RBFEx
ISSN Online: 2675-1372

Revista Brasileira de Fisiologia do Exercício

Original article

Screening for RED-S in female street runners: an alert about relative energy deficiency in sport

Triagem para RED-S em corredoras de rua: um alerta para deficiência energética relativa no esporte

Marcos Lira Feitosa da Silva, João Henrique Gomes, Renata Rebello Mendes

Universidade Federal de Sergipe, Aracaju, SE, Brazil

ABSTRACT

Introduction: The Relative Energy Deficiency in Sport (RED-S) syndrome has become a significant issue for endurance athletes, with low energy availability (LEA) being its main cause. There is no gold standard for diagnosis, but in 2023, the 3rd consensus on the subject proposed a new protocol. **Objective:** The objective was to evaluate the risk of LEA in female street runners to screen athletes at risk for RED-S, and to characterize weekly training volume. **Methods:** This is a cross-sectional observational study conducted with 34 female street runners (33.3 ± 5.8 years old, 6.2 years of training experience, BMI 23.2 ± 2.9), whose LEA risk was assessed by the Low Energy Availability in Females Questionnaire (LEAF-Q). The cutoff for risk classification consists of ≥ 8 total score, with emphasis on ≥ 2 score for the injuries subscale, ≥ 2 score for the gastrointestinal function subscale, and ≥ 4 score for the menstrual function subscale. **Results:** The prevalence of LEA risk was 23.5%; among the eight athletes identified at risk, 75% had high scores above cutoffs for more than one subscale. Menstrual dysfunction had a score ≥ 4 in 75% of those classified at risk. Although no significant correlation was found between LEA risk and training volume, the highest prevalence of risk was identified among athletes with volumes between 41-45 km weekly. **Conclusion:** The results indicate a high prevalence of LEA risk among endurance runners, suggesting the importance of screening for RED-S and the need to continue diagnostic processes in this population.

Keywords: relative energy deficiency in sport; running; energy intake; menstrual cycle; bone density.

RESUMO

Introdução: A síndrome de Deficiência de Energia Relativa no Esporte (RED-S) tornou-se problema relevante para atletas de endurance, sendo a baixa disponibilidade de energia (LEA) sua principal causa. Não há padrão ouro para diagnóstico, mas em 2023 o 3º consenso internacional sobre o tema sugeriu novo protocolo. **Objetivo:** Objetivou-se avaliar o risco de LEA em corredoras de rua para triar atletas em risco para RED-S, e caracterizar volume semanal de treinamento. **Métodos:** Estudo observacional transversal realizado com 34 mulheres corredoras de rua (33,3 ± 5,8 anos de idade, 6,2 anos de experiência em treinamento, IMC 23,2 ± 2,9), cujo risco de LEA foi avaliado pelo Low Energy Availability in Females Questionnaire (LEAF-Q). O corte para classificação de risco consiste em ≥ 8 de pontuação total, com destaque para pontuação ≥ 2 para a subescala de lesões, ≥ 2 para a subescala de função gastrointestinal, e ≥ 4 para a subescala de função menstrual. **Resultados:** A prevalência de risco de LEA foi 23,5%; dentre as oito atletas identificadas com risco, 75% apresentaram elevadas pontuações para mais de uma subescala. A disfunção menstrual apresentou pontuação ≥4 em 75% das classificadas com risco. Embora não tenha sido encontrada correlação significativa entre o risco de LEA e volume e frequência de treinamento, as maiores prevalências de risco foram identificadas entre atletas com volume semanal entre 41-45 km. **Conclusão:** Os resultados indicam elevada prevalência de risco de LEA entre as corredoras de endurance, sugerindo a importância da triagem para RED-S e a necessidade de dar continuidade aos processos diagnósticos nessa população.

Palavras-chave: deficiência de energia relativa no esporte; corrida; ingestão de energia; ciclo menstrual; densidade óssea.

Received: August 22, 2024; Accepted: October 17,2024.

Correspondence: Renata Rebello Mendes, remendes@academico.ufs.br

Introduction

The syndrome known as Relative Energy Deficiency in Sport (RED-S) has been considered a significant problem for endurance athletes, who generally have a high training volume, high caloric expenditure, gastrointestinal difficulties for adequate energy intake during exercise, need to be light to achieve better results in competitions and training, and a greater risk of restrictive eating habits, especially among women [1-4].

The main etiological factor of this syndrome is low energy availability (LEA), a situation observed when the daily caloric intake is not sufficient to satisfy both the demand of physical exercise and the energy needs of all the physiological systems of the body at rest [5]. For women, LEA has been suggested as energy availability (energy available only for extra-workout moments) of less than 30.0 calories per day per kg of lean mass, and when this situation is maintained for prolonged periods, a decline in sports performance and clinical complications may occur, such as changes in menstrual and bone functions, reductions in metabolic rate, immunity and protein synthesis, and damage to cardiovascular and psychological health, among others [6-9].

Understanding the complexity of RED-S, its risk factors, and complications is essential for implementing effective preventive and intervention strategies to ensure the health and performance of these athletes, and the first step is diagnosis [10]. However, diagnosing RED-S is still challenging for health professionals, as there isn't a gold standard protocol for this purpose.

