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Original article

Risk behaviors for relative energy deficiency in sport in young high-performance Brazilian rhythmic gymnasts

Comportamentos de risco para deficiência de energia relativa no esporte em jovens ginastas rítmicas brasileiras de alto rendimento

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ABSTRACT

Introduction: Rhythmic gymnastics is an aesthetic sport, whose rules encourage long line and lean biotype, exposing gymnasts to the risk of relative energy deficiency in sport (RED-S). Objective: To analyze risk behaviors for RED-S in high-performance Brazilian gymnasts from pre-infant, infant and juvenile categories, with national and international prominence. **Methods:** 36 Brazilian athletes (10 pre-infant, 9 infant and 17 juveniles) were evaluated for body composition, sexual maturation and risk of eating disorders. The investigation of training volume, menstrual cycles, monitoring of bone mineral density and laboratory tests, occurrence of stress fracture, specialized nutritional monitoring and consumption of food supplements, was carried out through a questionnaire adapted by Ackerman. **Results:** The gymnasts had a weekly training volume of 27.32 hours, % of fat mass of 12.1 ± 2.8, with infant having the lowest adiposity. As for sexual maturation, 66.1% were in the pubescent phase, and no athlete reached the post-pubescent phase. The frequency of risk of eating disorders was 55.6%, being the most affected juveniles (70.6%). Only 47.1% of the juveniles had menarche. Only 36.1% have access to a sports nutritionist, while 16.7% evaluated bone mineral density at least once in their career, and 52.8% regularly perform laboratory tests. Stress fracture was reported by 22.2% of the gymnasts, 44.4% in the juveniles. Food supplementation was found in 36.1% of the gymnasts, especially vitamins C and D, and proteins. **Conclusion:** Risk behaviors were found for RED-S in young Brazilian rhythmic gymnasts with high performance, with emphasis for eating disorders, especially in the juvenile category.

Keywords: relative energy deficiency in sport; feeding behavior; gymnastic; adolescent.

RESUMO

Introdução: A ginástica rítmica é uma modalidade esportiva estética, cujas regras encorajam biotipo longilíneo e magro, expondo ginastas ao risco de deficiência energética relativa no esporte (RED-S). Objetivo: Analisar comportamentos de risco para RED-S em ginastas brasileiras de alto rendimento de categorias pré-infantil, infantil e juvenil, com destaque nacional e internacional. **Métodos:** 36 atletas brasileiras (10 pré-infantis, 9 infantis e 17 juvenis) foram avaliadas quanto à composição corporal, maturação sexual e risco de transtornos alimentares. A investigação de volume de treinamento, ciclos menstruais, monitoramento de densidade mineral óssea e de exames laboratoriais, ocorrência de fratura por estresse, acompanhamento nutricional especializado e consumo de suplementos alimentares realizou-se por questionário de Ackerman adaptado. **Resultados:** As ginastas apresentaram volume de treinamento semanal de 27,32 horas, % de massa gorda de 12,1 ± 2,8, sendo as infantis as de menor adiposidade. Quanto à maturação sexual, 66,1% encontravam-se na fase púbere, e nenhuma atleta chegou à fase pós-púbere. A frequência de risco de transtornos alimentares foi de 55,6%, sendo as juvenis mais afetadas (70,6%). Apenas 47,1% das juvenis apresentaram menarca. Somente 36,1% têm acesso a nutricionista esportivo, enquanto 16,7% avaliaram a densidade mineral óssea ao menos uma vez na carreira, e 52,8% realizam exames laboratoriais regularmente. Foi relatada fratura por estresse por 22,2% das ginastas, sendo 44,4% nas juvenis. Encontrou-se suplementação alimentar em 36,1% das ginastas, com destaque para vitaminas C e D e proteínas. **Conclusão:** Foram encontrados comportamentos de risco para RED-S em jovens ginastas rítmicas brasileiras de alto rendimento, com destaque para transtornos alimentares, especialmente na categoria juvenil.

Palavras-chave: deficiência energética relativa no esporte; comportamento alimentar; ginástica; adolescência.

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Introduction

Rhythmic gymnastics (RG) is a sport modality of body movements that requires a combination of beauty, thinness, and elegance of classical ballet, associated with strength and physical fitness. Although the competition exercises last between 90 and 150 seconds, in the individual and group events, respectively, the training sessions are strenuous, consisting of warm-up, ballet, physical preparation, and series training, which can vary according to the periodization phase [1].

In the competitive context, body weight is considered a relevant requirement for good performance in acrobatic modalities, as "smaller" athletes seem to gain biomechanical advantages [2]. Additionally, as it is also an aesthetic modality, the rules of RG indirectly encourage a long biotype and low adiposity. Thus, body shape has been reported to be relevant to satisfy judges and the public, and body weight can be an eliminatory parameter in an elite gymnast selection [3].

The search for the thin biotype makes athletes more susceptible to dietary patterns characterized by an imbalance between energy intake and physical exercise. This increases the risk of adopting health and performance risk behaviors, including eating disorders (ED) [4].

For many years, ED was considered a pillar of the female athlete triad (FAT), together with menstrual dysfunction and impaired bone health [5]. Recently, low energy availability (LEA) was included as a causal factor of FAT, which may or may not be due to ED. Currently, ED continues to be used as diagnostic criteria for FAT and Relative Energy Deficiency in Sport (RED-S) [6].

The term RED-S is considered an expansion of FAT, as it includes other clinical outcomes resulting from LEA, such as the reduced metabolic rate at rest, decreases in immunity and protein synthesis capacity, damage to cardiovascular health, as well as gastrointestinal, hematological, psychological, growth, and development changes [7].

Thus, the assessment of behaviors related to health care of high-performance rhythmic gymnasts is essential to promote strategies for the prevention and treatment of RED-S [8]. This study aimed to describe risk behaviors for the development of RED-S in young athletes with national and international prominence in Brazilian rhythmic gymnastics.

Methods

Experimental design

This is a descriptive and exploratory research. Data were collected during the *Primeiro Estágio de Treinamento de Ginástica Rítmica do Brasil* (First Stage of Rhythmic Gymnastics Training in Brazil), which lasted one week. In the first visit, athletes, coaches, and guardians were informed about all the procedures inherent to the study and, after clarification, they signed the Free and Informed Consent Term (TCLE). On

the second visit, an anthropometric assessment was performed. On the third visit, the athletes answered the questionnaire to characterize the variables of interest and performed a self-assessment of sexual maturation. At the last visit, the athletes responded to tests to assess the risk of eating disorders.

