9º Congresso Nacional
9th National Congress
7º Congresso Internacional
7th International Congress

Ginástica na Sociedade Global
Gymnastics in the Global Society

Maria-Raquel G. Silva
Cidália Freitas
Gonçalo Marques
Francisco Saavedra
(Editores)

Federação de Ginástica de Portugal
Universidade de Trás-os-Montes e Alto Douro

Outubro 2024

Título	9º Congresso Nacional de Ginástica - 7º Congresso Internacional: Ginástica na Sociedade Global. Anais do Congresso
Title	*9th National Gymnastics Congress - 7th International Congress: Gymnastics in the Global Society. Proceedings of the Congress*
Editores	Maria-Raquel G. Silva, Cidália Freitas, Gonçalo Marques e Francisco Saavedra
Capa	Carolina Cordeiro Carujo
Tipo de suporte	Eletrónico
Detalhe do suporte	PDF
Edição	1ª Edição
Ano	2024
Publicado por	Federação de Ginástica de Portugal
ISBN (eletrónico)	978-989-8650-67-2

A informação contida nos artigos é decorrente dos trabalhos apresentados durante o 9º Congresso Nacional de Ginástica - 7º Congresso Internacional: Ginástica na Sociedade Global, organizado pela Federação de Ginástica de Portugal. Os artigos sofreram um processo de *revisão* por pares. As versões finais são da inteira responsabilidade dos seus autores.

The contents of the articles are based on the work presented during the 9th National Gymnastics Congress - 7th International Congress: Gymnastics in the Global Society, organised by the Portuguese Gymnastics Federation. The articles were peer-reviewed. The final versions are the sole responsibility of their authors.

Relative energy deficiency in sport in young Portuguese gymnasts

Défice energético relativo no desporto em jovens ginastas portuguesas

Maria-Raquel G Silva*[1,2,3,4,5,6,7], Mariana Silva[1], Afonso Silva[8], Teresa Paiva[3,7], Hugo-Henrique Silva[9,10]

[1]FP-I3ID and Faculty of Health Sciences, University Fernando Pessoa, 4200-150 Porto, Portugal

[2]CI-IPOP - IPO Porto Research Center, Portuguese Oncology Institute of Porto, Porto, Portugal

[3]CHRC-Comprehensive Health Research Centre-Nova Medical School, Nova University of Lisbon, 1150-090 Lisboa, Portugal

[4]CIAS-Research Centre for Anthropology and Health - Human Biology, Health and Society, University of Coimbra, 3000-456 Coimbra, Portugal

[5]RISE-Health, Network of Research in Health, Fundação Fernando Pessoa, Porto, Portugal

[6]Gymnastics Federation of Portugal – Scientific Committee, 1600-159 Lisboa, Portugal

[7]CENC-Sleep Medicine Centre, Lisbon, Portugal

[8]School of Health Fernando Pessoa, 4200-253 Porto, Portugal

[9]ICBAS-School of Medicine and Biomedical Sciences, University of Porto, 4050-313 Porto, Portugal

[10]Portuguese Ministry of Education, 1399-025 Lisbon, Portugal

*E-mail: raquel@ufp.edu.pt

Abstract

Objective: Research on energy-deficient athletic cohorts has broadened the concept of the Female Athlete Triad into the Relative Energy Deficiency in Sport syndrome, that represents a spectrum of abnormalities induced by low energy availability, affecting competing athletes, in particular gymnasts. The present study aimed to evaluate the nutritional status, body composition, including bone mineral density, of rhythmic and artistic gymnasts, during the competitive period. Methods: Data were collected using a questionnaire about sociodemographic data, training, food intake (3- non-consecutive days food record) and body composition (anthropometry, bioelectrical impedance and bone densitometry). All participants (n=59) provided informed consent. Statistical analysis was performed using the Statistical Package for Social Sciences version 27 for Windows. Main results: The athletes' mean age was 12.0±2.8 years old and they trained 13.6±5.5 hours/week. They showed reduced body weight, height and body fat, and a high fat-free mass (37.0±9.8Kg; 144.9±12.4cm; 9.8±2.9%; 96.1±1.7%; respectively). Their bone mineral density estimated was 0.60±0.08g/cm², which doesn't represent a risk to bone health. They showed an energy intake of 1370.0±454.2kcal/day and an energy availability of 35.8±15.9kcal/kg fat-free mass/day. Regarding the distribution of macronutrients, 62.7% were below carbohydrates recommendations, 67.8% exceed those of protein and 62.7% consumed fat according to the recommendations. In terms of micronutrients, vitamins D, E and K, and minerals' consumption, such as calcium, magnesium and potassium were below the recommendations (13.9±6.2µg/day; 591.0±259.2mg/day; 165.2±51.0mg/day; 1920.4±618.6mg/day; respectively). Conclusions: Gymnasts revealed energy deficiency, as well as, low energy availability, which were reflected in

their body composition. Therefore, nutritional education is urgent for gymnasts and all around them.