Until 2023, studies used very different protocols to diagnose RED-S and sometimes mistakenly adopted the terms LEA and RED-S as interchangeable, resulting in prevalences between 23 and 79.5% in women and 15 and 70% in men [3]. However, in September 2023, the 3rd international consensus on this syndrome was published [8], which proposed a three-stage assessment model. First, the application of screening questionnaires to detect possible symptoms of low energy availability; for this stage, one of the recommended questionnaires for women who exercise is the Low Energy Availability in Females Questionnaire (LEAF-Q), recently translated and validated into Brazilian Portuguese [11]. The following steps involve anamnesis and evaluations by a multidisciplinary team, which may or may not confirm the diagnosis of RED-S and, if necessary, guide appropriate treatment.

The scarcity of studies that have applied the RED-S assessment method suggested by the 2023 consensus makes it difficult to compare and generalize epidemiological data on this syndrome. Therefore, there is an urgent need for more studies that follow the recommendations of the 2023 consensus to assess the prevalence and impact of RED-S in different sporting contexts, especially in endurance athletes [6]. Thus, the present study aimed to evaluate the risk of LEA in female runners of long-distance road races to screen athletes at risk for RED-S development.

Methods

Experimental design

This observational, cross-sectional, quantitative study was carried out in three stages [1]. After the approvement of the research project by the Research Ethics Committee, the first meeting happened virtually; on this occasion, the aim was to present the objectives and procedures related to the study to coaches and runners; the terms of free and informed consent (TCLE) were also presented to the runners, for later reading and signing by those who met the inclusion criteria and were interested in participating [2]. One week after the initial presentations, interested runners were instructed on how to fill out the questionnaires, and any possible doubts were clarified [3]. Finally, the LEAF-Q questionnaire was completed online, with questions necessary to characterize the participants.

Participants

Thirty-four female street runners engaged in training programs, whose objective was to complete street races longer than 21.1 km (half marathon), were included. Recruitment was carried out by contacting the coaches responsible for prescribing running training at the six main running clubs in the city of Aracaju.

The main inclusion criteria were to currently have or have had in the last 12 months an average weekly training volume greater than 35 km and to be over 18 years of age. The exclusion criteria were: (a) having locomotor system diseases capable of increasing the risk of injuries, regardless of caloric intake; (b) having diseases capable of causing changes in intestinal rhythm and/or menstrual cycles, regardless of caloric intake; (c) not having chronic thyroid problems; (d) not being pregnant or lactating.

Assessment instruments

For the evaluation of the participants, the Low Energy Availability Questionnaire in Women (LEAF-Q) was adopted, consisting of a self-administered questionnaire originally presented in English (2015) and recently translated into Portuguese [11]. It consists of items related to menstrual and gastrointestinal status and the occurrence of injuries, that is, factors associated with persistent energy deficiency that allow the identification of the risk of low energy availability when the score is ≥ 8.0. Additionally, partial cutoff points can be adopted; as follows: ≥ 2.0 for the section on questions about injuries; ≥ 2.0 for the section on gastrointestinal changes; ≥ 4.0 for the section on menstrual function.

According to Logue *et al*. [3], the LEAF-Q is an easy-to-administer instrument, validated for use in endurance-trained women to investigate the risk of LEA, alleviating some of the challenges associated with the direct measurement of energy availability, as well as being considered an adequate screening tool for RED-S among young female athletes [12].

Finally, a semi-structured questionnaire was developed to characterize the participants regarding their training routine, experience in the sport, age, and anthropometry.

Statistical analysis

Descriptive statistics were used, with some data presented as mean, standard deviation, minimum, and maximum, and others as absolute and relative frequency. To test possible correlations between variables, data normality and homogeneity were initially tested using the Shapiro-Wilk and Levene tests, respectively. Depending on the results, Spearman or Friedman correlation tests were used for nonparametric and parametric data, respectively. All analyses were performed using SPSS-22.0 software (IBM, SPSS Inc., Chicago, IL, USA). Significance was set at $p < 0.05$.

Results

Tabela I - Characterization of participants regarding age, anthropometry, weekly frequency of running training, and weekly training volume (n = 34)

Variables	Mean	SD	Min	Max
Age	33.3	5.8	27.0	48.0
Street-running training experience (years)	6.2	4.1	1.0	20.0
Weight (kg)	61.6	8.5	41.0	79.0
Stature (m)	1.60	0.1	1.50	1.72
BMI (kg/m2)	23.3	2.9	18.2	29.17
Weekly training frequency	4.1	0.7	2.0	6.0
Maximum weekly training volume in the last year (km)	49.0	20.7	25.0	110.0
Current training volume (km)	35.9	10.1	28.0	60.0

Table II shows that most participants are training volumes between 25 and 30 km per week, followed by volumes between 31 and 35 km, and those who train between 46-50 km.

Table II - Distribution of participants according to current weekly running training volume.