Participants

Thirty-six high-performance Brazilian rhythmic gymnastics athletes were evaluated, with an average age of 12 ± 1.9 years, who participated in the *Primeiro Estágio de Treinamento de Ginástica Rítmica do Brasil* (First Stage of Rhythmic Gymnastics Training in Brazil), an event organized by the Brazilian Gymnastics Confederation, held at Aracaju/SE. To this end, Brazilian gymnasts were invited from the pre-infant (9 to 10 years old), infant (11 to 12 years old) and juvenile (13 to 15 years old) categories, medalists in national and international championships in 2019, in general or with apparatus tests, as well as the gymnasts who represented the South American champion groups, configuring themselves as the elite practicing the sport in Brazil. As exclusion criteria, hormonal contraceptives use was adopted.

Body composition

To characterize the body composition, anthropometry was performed, with collection of body weight, height and skinfolds. Weight and height were measured on an analog scale with a coupled stadiometer (Toledo®) with a precision scale of 100 g and 1.0 cm, respectively. To estimate the percentage of body fat (%FM), the triceps and subscapular skinfolds were measured with a scientific adipometer (Sanny®), with 0.1 mm precision, according to the standards determined by the International Society for Advancement of Kinanthropometry (2001). The measurements were taken three times by the same examiner, not consecutively, considering the mean of the values, which was then applied to the equation of Slaughter et al. (1992) [9] and classified according to Lohman (1992) [10].

Eating disorders

For the risk assessment for eating disorders, the Eating Attitudes Test (EAT-26) in its validated version for females [11] and the Bulimic Investigatory Test Edinburgh (BITE) were adopted. The EAT is a questionnaire consisting of 26 questions, evaluated on a Likert scale with 6 response options (from "always" to "never"), divided into three factors: a) diet – related to pathological refusal to high-content foods caloric and concern with physical appearance; b) bulimia and preoccupation with food: refers to episodes of binge eating, followed by purgative behaviors to lose/control body weight and; c) oral self-control: reflects self-control concerning food and assesses the environmental and social forces that stimulate food intake. The BITE is a validated questionnaire to identify individuals with binge eating and assess cognitive and behavioral aspects related to nervous bulimia [12].

Sexual maturation

Sexual maturation was self-assessed using a board that assesses the development of breasts and pubic hair, according to criteria proposed by Tanner [13], with stage 1 corresponding to the prepubertal phase, stages 2, 3, and 4 characterizing the pubertal period, and stage 5, the post-pubertal phase. In cases where athletes have marked different stages for each secondary sexual character (breasts and pubic hair), the smallest stage was considered, according to Tanner [13].

Risk factors for RED-S

The evaluation of training volume, menstrual cycles, monitoring of bone mineral density (BMD) through Dual-energy X-ray Absorptiometry (DEXA), regular laboratory tests (LT), history of stress fracture (SF), monitoring by a sports nutritionist, as well as the consumption of food supplements, was performed using a questionnaire adapted from Ackerman et al. [6].

Statistical analysis

The collected data were submitted to descriptive statistics, presented as mean and standard deviation. For the normality test, the Kolmogorov-Smirnov test was used. Analysis of Variance (ANOVA) was used, and the significance adopted was $p \leq 0.05$. All statistical procedures were performed using SPSS (*Statistical Package for the Social Sciences*) software, version 21.0.

Ethical aspects

This study followed the guidelines and norms that monitor research with human beings (Law 196/96) and was approved by the local Ethics Committee (opinion 3.121.613). After informing the athletes and their guardians of the risks and testing procedures, the guardians signed an informed consent form.

Results

Table I shows that there were statistical differences in variables such as age, body weight, height, BMI, fat mass, and lean mass, with juvenile athletes being the heaviest, tallest, with higher values of BMI, fat mass, and lean mass in kg, while infants were the gymnasts with the highest percentage of lean body mass.

Figures 1 to 5 demonstrate the frequencies found in the studied population concerning the variables of interest. The association between duration and frequency of the most cited training sessions in all categories evaluated (figure 1) culminated in an average volume of 27.3 hours per week.

Regarding the EAT-26, most gymnasts showed risk behaviors for the development of ED, with the juvenile and pre-infant categories being the most affected. The figure also shows that the risk of bulimia was lower than the results obtained by the EAT-26, with a higher frequency among infant gymnasts (Figure 2).

Table I - Descriptive statistics (mean ± standard deviation) regarding age, training routine, body composition, and risk test scores for eating disorders among young high-performance Brazilian rhythmic gymnasts, according to categories

Variables	Pre-infant (N = 10)	Infant (N= 9)	Juvenile (N = 17)	p	All (N = 36)
Age (years)	9.9 ± 0.3 [c]	11,7 ± 0,5 [b]	14,1 ± 0,6 [a]	0,000	12 ± 1,9
Weekly training frequency	5.8 ± 0.4	5.7 ± 0.5	5,8 ± 0,5	0,736	5,8 ± 0,5
Training sessions duration (h)	4.4 ± 1.3	5.0 ± 1.0	4,7 ± 0,8	0,423	4,7 ± 1,0
Weekly training volume (h)	25.52 ± 7.06	28.5 ± 2.3	27.26 ± 3.8	0.423	27.32 ± 1.0
Weight (kg)	30.4 ± 3.63 [c]	35.9 ± 5.44 [b]	46.2 ± 5.61 [a]	0.000	39.5 ± 8.49
Height (m)	1.36 ± 0.04 [c]	1.48 ± 0.07 [b]	1.58 ± 0.06 [a]	0.000	1.50 ± 0.11
BMI (kg/m²)	16.4 ± 1.1 [b]	16.2 ± 1.1 [b]	18.5 ± 1.4 [a]	0.000	17.4 ± 1.6
% Fat mass	12.3 ± 3.2 [a]	9.4 ± 1.5 [b]	13.9 ± 1.7 [a]	0.000	12.1 ± 2.8
Fat mass (kg)	3.8 ± 1.4 [b]	3.4 ± 0.9 [b]	6.5 ± 1.4 [a]	0.000	4.8 ± 1.92
% Lean mass	87.7 ± 3.2 [b]	90.6 ± 1.5 [a]	86.1 ± 1.42 [b]	0.000	87.9 ± 2.82
Lean body mass (kg)	26.6 ± 2.4 [c]	32.5 ± 4.7 [b]	39.7 ± 4.34 [a]	0.000	34.1 ± 6.8
BITE Score	5.9 ± 3.0	7.0 ± 7.6	8.8 ± 6.1	0.441	7.6 ± 5.8
EAT-26 Score	20.9 ± 10.2	15.8 ± 7.1	23.6 ± 9.6	0.133	20.9 ± 9.5

Values with different letters indicate means with a significant difference ($p < 0.05$). Statistical differences were determined by one-way ANOVA followed by Tukey's test

