficiency cause.

Although cases of ED/DE in athletes often evolve into an energy deficiency and, consequently, FAT and RED-S, other determinants of eating behavior, such as the inadvertent undereating due to suppression of hunger in response to the training intensity or volume, inability to consume sufficient food to match an extreme exercise period, lack of motivation to prepare food due to fatigue, reduced opportunities to food-time when training demand many hours and presence of a rich in fiber and low energy-dense diet which promotes fast satiety (Burke et al., 2018; Burke et al., 2001; Melin et al., 2016), can be the cause of energy deficiency. Therefore, LEA for reasons beyond ED/DE may be more frequent.

Investigating the occurrence of LEA, regardless of DE/ED presence, is important for FAT and RED-S diagnosis, even in athletes who do not undergo intentional energy restriction. This practice can prevent a large number of female athletes from suffering health and performance impairments.

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The authors report no conflict of interest.

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