Current weekly volume	n	%
25-30 km	16	47.06
31-35 km	6	17.65
36-40 km	2	5.88
41-45 km	2	5.88
46-50 km	4	11.76
51-55 km	1	2.94
55-60 km	3	8.82

Table III - Total and subscale scores that make up the LEAF-Q (n=34)

Variables	Mean	SD	Min	Max
Injury subscale (risk score ≥ 2 points)	1.11	1.06	0	5
Gastrointestinal function subscale (risk score ≥ 2 points)	2.14	2.28	0	10
Menstrual function subscale (risk score ≥ 4 points)	2.83	1.99	0	8
Total score (risk score ≥ 8 points)	6.06	3.82	0	20

Figure 1 demonstrates a predominance of runners without risk of LEA; however, among those screened with risk of LEA (LEAF-Q with a total score equal to or higher than 8 points - Figure 2), it is noted that most of the runners presented high scores (higher than the cut-off scores) for more than one LEAF-Q subscale, with a predominance of menstrual dysfunctions.

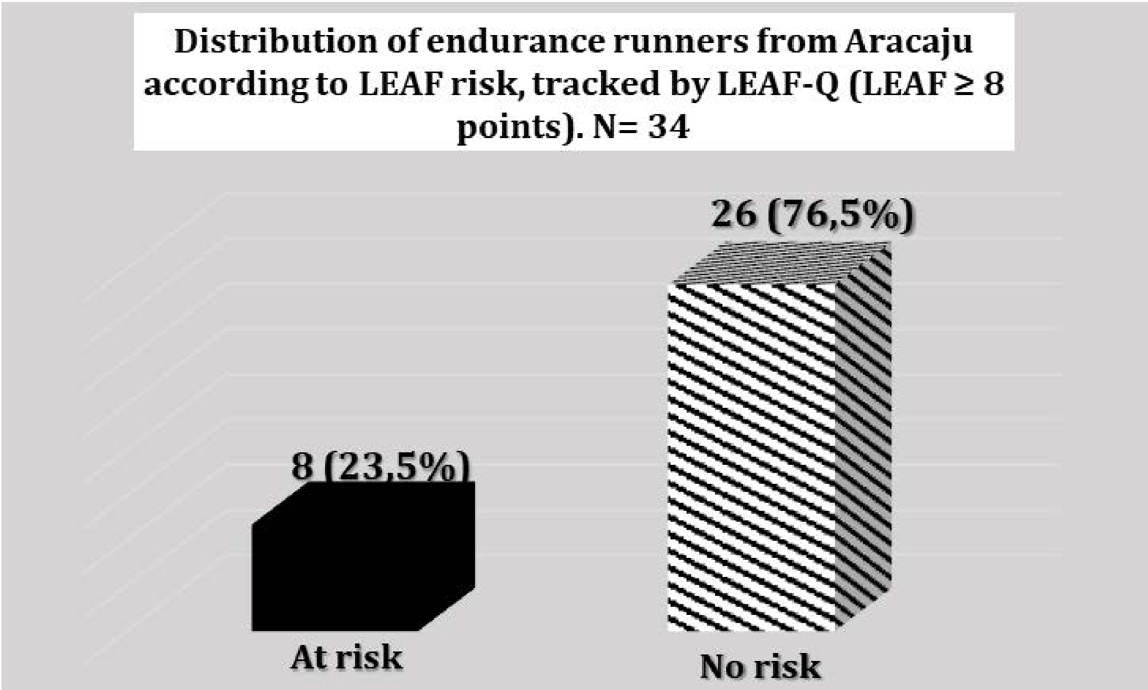
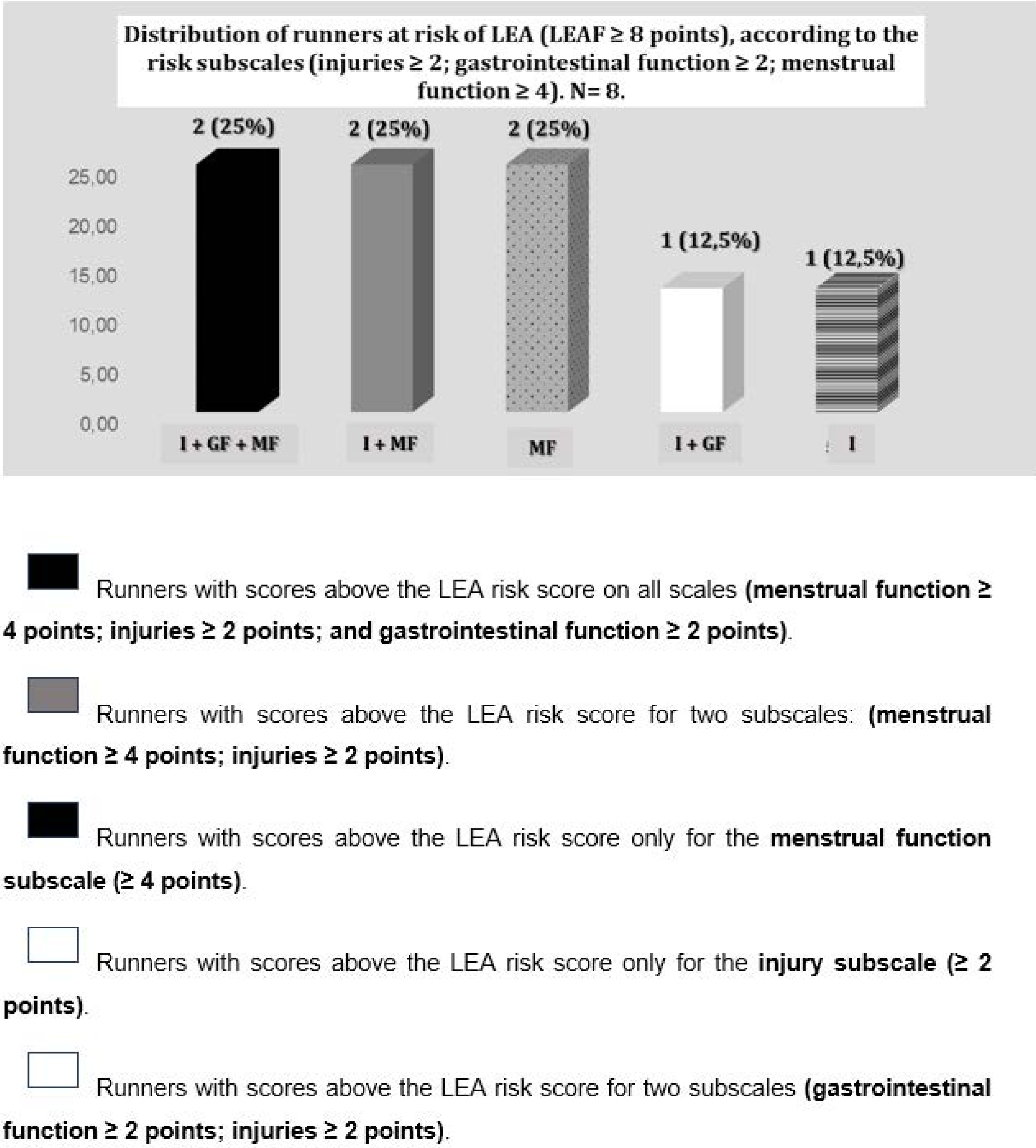