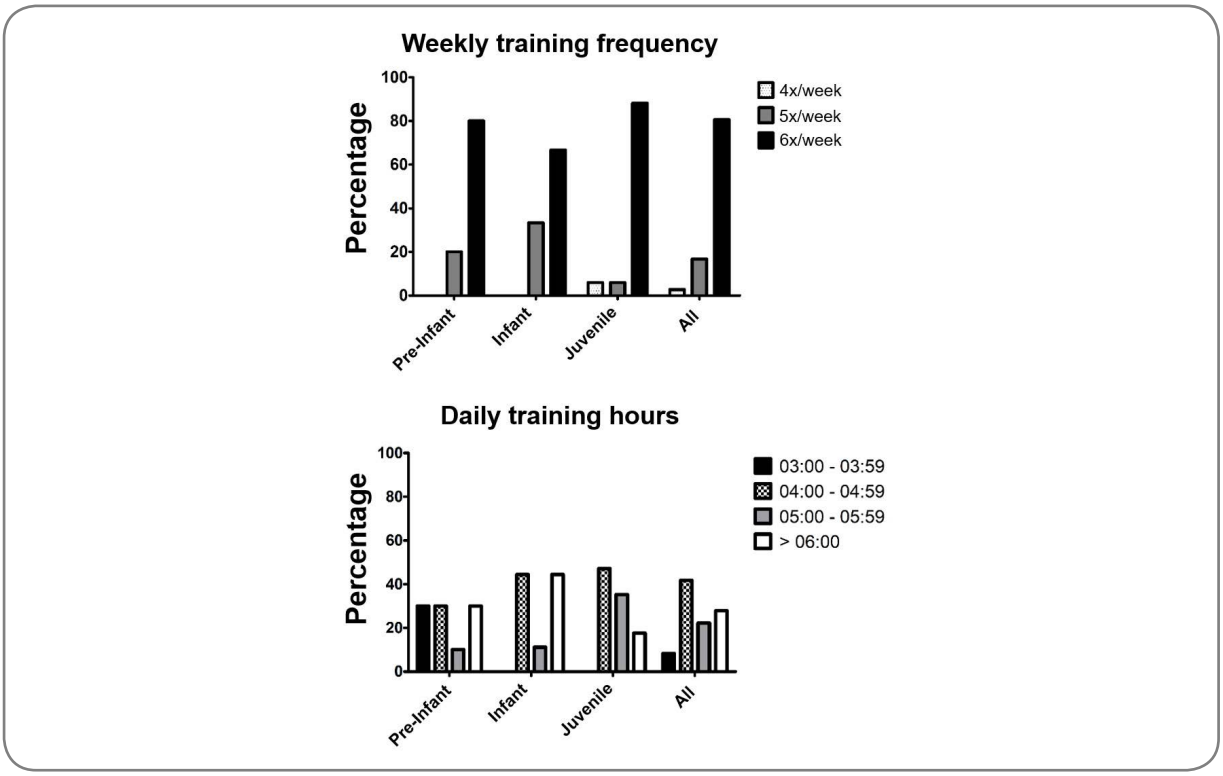

Figure 1 - Weekly frequency and duration of training sessions of the evaluated rhythmic gymnasts, according to the categories

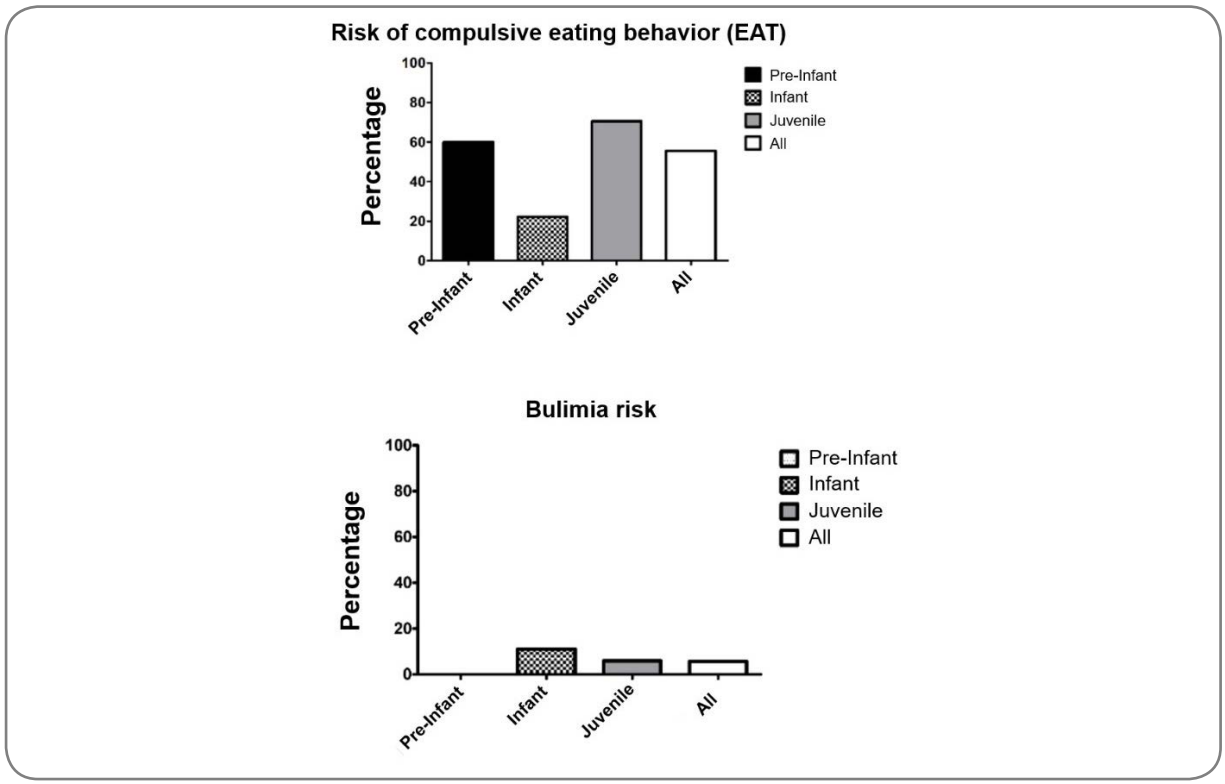

Figure 2 - Risk of eating disorders according to the EAT-26 and BITE instruments, in the evaluated rhythmic gymnasts, according to the categories

As shown in Figure 3, most gymnasts evaluated are in their pubescent stage. When stratifying the results into categories, most pre-infants and infants are in the pre-pubescent phase, and the pubescent phase is unanimous among the juveniles. There was no self-assessed athlete in the postpubertal phase. No athlete in the pre--infant and infant categories had menarche, and a minority of juveniles had menarche. In addition, among the 17 youth gymnasts, 12 (70.6%) athletes were 14 years old, 3 (17.6%) were 15 years old, and 2 (11.8%) were 13 years old.