Keywords: relative energy deficiency in sport; nutrition; body composition; bone mineral density; gymnastics.

Resumo

Objetivo: A investigação em coortes com atletas sobre deficiência energética alargou o conceito da Tríade da Mulher Atleta para a síndrome da Deficiência Energética Relativa no Desporto, que representa um espectro de alterações induzidas pela baixa disponibilidade energética, afetando atletas de competição, em particular, ginastas. O presente estudo teve como objetivo, avaliar o estado nutricional, a composição corporal, incluindo a densidade mineral óssea de ginasta de ginástica rítmica e artística, durante o período competitivo. Métodos: Os dados foram recolhidos através de um questionário sobre dados sociodemográficos, treino, consumo alimentar (registo alimentar de 3 dias não consecutivos) e composição corporal (antropometria, bioimpedância elétrica e densitometria óssea). Todos os participantes (n=59) forneceram consentimento informado. A análise estatística foi realizada com o programa *Statistical Package for Social Sciences*, versão 27, para *Windows*. Principais resultados: A média de idades dos atletas foi de 12,0±2,8 anos e treinaram 13,6±5,5 horas/semana. Apresentaram peso corporal, estatura e gordura corporal reduzidos e elevada massa livre de gordura (37,0±9,8Kg; 144,9±12,4cm; 9,8±2,9%; 96,1±1,7%, respetivamente). A densidade mineral óssea estimada foi de 0,60±0,08g/cm², o que não representa risco para a saúde óssea. Apresentaram um aporte energético de 1370,0±454,2kcal/dia e uma disponibilidade energética de 35,8±15,9kcal/kg massa livre de gordura/dia. Quanto à distribuição dos

macronutrientes, 62,7% estavam abaixo das recomendações de hidratos de carbono, 67,8% superavam as de proteínas e 62,7% consumiam gorduras, de acordo com as recomendações. Em termos de micronutrientes, os consumos de vitaminas D, E e K, e de minerais, como cálcio, magnésio e potássio, ficaram abaixo das recomendações (13,9±6,2µg/dia; 591,0±259,2mg/dia; 165,2±51,0mg/dia; 1920,4±618,6mg/dia respetivamente). Conclusões: As ginastas revelaram deficiência energética, bem como, baixa disponibilidade energética, o que se refletiu na sua composição corporal. Como tal, a educação nutricional é urgente para os ginastas e para todos os que os rodeiam.

Palavras-chave: deficiência energética relativa no desporto; nutrição; composição corporal; densidade mineral óssea; ginástica.

Introduction

Rhythmic (RG) and Women's Artistic Gymnastics (WAG) are characterized by regular training producing high mechanical impact on the musculoskeletal system (Jürimäe, Gruodyte-Raciene, & Baxter-Jones, 2018; Tamoliené et al., 2021) and a strong aesthetic dimension (Martínez Rodríguez et al., 2020).

High-performance athletes tend to have an intense volume of training and competition. Given the aesthetic aspect and the intensity of training and competitions at such young ages, there is a great concern with body weight and body image (Aguilo et al., 2021). This concern results in a tendency towards energy and nutritional restriction and/or excessive energy expenditure, which can result in low energy availability (LEA) (Amato et al., 2021).

LEA is characterized by insufficient energy for physiological needs (Villa et al., 2021) and can have several health impacts, such as reproductive (amenorrhea), bone

health (osteoporosis) (Amato et al., 2021), changes in growth and maturation and potential risk of injury (Silva & Paiva, 2016; Jakše et al., 2021). Furthermore, it also has an impact on sports performance (Silva & Paiva, 2015).

Based on some studies focused on the evaluation of the food and nutritional intake of athletes, it was found that their diet tends to be low in energy and with inadequacies in relation to protein, carbohydrates and micronutrients' needs, despite varying between some age-groups (Silva & Paiva, 2015; Jakše et al., 2021).