Figure 1 - Distribution of endurance runners from Aracaju according to LEA risk, tracked by LEAF-Q. N = 34

Figure 2 shows that among the participants screened for LEA risk (LEAF-Q with a total score equal to or greater than 8 points), the majority presented scores higher than the risk score for more than one subscale, and menstrual dysfunction appears prominently among 75% of participants at risk for LEA.



I = Injury subscale; MF = Menstrual function subscale; GF = Gastrointestinal function subscale
Figure 2 - Distribution of runners at risk of LEA (LEAF ≥ 8 points), according to the risk subscales (injuries ≥ 2; Gastrointestinal function ≥ 2; Menstrual function ≥ 4). N = 8

Figure 3 shows that among the participants screened for LEA risk (LEAF-Q with a total score equal to or higher than 8 points), the majority were subjected to a running training volume less than or equal to 30 km per week, followed by athletes with a volume between 31 and 35 km per week. However, Figure 4 shows that, when correcting the frequency of athletes with LEA risk according to the number of participants in each category of weekly training volume, it is noted that the emphasis is on athletes with volumes between 41 and 45 km and greater than 55 km.

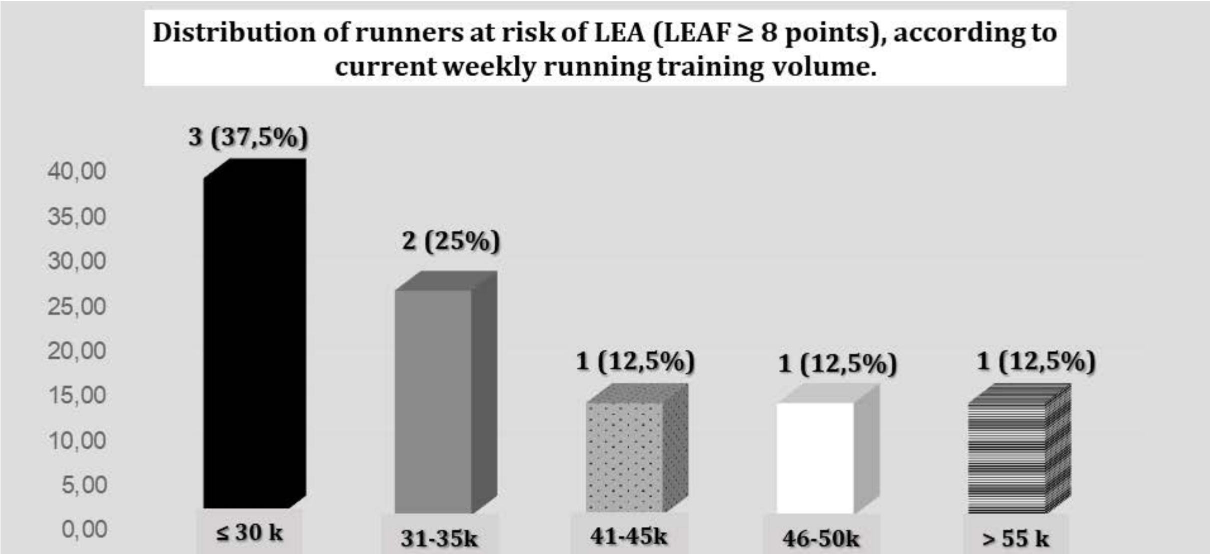


Figure 3 - Distribution of runners at risk of LEA (LEAF ≥ 8 points), according to the current weekly running training volume