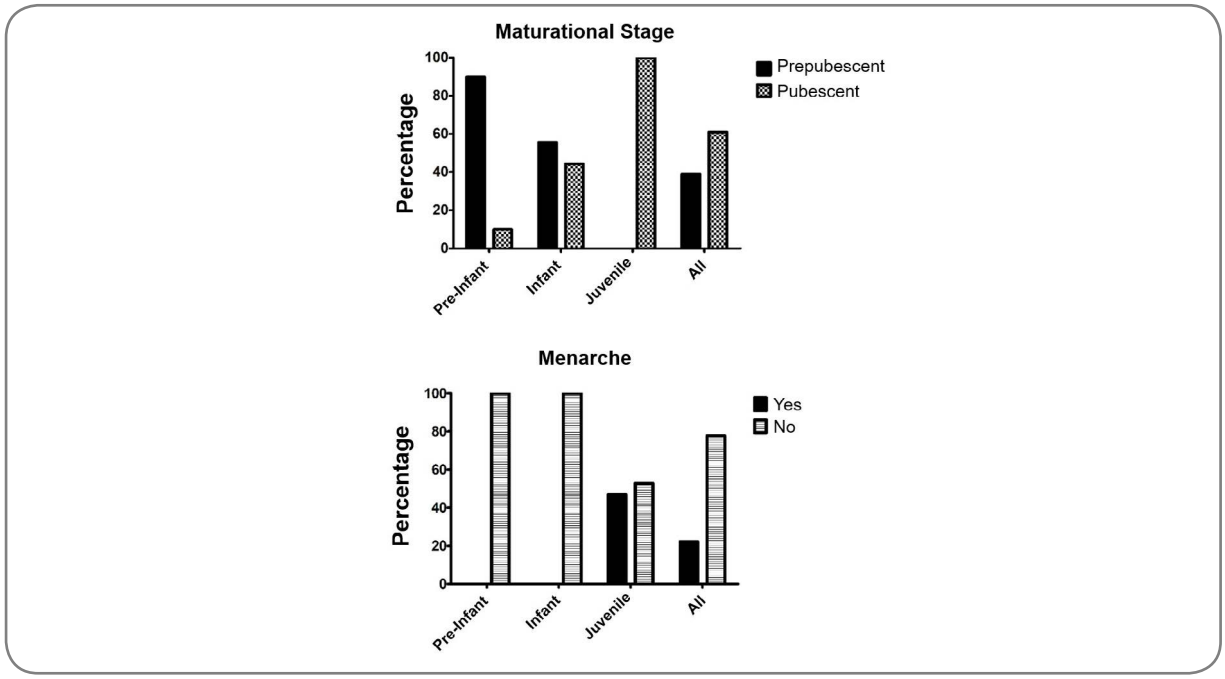

Figure 3 - Sexual maturation and presence of menarche in the evaluated rhythmic gymnasts, according to the categories

Figure 4 shows that a minority of gymnasts have access to specialized nutritional care in the sports area, with this behavior being similar in all categories. About 45% of athletes do not undergo laboratory tests regularly. Figure 4 also shows that few gymnasts performed DEXA at least once in their sports career, with a history of stress fractures, especially those in the infants' category.

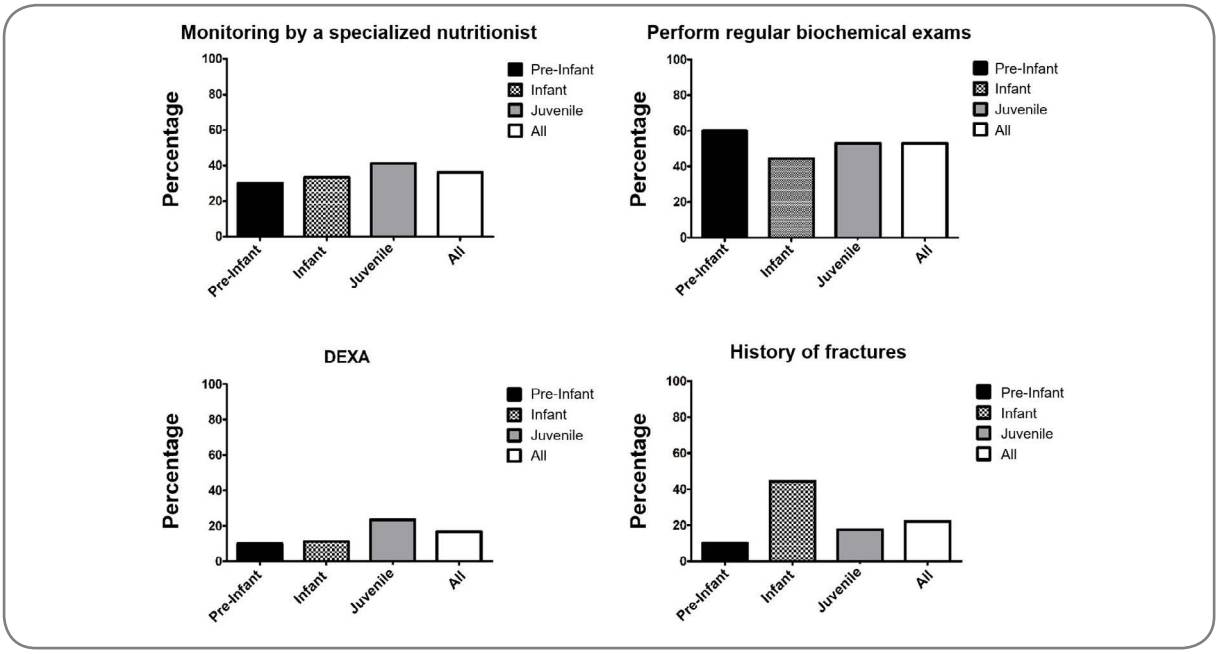

Figure 4 - Monitoring by a sports nutritionist, history of stress fractures, the performance of laboratory biochemical tests, and DEXA by rhythmic gymnasts evaluated, according to the categories

Figure 5 shows that most gymnasts had a low fat-mass percentage, especially in the infants' category.