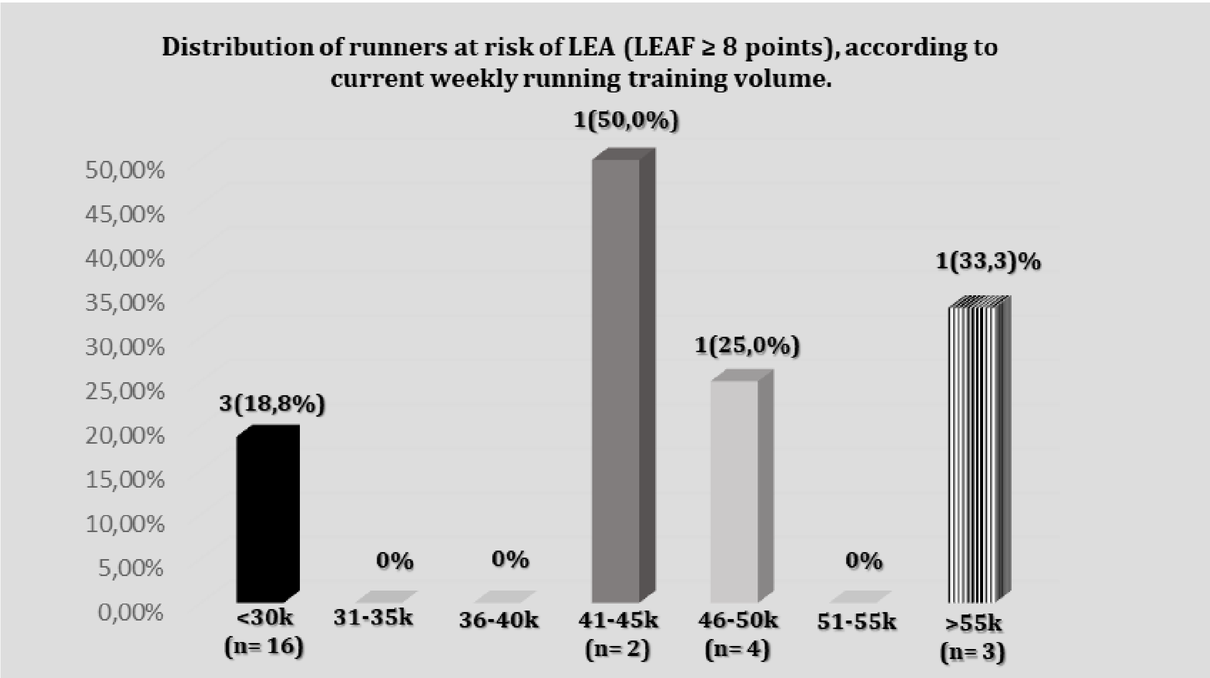


Figure 4 - Prevalence of LEA risk (LEAF-Q ≥ 8 points) in each category of runners, considering the current weekly training volume

Correlations

After thoroughly analyzing all variables, no correlation was found between them in this study. However, it is worth noting that even without any correlations being observed, this does not necessarily rule out the possibility of relationships between the variables but only that it was not possible to identify statistically significant associations between them. Therefore, it is suggested that future research in this regard is necessary.

Discussion

This study aimed to evaluate the risk of LEA in female endurance runners as a way of screening for risk and RED-S, as well as to describe the weekly training volume and test the correlation between these variables. The main findings were that 23.5% of the participants were at risk for LEA, according to the total LEAF-Q score, with an average of 6.06 total points. The menstrual dysfunction subscales stood out, and there was a higher frequency of LEA risk for those who had a weekly running volume between 41 and 45 km. However, there was no statistically significant correlation between the risk of LEA and training volume. Regarding the prevalence of LEA risk through the LEAF-Q instrument, it is possible to observe similarity with the data mentioned in the 3rd RED-S consensus, which reports a risk of LEA and RED-S between 23% and 79.5% in female athletes. However, the biggest criticism mentioned in this consensus is precisely the fact that the terms LEA and RED-S are used as if they refer to the same phenomenon, which is not true. Not all athletes with low energy availability will develop relative energy deficiency syndrome in sports, with its characteristic symptoms in performance and/or health [8]. Adopting a common analogy in the area of nutrition, it can be said that LEA is for iron deficiency, just as RED-S would be for iron deficiency anemia; that is, not every athlete with iron deficiency will develop iron deficiency anemia, just as not every athlete at risk of LEA will develop RED-S. In fact, in the last consensus on RED-S, the term adaptive LEA was adopted for the first time, with benign effects and mild and rapidly reversible changes in biomarkers of several body systems, but which, if maintained chronically, could become a problematic LEA, culminating in RED-S [8].

For these reasons, it is essential that the prevalence of LEA found in the present study, using the LEAF-Q, be compared to data obtained using the same instrument. Therefore, in our searches, we found some recent studies that used the same instrument to verify the risk of LEA [12-21], but few were conducted with endurance runners [15,18,21], which makes the contribution of the present study explicit.

Black *et al*. [22] evaluated 38 female recreational athletes (mean age 22 years) who performed between 2.5 and 5 hours of moderate-intensity exercise per week, or 1.25 to 2.5 hours of vigorous exercise per week, or an equivalent combination of both types of exercise, regardless of the modality. The authors found a prevalence of LEA risk of 63.2%, with a mean of 8.9 points on the LEAF-Q. Civil *et al*. [14] also found a high prevalence of LEA risk (65% with LEAF-Q ≥ 8) when evaluating 20 students in professional ballet training in Scotland, which is an aesthetic modality and, therefore, with a bigger concern related to thinness and dietary restriction. With similar results, Łuszczki *et al*. [12] found a prevalence of 64.7% of LEA risk in adolescent soccer players; this age group also being considered at high risk for LEA and RED-S [23].

Meng *et al*. [16] evaluated women in aesthetic modalities, comparing elite athletes (n = 52) with recreational athletes (n = 113), and found a prevalence of LEA risk (LEAF-Q ≥ 8) of 55.8% and 35.1%, respectively. Similar results were found by Slater *et al.* [17], who evaluated 109 women who practiced recreational exercises in gyms and fitness spaces and found a 45% prevalence of LEA risk through the LEAF-Q.

Among the studies carried out with running and LEAF-Q, Kyte *et al.* [21] evaluated amateur endurance runners and obtained a prevalence of 44.0% of LEA risk through LEAF-Q, while Dambacher *et al.* [16] found 54.5% in a study carried out with 156 of the same type of athlete. Among elite runners, Heikura *et al.* [15] found that among those who presented energy availability between 30 and 45 kcal/kg MMg, the average LEAF-Q was 9.04 points, and in those with low energy availability (<30 kcal/kg MMg), 11.04. However, the authors did not report the prevalence of LEA risk based on this instrument.

Although the risk in our study (23.5%) is relatively lower than the risks observed in the studies described above, it is important to highlight that the prevalence of LEA risk found in our study is still considered high, according to Mountjoy *et al.* [8], since practically a quarter of the sample studied has a chance of developing RED-S, which can culminate in serious health problems and performance impairments.

In the same sense, although our average total LEAF-Q score (6.06) was lower than that of the study by Heikura *et al.* [15] (between 9.04 and 11.04), probably due to the difference in training level [18], it is essential to highlight that the athletes we identified as at risk should be referred to the next stages of evaluation, to investigate possible clinical symptoms of RED-S and the need for treatment [20].

Concerning training volume, the study by Meng *et al.* [16] showed that elite Chinese athletes with higher training volumes and frequencies than amateur athletes had a higher risk of developing LEA with menstrual and bone disorders. Slater *et al.* [17] also found that for each extra hour of weekly exercise practiced by recreational athletes, there was a 1.13-fold increase in the risk of LEA. However, in the present study, no correlations were found between training volume and frequency and the risk of LEA. The absence of this correlation in the present study may be related to two possible factors: a) regardless of the training volume, the energy intake of athletes at risk of LEA should be evaluated because even if the training volume is reduced, if the energy availability is very low, menstrual and gastrointestinal symptoms and the emergence of injuries may occur; that is, it is not only how much you train that matters, but also how you replace the energy expended over the 24 hours; b) reduced sample in the categories with the highest weekly volume (in the present study), demonstrating the relevance of future research involving larger groups, with different training volumes and frequencies.

The presence of menstrual dysfunction in most participants in this study corroborates many studies that evaluate LEA, since the time when the female athlete triad was evaluated [8]. According to Mendes *et al.* [5], the menstrual disorder related to LEA is based on the relationship between the insufficient arrival of metabolic fuels to meet the needs of the brain and the interruption of the pulsatility of the gonadotropin-releasing hormone (GnRH) in the hypothalamus. Consequently, there are changes in the release of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) by the pituitary gland and a drop in blood concentrations of estradiol and progesterone [22]. Such changes can culminate in subclinical menstrual disorders (anovulatory cycles) up to long menstrual cycles and primary/secondary amenorrhea (functional hypothalamic amenorrhea).

The lesions scored in the LEAF-Q, especially the bone ones, as observed in the present study, have been justified by a decrease in bone mineral density caused by multifactorial conditions related to LEA, such as hypoestrogenism, decrease in blood concentrations of leptin, insulin, insulin-like growth factor 1 (IGF-1), and increased cortisol. Such factors are associated with reduced osteoblast activity and reduced synthesis of type I collagen, culminating in bone demineralization and increased risk of stress fractures [5,24].