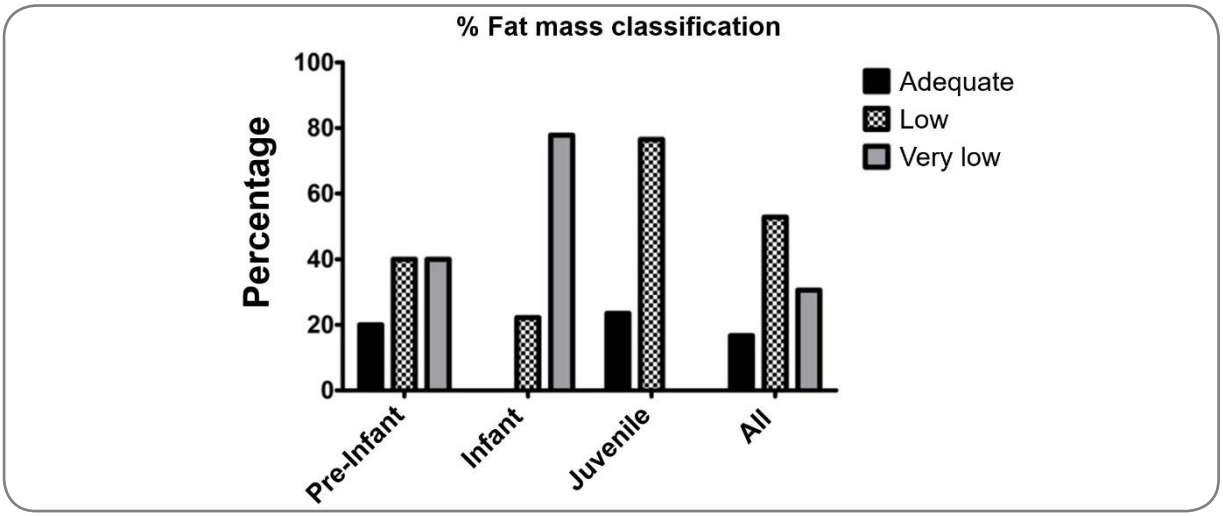

Figure 5 - Classification of the fat mass of the evaluated rhythmic gymnasts, according to the categories

Table II shows the consumption of food supplements, with the juvenile group being the largest consumer, with emphasis on vitamin C, vitamin D, and proteins.

Table II - Frequency of consumption of nutritional supplements and products mentioned by gymnasts

Variables	Pre-infant (N = 10)	Infant (N = 9)	Juvenile (N = 17)	All (N = 36)
Consumption of food supplements	4 (40%)	1 (11.1%)	8 (47.1%)	13 (36.1%)
Maltodextrin	0 (0%)	0 (0%)	3 (17.6%)	3 (8.3%)
Protein supplements	2 (20%)	0 (0%)	2 (11.8%)	4 (11.1%)
Glutamine	0 (0%)	0 (0%)	1 (5.9%)	1 (2.8%)
Arginine	1 (10%)	0 (0%)	0 (0%)	1 (2.8%)
Vitamin C	5 (50%)	1 (11.1%)	6 (35.3%)	12 (33.3%)
MVC	0 (0%)	0 (0%)	1 (5.9%)	1 (2.8%)
Caffeine	0 (0%)	0 (0%)	1 (5.9%)	1 (2.8%)
Coconut oil	0 (0%)	0 (0%)	1 (5.9%)	1 (2.8%)
Marine omega 3	0 (0%)	0 (0%)	3 (17.6%)	3 (8.3%)
Vitamin D	2 (20%)	1 (11.1%)	4 (23.5%)	7 (19.4%)

MVC = Multivitamin and Mineral Complexes

Discussion

The main findings of the present study show that the elite rhythmic gymnasts evaluated had a high training volume and low adiposity, with child athletes being the thinnest. Most gymnasts evaluated were in the pubescent stage, with pre-infants predominantly categorized as pre-pubescent and juveniles as pubescent. High risk for ED was found in most athletes, with juvenile and pre-infant categories being the most affected. Menarche was only identified in juvenile athletes, although most athletes in this category have not yet had their first menstruation. Most gymnasts do not have access to specialized nutritional care in the sports field and do not perform exams considered essential for assessing bone mineral density. Stress fractures were mentioned in all categories, especially those in the children's category. Most gymnasts do not consume nutritional supplements. According to our searches, to date, this is the first national and international study that analyzes behaviors for RED-S in elite young rhythmic gymnasts, stratified by categories.

The high volume of training, associated with low adiposity, and the high risk of eating disorders, has been associated with low energy availability (LEA), the latter being the main etiological factor of RED-S. As a consequence, athletes in LEA can present damage in the hypothalamic-pituitary-gonadal axis, culminating in hypoestrogenism, amenorrhea, alterations in sexual maturation, and even damage to cardiac health [6].

LEA and eating disorders have also been correlated with less release of leptin, insulin, and triiodothyronine (T3), and a greater synthesis of cortisol and parathormone, with these hormonal changes being able to reduce osteoblast activity, culminating in bone demineralization and greater risk of stress fractures. Thus, the International Olympic Committee advises that athletes exposed to the risk of RED-S

perform bone mineral density assessment, through DEXA, every one or two years and that the assessment of biochemical exams be performed every six months [7], thus as the Australian Institute of Sport (AIS) states that such athletes must be accompanied by a specialist nutritionist [14].

The International Society of Sports Nutrition (ISSN) [15] reports that athletes undergoing high-volume training often face difficulties consuming enough food to meet their caloric needs, especially carbohydrates, for reasons related to gastrointestinal discomfort during training and induced hunger suppression by intense exercise. Thus, the ISSN suggests that, in these cases, the use of carbohydrate supplements during training is convenient to prevent low energy availability and RED-S.

Thus, it is possible to infer that the findings of our study point to important signs for the development of RED-S in the evaluated gymnasts, which, in addition to the aforementioned outcomes, can also promote immunological, hematological, psychological, and performance damage [7].

The findings' stratification of the present study, according to age groups, also brought important observations to light. Regarding anthropometric data, the difference in body weight between the three groups may be associated with changes in height, which is expected; however, the higher BMI of the juveniles may be related to the gymnasts' transition to different stages of pubertal development, since in this category all athletes were in the pubertal stage. Gonçalves et al. [16] state there is an increase in body mass as the pre-pubertal individual moves to the pubescent and post-pubescent stages. As for body composition, it is believed that the higher percentage of body fat in pre-infants, concerning children, is related to the process of energy repletion, characteristic of the pre-pubertal phase, and so necessary for future development (pubertal spurt) [17]. The lower percentage of fat mass found in children's gymnasts can also be linked to the stage of sexual maturation, since practically half of the group is pubescent, and according to Fidencio et al. [18], this is the stage in which the spurt usually occurs, favoring the reduction of fat mass. And the greater adiposity found in juveniles, compared to children, may also be related to biological maturation [19]. In Gemelli, Farias, and Spritzer [20], the occurrence of menarche was associated with body fat gain.

The training volume found in the present study was about 27.3 hours, varying between 24 and 30 hours per week. Batista et al. [21] reported a volume of 36 hours/week in athletes from the Brazilian and Portuguese teams of RG, data that are consistent with the results of the present study.

In aesthetic modalities, the combination of intense training and pressure to achieve weight and performance goals can lead athletes to develop risky dietary patterns [21], as well as RED-S [6,7]. The term eating disorder refers to severe disturbances in eating behavior and body image, among which are nervous anorexia and nervous bulimia. The EAT was proposed as an objective and self-report measure of the symptoms of nervous anorexia, thus being more sensitive to the indication of the presence of symptoms common to this type of disorder and has been one of the most

used instruments in research related to ED due to its validity and reliability [22].

In the present study, the investigation using the EAT-26 demonstrated that 55.6% of rhythmic gymnasts presented risk behavior for eating disorders. A prevalence between 10 and 25% of eating disorders in athletes has been found, which are considered higher than the prevalence in non-athletes [23]. However, studies carried out with athletes in aesthetic modalities show even higher frequencies, on average 40%, which is similar to our results [24].

Martínez et al. [4] found a score of 8.73 ± 6.94 and the presence of disorder in two, in a total of 33 gymnasts. Stofeles Cecon et al. [25] found a positive correlation between the percentage of fat mass and body dissatisfaction, indicating that individuals with higher percentages of fat may be more susceptible to the development of ED. In our study, the athletes who were at higher risk were those who had higher adiposity in a modality that requires thinness, which could indicate an association between body image dissatisfaction and the onset of eating disorders. However, a limitation of the present study was the lack of self-perceived image assessment and body satisfaction.

Athletes in aesthetic sports are more likely to develop characteristic behaviors of low energy availability (LEA), as they seek to maintain a body composition that meets the standards required by the sport [21]. Although we have not evaluated the total energy intake and the energy expenditure added by the training of the gymnasts evaluated in this study, which we consider a limitation, a high frequency of athletes classified as having a very low percentage of fat mass was observed, and thinness has been correlated with LEA [26].

It is known that the two main outcomes of RED-S are impairment of menstrual function and bone health [5]. Although genetic factors are the main determinants of puberty onset, nutritional, health, and psychological status may be involved in the process. Additionally, a high level of physical exercise can promote pubertal development delay [27]. The age at which menarche occurs varies considerably between countries; in Brazil, studies carried out between 2010 and 2014 showed a mean age of 12.2 years [20]. Camargo [28] found the presence of menarche in only 26% of its sample of 132 Brazilian athletes from RG, with an average of 13.2 years. Adolescents with marked thinness and thinness had a mean of 13.53 years and 13.39 years, respectively [29]. In our study, no athlete from the infantile category had menarche, and only 47.1% of the juvenile athletes had the first cycle, which may indicate a delay in pubertal development, indicating menstrual impairment [7].

As for bone health, our study found that, although very young, practically a quarter of the athletes have already had stress fractures and almost half of the juvenile gymnasts. It is noteworthy that these fractures are less common in children and adolescents when compared to adults [30]. Additionally, it has been shown that only less than one-fifth of rhythmic gymnasts have undergone bone mineral density assessment by DEXA, although this is a test suggested by the International Olympic Committee [7] and the Australian Institute of Sport [14] for screening for high-performance athletes, to diagnose RED-S early.

Concerning aesthetic modalities, in which eating disorders and RED-S are more prevalent, in addition to the investigation of the two main outcomes (menstrual and bone damage), it is essential to investigate other clinical possibilities, such as the follow-up of RED-S-related biomarkers, such as leptin, T3 and free thyroxine (T4l), estradiol, testosterone, cortisol, and lipid profile and blood count [31]. For this purpose, the Australian Institute of Sports [14] determines that the interdisciplinary team must be composed of at least one doctor, a sports nutritionist, and a psychologist, this being called the "central multidisciplinary team". However, in the present study, only 36.1% of the evaluated rhythmic gymnasts are accompanied by a sports nutritionist, and practically half of those evaluated are not regularly submitted to laboratory tests.

About food supplementation, there was an average consumption of 36.1%, highlighting a higher frequency of consumption of vitamin C, followed by vitamin D and proteins, while only 8.3% reported consuming carbohydrates (maltodextrin). This result differs from the study by Jovanov et al. [32], in which consumption of supplements was seen by 82.2% of 348 athletes and a tendency by younger athletes (15-16 years) to use carbohydrates, beta-alanine, glutamine, vitamins, and mineral complexes. It is necessary to highlight that the average duration of the gymnasts' training sessions evaluated in this study was 4.7 hours, and, according to the International Society of Sports Nutrition (ISSN) [15], athletes engaged in prolonged training sessions can benefit by supplementing carbohydrates in solutions with concentrations between 6 and 8% of this nutrient, also because in this dilution the digestion and absorption of carbohydrate would be facilitated. It is noteworthy that better gastric emptying can be considered an advantage in an acrobatic modality, in which there are many jumps and aerial activities.

Vitamin C (ascorbic acid) was the most used supplement by athletes, and its use in sports is associated with increased antioxidant capacity and reduced excessive production of reactive oxygen species during and immediately after exercise. However, the results are still controversial, since in some studies no positive effects on markers of performance or recovery after exercise were observed [33]; while, others suggest that 400 mg supplementation can act in the reduction of late-onset muscle pain and recovery of maximum contractile function [34]. It is noteworthy that vitamin C supplementation can be considered a positive factor in the prevention of RED--S, provided that it is guided by a sports nutritionist, since iron deficiency is a crucial factor in the hematological outcomes of RED-S [35] and vitamin C is a determining factor in increasing iron bioavailability [36].

In the present study, some gymnasts also mentioned the intake of vitamin D supplements. Low serum vitamin D concentrations have been associated with an increased risk of fractures [37]. Vitamin D can be obtained from diet and sun exposure. However, this exposure is highly variable depending on environmental factors, skin pigmentation, clothing, and the use of sunscreen. Therefore, obtaining it from diet or supplements may be necessary [34]. According to Mountjoy et al. [7], athletes with

bone damage due to RED-S, or at risk for it, may benefit from a daily intake of 1500 to 2000 IU of vitamin D until serum concentration of 25-hydroxy vitamin D between 38-50 ug/day.

About protein supplementation, it is known that whey protein, the most mentioned protein supplement by the participants in this study, has some relevant qualities, especially concerning digestion speed and leucine concentration [38]. However, the use of this supplement should be evaluated by a sports nutritionist, as the sum of proteins ingested via food and supplement must be considered since high-protein diets can be associated with a reduction in pH, which in healthy and non-athletes, is easily reversed through buffers such as bicarbonate. However, in high-performance athletes, metabolic acidosis has been the subject of great debate, as carnosine and bicarbonate are not always sufficient to control the drop in pH generated by exercise [39], and protein excess could contribute even more for this ergolytic situation.