With regard to changes in gastrointestinal function, also scored in the present study, it is possible to report that LEA is usually accompanied by insufficient iron intake, as well as training sessions capable of promoting an increase in interleukin-6 and hepcidin, culminating in reduced intestinal iron absorption. Given the lower bioavailability of iron, it is possible that there will be less synthesis of thyroxine and a decrease in its conversion to triiodothyronine, thus increasing the risk of developing hypothyroidism, which in turn can cause changes in intestinal rhythm [5;25].

After the diagnosis of LEA risk (LEAF-Q score ≥ 8), the recommended referral is a comprehensive and holistic multidisciplinary approach to investigate possible cases of RED-S, categorize severity, and, if necessary, define treatment strategies [8].

It is worth noting that the continuity of the diagnostic process, in addition to screening via LEAF-Q, is essential, as this is a complex syndrome that can become serious. In addition to the injuries and menstrual and gastrointestinal dysfunctions addressed in LEAF-Q, other changes are also observed in athletes diagnosed with RED-S, such as changes in glucose and lipid metabolism, impairment of cardiovascular and endothelial function, impairment of the immune system, impairment of sleep quality and general well-being. From a mental point of view, some women have difficulty motivating themselves, as well as developing anxiety, addiction or dependence on training, and depression [6]. Thus, the consequences of RED-S syndrome are devastating, serious, and even fatal, ranging from an unwillingness to train to extreme complications, such as suicide [8]. The most reported consequences of athletic performance are decreased response to training, loss of strength, reduced recovery capacity, and a general impairment in endurance events and exercises [8].

Therefore, according to Witkoś *et al.* [20], carrying out screening processes for RED-S may represent a fundamental strategy for identifying and treating this syndrome to avoid extreme complications, improving not only the athletic performance of this athlete but also her quality of life.

Conclusion

A high prevalence of LEA risk was found among endurance runners (23.5%), with a predominance of menstrual dysfunctions (75%) among athletes at risk and a higher relative prevalence among runners with a weekly training volume between 41 and 55 km, demonstrating the need to continue the diagnostic processes for RED-S in this population.

Conflicts of interest
There are no conflicts of interest.

Sources of funding
There was no funding.

Authors' contributions
Conception and design of the research: Silva MLF, Gomes JH, Mendes RR; Data collection: Silva MLF, Mendes RR; Data analysis and interpretation: Silva MLF, Mendes RR; Statistical analysis: Gomes JH; Manuscript writing: Silva MLF, Mendes RR; Critical revision of the manuscript for important intellectual content: Silva MLF, Gomes JH, Mendes RR

References

1. Drew M, Vlahovich N, Hughes D, Appaneal R, Burke LM, Lundy B, *et al*. Prevalence of illness, poor mental health and sleep quality and low energy availability prior to the 2016 Summer Olympic Games. Br J Sports Med. 2018;52(1):47-53. doi: 10.1136/bjsports-2017-098208

2. Hackney AC, Zieff GH, Lane AR, Register-Mihalik JK. Marathon running and sexual libido in adult men: exercise training and racing effects. J Endocrinol Sci. 2022;4(1):10-12. PMID: 36068871.

3. Logue DM, Madigan SM, Melin A, Delahunt E, Heinen M, Donnell SM, Corish CA. Low energy availability in athletes 2020: an updated narrative review of prevalence, risk, within-day energy balance, knowledge, and impact on sports performance. Nutrients. 2020;12(3):835. doi: 10.3390/nu12030835

4. Melin AK, Areta JL, Heikura IA, Stellingwerff T, Torstveit MK, Hackney AC. Direct and indirect impact of low energy availability on sports performance. Scand J Med Sci Sports. 2024;34(1):e14327. doi: 10.1111/sms.14327

5. Mendes RR, Bevilacqua M, Rossi L. Relative Energy Deficiency in Sport (RED-S). Capítulo 48. In: Tratado de Nutrição e Dietoterapia. 2a ed. Rio de Janeiro: Guanabara Koogan: 2023. p.1-3.

6. Langbein RK, Martin D, Allen-Collinson J, Crust L, Jackman PC. "I'd got self-destruction down to a fine art": a qualitative exploration of relative energy deficiency in sport (RED-S) in endurance athletes. J Sports Sci. 2021;39(14):1555-64. doi: 10.1080/02640414.2021.1883312

7. Mountjoy M, Sundgot-Borgen JK, Burke LM, Ackerman KE, Blauwet C, Constantini N, *et al*. IOC consensus statement on relative energy deficiency in sport (RED-S): 2018 update. Br J Sports Med. 2018;52(11):687-97. doi: 10.1136/bjsports-2018-099193

8. Mountjoy M, Ackerman KE, Bailey DM, Burke LM, Constantini N, Hackney AC, *et al*. 2023 International Olympic Committee's (IOC) consensus statement on Relative Energy Deficiency in Sport (REDs). Br J Sports Med. 2023;57(17):1073-97. doi: 10.1136/bjsports-2023-106994. Erratum in: Br J Sports Med. 2024; 58(3):e4. doi: 10.1136/bjsports-2023-106994corr1