Additionally, acidosis has been associated with the use of bone alkaline reserves for tamponade, which would incur less bone mineralization, which could be an aggravating factor in aesthetic modalities where the risk of RED-S is greater. It is noteworthy that, although less frequently, caffeine was cited by the rhythm gymnasts evaluated, and its consumption has been associated with a reduction in BMD and increased risk of fracture, mainly due to the adverse effects on calcium balance, increasing its excretion or decreasing its absorption [40]. Its use without professional monitoring can generate a potential risk to the bone health of the rhythmic gymnasts evaluated in this study, especially when we associate this practice with other detected risk factors, such as low frequency of monitoring of bone mineral density by DEXA, low frequency of menarche in juvenile athletes, very low concentrations of fat mass, low frequency of laboratory tests, high training volume, and especially, high frequency of eating disorders.

The present study contributes to a better understanding of the risk factors for the development of RED-S in RG athletes stratified by categories, little explored in previous research. Brazilian rhythmic gymnastics is a modality on the rise in Brazil, with the Brazilian team having recently qualified for the Olympic Games in Tokyo. Therefore, our findings can contribute to the development and implementation of effective strategies to guide actions for the prevention and/or treatment of eating disorders and RED-S by inter or transdisciplinary teams.

Conclusion

The study showed a high prevalence of eating disorders associated with high training volume, low adiposity, reduced bone mineral density monitoring, presence of training-related fractures, low frequency of follow-up by a sports nutritionist, and irregular laboratory tests in young high-performance Brazilian gymnasts in the pre-infant, infant and juvenile categories. And in the juvenile category, a delay in pubertal development was found. Such factors are related to a higher risk of relative energy deficiency in sport.

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Potential conflict of interest
No conflicts of interest were reported.

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Authors' Contribution
Conception and design of the research: Marques IL, Mendes RR; **Obtaining data:** Marques IL, Menezes VO, Silva RJ; **Data analysis and interpretation:** Marques IL, Menezes VO, Silva RJ, Mendes RR; **Statistical analysis:** Gomes JH; **Obtaining financing:** Marques IL. **Manuscript writing:** Marques IL, Mendes RR; **Critical review of the manuscript for important intellectual content:** Mendes RR.

References

1. Gram MCD, Bø K. High level rhythmic gymnasts and urinary incontinence: Prevalence, risk factors, and influence on performance. Scand J Med Sci Sport 2019;00:1-7. doi: 10.1111/sms.13548

2. Wasserfurth P, Palmowski J, Hahn A, Krüger K. Reasons for and consequences of low energy availability in female and male athletes: social environment, adaptations, and prevention. Sport Med Open 2020;6(1):44. doi: 10.1186/s40798-020-00275-6

3. San Mauro Martín I. Aspectos nutricionales, antropométricos y psicológicos en gimnasia rítmica. Nutr Hosp 2016;33(4). doi: 10.20960/nh.383

4. Martínez-Rodríguez A, Reche-García C, Martínez-Fernández MDC, Martínez-Sanz JM. Assessment of nutritional-dietary status, body composition, eating behavior, and perceived image in rhythmic gymnastics athletes. Nutr Hosp 2020;37(6):1217-25. doi: 10.20960/nh.03141

5. Brook EM, Tenforde AS, Broad EM, Matzkin EG, Yang HY, Collins JE, et al. Low energy availability, menstrual dysfunction, and impaired bone health: A survey of elite para athletes. Scand J Med Sci Sports 2019;29(5):678-85. doi: 10.1111/sms.13385

6. Ackerman KE, Holtzman B, Cooper KM, Flynn EF, Bruinvels G, Tenforde AS, et al. Low energy availability surrogates correlate with health and performance consequences of Relative Energy Deficiency in Sport. Br J Sports Med 2019;53(10):628-33. doi: 10.1136/bjsports-2017-098958

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. Moraes LCL, Moraes e Silva M, Rinaldi IPB, Rojo JR, Gomes LDC. Ginástica rítmica: perfil sobre a produção científica em periódicos da América Latina, Caribe e Países Ibéricos. Pensar Mov [Internet] 2019 [cited 2020 Nov 19];17(1):e33546. Available from: https://revistas.ucr.ac.cr/index.php/pem/article/view/33546

9. Slaughter MH, Lohman TG, Boileau RA, Horswill CA, Stillman RJ, Van Loan MD, et al. Skinfold equations for estimation of body fatness in children and youth. Hum Biol [Internet].1988 [cited 2020 Nov 19];60(5):709-23. Available from: http://www.ncbi.nlm.nih.gov/pubmed/3224965

10. Lohman TG. Advances in body composition assessment. Champaign IL: Human Kinetics Publishers; 1992.

11. Bighetti F. Tradução e validação do Eating Attitudes Test (EAT-26) em adolescentes do sexo feminino na cidade de Ribeirão Preto - SP [Internet]. [Ribeirão Preto]: Universidade de São Paulo; 2003. [cited 2020 Nov 20]. Available from: http://www.teses.usp.br/teses/disponiveis/22/22133/tde-12042004-234230/

12. Henderson M, Freeman CP. A self-rating scale for bulimia. The "BITE". Br J Psychiatry 1987;150:18–24. doi: 10.1192/bjp.150.1.18

13. Tanner JM. Growth at adolescence. With a general consideration of the effects and environmental factors upon growth and maturation from birth to maturity. 2 ed. Vol. 28, Oxford: Blackwell Scientific; 1962. 325 p.

14. Wells KR, Jeacocke NA, Appaneal R, Smith HD, Vlahovich N, Burke LM, et al. The Australian Institute of Sport (AIS) and National Eating Disorders Collaboration (NEDC) position statement on disordered eating in high performance sport. Br J Sports Med 2020;54(21):1247–58. doi: 10.1136/bjsports-2019-101813

15. Kerksick CM, Wilborn CD, Roberts MD, Smith-Ryan A, Kleiner SM, Jäger R, et al. ISSN exercise &

sports nutrition review update: Research & recommendations. J Int Soc Sports Nutr 2018;15(1):38. doi: 10.1186/s12970-018-0242-y

16. Gonçalves LGC, Aquino RLQT, Filho HT, Puggina EF. Caracterização do perfil de jovens jogadores de futebol: uma análise das habilidades técnicas e variáveis antropométricas. Motricidade 2016;12(2):27. doi: 10.6063/motricidade.6718

17. Takahashi LAR, Santos Figueiredo FW, Benedet J, Vasconcelos FAG, Adami F. Influence of sexual maturation status on the relationship between body adiposity indicators and age: a cross-sectional study. BMC Res Notes 2019;12(1):61. doi: 10.1186/s13104-019-4095-5