9. Stellingwerff T, Heikura IA, Meeusen R, Bermon S, Seiler S, Mountjoy ML, Burke LM. Overtraining Syndrome (OTS) and Relative Energy Deficiency in Sport (RED-S): shared pathways, symptoms and complexities. Sports Med. 2021;51(11):2251-80. doi: 10.1007/s40279-021-01491-0

10. Nattiv A, Souza MJ, Koltun KJ, Misra M, Kussman A, Williams NI, *et al*. The Male Athlete Triad-A Consensus Statement From the Female and Male Athlete Triad Coalition Part 1: definition and scienti-

fic basis. Clin J Sport Med. 2021;31(4):335-48. doi: 10.1097/JSM.0000000000000946

11. Maria UM, Juzwiak CR. Cultural adaptation and validation of the low energy availability in females questionnaire (LEAF-Q). Rev Bras Med Esporte. 2021;27(2):184-8. https://doi.org/10.1590/1517-869220212702223889

12. Łuszczki E, Jagielski P, Bartosiewicz A, Kuchciak M, Dereń K, Stolarczyk A, Pakosz P, *et al*. The LEAF questionnaire is a good screening tool for the identification of the Female Athlete Triad/Relative Energy Deficiency in Sport among young football players. Peer J. 2021;3;9:e12118. doi: 10.7717/peerj.12118

13. Black K, Slater J, Brown RC, Cooke R. Low energy availability, plasma lipids, and hormonal profiles of recreational athletes. J Strength Cond Res. 2018;32(10):2816-24. doi: 10.1519/JSC.0000000000002540

14. Civil R, Lamb A, Loosmore D, Ross L, Livingstone K, Strachan F, *et al*. Assessment of dietary intake, energy status, and factors associated with RED-S in vocational female ballet students. Front Nutr. 2019;9(5):136. doi: 10.3389/fnut.2018.00136

15. Heikura IA, Uusitalo ALT, Stellingwerff T, Bergland D, Mero AA, Burke LM. Low energy availability is difficult to assess but outcomes have large impact on bone injury rates in elite distance athletes. Int J Sport Nutr Exerc Metab. 2018;28(4):403-11. doi: 10.1123/ijsnem.2017-0313

16. Meng K, Qiu J, Benardot D, Carr A, Yi L, Wang J, Liang Y. The risk of low energy availability in Chinese elite and recreational female aesthetic sports athletes. J Int Soc Sports Nutr. 2020;17(1):13. doi: 10.1186/s12970-020-00344-x

17. Slater J, McLay-Cooke R, Brown R, Black K. Female recreational exercisers at risk for low energy availability. Int J Sport Nutr Exerc Metab. 2016; 26(5):421-7. doi: 10.1123/ijsnem.2015-0245

18. Dambacher L, Pritchett K, Pritchett R, Larson A. Risk of low energy availability, disordered eating, and menstrual dysfunction in female collegiate runners. J Athl Train. 2023. doi: 10.4085/1062-6050-0454.23

19. Jesus F, Castela I, Silva AM, Branco PA, Sousa M. Risk of low energy availability among female and male elite runners competing at the 26th European Cross-Country Championships. Nutrients. 2021;13(3):873. doi: 10.3390/nu13030873

20. Witkoś J, Błażejewski G, Gierach M. An Assessment of the early symptoms of energy deficiency as a female athlete triad risk among the polish national kayaking team using LEAF-Q. Int J Environ Res Public Health. 2022;19(10):5965. doi: 10.3390/ijerph19105965

21. Kyte KH, Stensrud T, Berg TJ, Seljeflot I, Hisdal J. Vascular function in norwegian female elite runners: a cross-sectional, controlled study. Sports (Basel). 2022;10(3):37. doi: 10.3390/sports10030037.

22. Souza MJ, Koltun KJ, Williams NI. The role of energy availability in reproductive function in the female athlete triad and extension of its effects to men: an initial working model of a similar syndrome in male athletes. Sports Med. 2019;49(Suppl 2):125-37. doi: 10.1007/s40279-019-01217-3

23. Gould RJ, Ridout AJ, Newton JL. Relative Energy Deficiency in Sport (RED-S) in Adolescents - A Practical Review. Int J Sports Med. 2023;44(4):236-46. doi: 10.1055/a-1947-3174

24. Southmayd EA, Mallinson RJ, Williams NI, Mallinson DJ, De Souza MJ. Unique effects of energy versus estrogen deficiency on multiple components of bone strength in exercising women. Osteoporos Int. 201728(4):1365-76. doi: 10.1007/s00198-016-3887-x

25. McKay AKA, Peeling P, Pyne DB, Tee N, Whitfield J, Sharma AP, Heikura IA, Burke LM. Six days of low carbohydrate, not energy availability, alters the iron and immune response to exercise in elite athletes. Med Sci Sports Exerc. 2022;54(3):377-87. doi: 10.1249/MSS.0000000000002819