18. Fidencio J, Gonçalves Ferreira M, Ana Czarnobay S, Meurer Campos V. Associação entre estado nutricional, horas de consumo de tela e de atividade física em adolescentes. Revista Brasileira de Obesidade, Nutrição e Emagrecimento [Internet]. 2018 [cited 2020 Nov 12];12(72):535-41. Available from: https://dialnet.unirioja.es/servlet/articulo?codigo=6985681

19. Chung S. Growth and puberty in obese children and implications of body composition. J Obes Metab Syndr 2017;26(4):243-50. doi: 10.7570/jomes.2017.26.4.243

20. Gemelli IFB, Farias ES, Spritzer PM. Association of body composition and age at menarche in girls and adolescents in the Brazilian Legal Amazon. J Pediatr (Rio J) 2020;96(2):240-6. doi: 10.1016/j.jped.2018.10.012

21. Batista A, Garganta R, Ávila-Carvalho L. Morphological characteristics and biological maturation of brazilian and portuguese gymnasts. Int J Morphol [Internet]. junho de 2019;37(2):561-7. http://doi.org/10.4067/S0717-95022019000200561

22. Spivak-Lavi Z, Peleg O, Tzischinsky O, Stein D, Latzer Y. Differences in the factor structure of the Eating Attitude Test-26 (EAT-26) in different cultures in Israel: Jews, Muslims, and Christians. Nutrients 2021;13(6):1899. doi: 10.3390/nu13061899

23. Petisco-Rodríguez C, Sánchez-Sánchez LC, Fernández-García R, Sánchez-Sánchez J, García-Montes JM. Disordered Eating Attitudes, Anxiety, Self-Esteem and Perfectionism in Young Athletes and Non-Athletes. Int J Environ Res Public Health 2020;17(18):6754. doi: 10.3390/ijerph17186754

24. Fortes L, Almeida S, Ferreira M. Influência da ansiedade nos comportamentos de risco para os transtornos alimentares em ginastas. Rev Bras Atividade Física Saúde 2013;18(5). doi: 10.12820/rbafs.v.18n5p546

25. Stofeles Cecon R, Castro Franceschini SC, Gouveia Peluzio MC, Miranda Hermsdorff HH, Priore SE. Anthropometric profile, body composition and body image perception of adolescents with positive screening for eating disorders. Rev Chil Nutr 2017;44(4):337-40. doi: 10.4067/s0717-75182017000400337

26. Sim A, Burns SF. Review: questionnaires as measures for low energy availability (LEA) and relative energy deficiency in sport (RED-S) in athletes. J Eat Disord 2021;9(1):41. doi: 10.1186/s40337-021-00396-7

27. Campos CG, Carlos FM, Muniz LA, Bila WC, Damasceno VO, Romano MCC, et al. Atividade física na adolescência e maturidade sexual: uma revisão sistemática. Cienc Saude Colet [Internet]. 2021 [cited May 2021];26(5):1823-32. Available from: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1413-81232021000501823&tlng=pt

28. Camargo CTA, Gomez-Campos RA, Cossio-Bolaños MA, Barbeta VJDO, Arruda M, Guerra-Junior G. Growth and body composition in Brazilian female rhythmic gymnastics athletes. J Sports Sci 2014;32(19):1790-6. doi: 10.1080/02640414.2014.926381

29. Barros BS, Kuschnir MCMC, Bloch KV, Silva TLN. ERICA: age at menarche and its association with nutritional status. J Pediatr (Rio J) 2019;95(1):106-11. doi: 10.1016/j.jped.2017.12.004

30. Prado MP, Abussamra A, Mendes M, Medeiros BC, Longo CH, Alberto L. Fraturas por estresse do pé e tornozelo na criança. Assoc Bras Med e Cir do Tornozelo e Pé 2012;6:2-9. Available from: https://jfootankle.com/ABTPe/article/view/603

31. Elliott-Sale KJ, Tenforde AS, Parziale AL, Holtzman B, Ackerman KE. Endocrine effects of relative energy deficiency in sport. Int J Sport Nutr Exerc Metab 2018;28(4):335-49. doi: 10.1123/ijsnem.2018-0127

32. Jovanov P, Đorđić V, Obradović B, Barak O, Pezo L, Marić A, et al. Prevalence, knowledge and attitudes towards using sports supplements among young athletes. J Int Soc Sports Nutr 2019;16(1):27. doi: 10.1186/s12970-019-0294-7

33. Oliveira DCX, Rosa FT, Simões-Ambrósio L, Jordao AA, Deminice R. Antioxidant vitamin supplementation prevents oxidative stress but does not enhance performance in young football athletes. Nutrition 2019;63/64:29-35. doi: 10.1016/j.nut.2019.01.007

34. Heaton LE, Davis JK, Rawson ES, Nuccio RP, Witard OC, Stein KW, et al. Selected in-season nutritional strategies to enhance recovery for team sport athletes: a practical overview. Sports Med [Internet]. 2017;47(11):2201-18. Available from: http://www.ncbi.nlm.nih.gov/pubmed/28702900

35. Williams NI, Statuta SM, Austin A. Female athlete triad: future directions for energy availability and eating disorder research and practice. Clin Sports Med 2017;36(4):671-86. doi: 10.1007/s40279-017-0759-2

36. Lynch S, Pfeiffer CM, Georgieff MK, Brittenham G, Fairweather-Tait S, Hurrell RF, et al. Biomarkers of Nutrition for Development (BOND) Iron Review. J Nutr 2018;148(suppl1):1001S-1067S. doi: 10.1093/jn/nxx036

37. Krahenbühl T, Borges JH, Barros-Filho AA, Guerra-Junior G, Gonçalves EM. Assessment of bone

mineral density in young female handball players. Rev Bras Cineantropom Desempenho Hum 2018;20(1):102-13. doi: 10.5007/1980-0037.2018v20n1p102

38. Jäger R, Kerksick CM, Campbell BI, Cribb PJ, Wells SD, Skwiat TM, et al. International Society of Sports Nutrition Position Stand: protein and exercise. J Int Soc Sports Nutr 2017;14(1):20. doi: 10.1186/s12970-017-0177-8

39. Huerta Ojeda Á, Tapia Cerda C, Poblete Salvatierra MF, Barahona-Fuentes G, Jorquera Aguilera C. Effects of beta-alanine supplementation on physical performance in aerobic-anaerobic transition zones: a systematic review and meta-analysis. Nutrients 2020;12(9):2490. doi: 10.3390/nu12092490

40. Chau Y-P, Au PCM, Li GHY, Sing C-W, Cheng VKF, Tan KCB, et al. Serum metabolome of coffee consumption and its association with bone mineral density: The Hong Kong Osteoporosis Study. J Clin Endocrinol Metab 2020;105(3):e619-27. doi: 10.1210/clinem/dgz210