In addition to the great concern with body image, dietary restrictions may also be due to the high number of hours of training and, consequently, few opportunities to have adequate meals to athletes' needs (Meng et al., 2020). Thus, considering the inadequate intake and possible physiological consequences, the role of food education becomes important for athletes, their families and coaches. Thus, adequate support for carrying out food plans suited to their needs, whether pre-, during or post-training, promoting the optimization of their performance and health promotion is needed.

Gymnasts are characterized by lean body mass (Martinez Rodriguez et al., 2020), low body fat mass (Meng et al. 2020) and low body weight (Jakše et al., 2021).

However, these components may vary depending on the period of the sport season, and may be influenced by various factors, such as: genetics, endocrine status, nutritional status, and physical activity (Silva et al., 2015; Silva et al., 2022, 2023).

Competitive gymnastics promotes an osteogenic effect on the skeleton system due to its high mechanical impact on a regular basis, which is normally practiced in a phase of growth and maturation (Parm et al., 2012).

Some studies have found that athletes, mainly in RG at prepubertal age, demonstrate greater bone development compared to non-athletes, and that they have high bone mineral density (BMD) (Parm et al., 2012), which in turn remain in adulthood.

These high BMD values are a good marker for bone health and osteoporosis prevention (Jürimäe et al., 2018).

As is well known, osteoporosis is a consequence of LEA in these athletes resulting from a prolonged energy restriction which, in turn, leads to hormonal changes affecting reproductive health and BMD (Silva & Paiva, 2015). Thus, the positive effect of intense training on BMD may override the negative effect of LEA (Parm et al., 2012; Silva & Paiva, 2015).

Given the characteristics already recognized of these athletes, but still understudied in Portuguese gymnasts, the present work aims to evaluate the nutritional intake, body composition and bone mineral density in Portuguese gymnasts (RG and WAG) in the competitive period.

Methods

A questionnaire was applied in which sociodemographic data, medical history (presence/absence of disease, medication/supplementation, occurrence of bone fractures), and data on sports practice (years of gymnastics practice, hours of training per day and number of times per week) were collected during a competitive period of the athletic season.

Regarding the assessment of food intake, food diaries of 3 non-consecutive days were provided, including a weekend day. Gymnasts recorded all foods and drinks consumed during the 3 days, taking into account the preparation/cooking methods, product labels and the respective times and places of consumption. Portions were recorded as household measures, which were later converted into quantitative measures (grams and millilitres) for further analysis. Subsequently, the food data were converted to nutrients by the software *Food Processor*.

Energy availability (EA) was calculated by subtracting energy expenditure in physical exercise from energy intake adjusted for fat-free mass (FFM).

Energy expenditure was obtained by multiplying the Metabolic Equivalent of Tasks (MET) by the weight in kilograms and the duration of the exercise in hours.

EA is considered healthy when equal to or greater than 45 kcal/kg of FFM/day. and when below. this it is considered LEA. It was also assumed that less than 30 kcal/kg of FFM/day negatively compromises reproductive function and bone health (Silva & Paiva, 2015).

At the same time, the athletes' body composition measurement was performed by trained evaluators in a standardized way. Anthropometric data were collected according to International Society for the Advancement of Kinanthropometry (ISAK) procedures (Marfell-Jones, Stewart, & de Ridder, 2012), in triplicate, with the final recording of the average of the 3 measurements. Athletes were evaluated wearing only sports tops and gym shorts.

Height, the perimeter of the relaxed arm at the *Mid-Acromial-Radiale point*, the waist circumference and the hip circumference were assessed (Silva, 2015).

Fat mass, fat-free mass and total body water were measured by electrical bioimpedance (Silva, 2015).

Body mass index (BMI) was calculated by dividing body weight, in kilograms, by the square of height, in meters (Kg/m^2).

BMD was estimated by bone densitometry of the calcaneus, according to Silva (2015).

The study was approved by the Ethics Committee of University Fernando Pessoa (Porto, Portugal), and all participants gave informed consent.

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS Statistics, IBM) version 27.0 for Windows. The normality of variables was assessed by Kolmogorov-Smirnov for samples greater than 30 and by Shapiro-Wilk for samples less than 30. To compare variables, the T-student statistical tests were used, for variables with a normal distribution, and Mann-Whitney, for variables where at least one does not present a normal distribution. To compare results with reference values, the One-sample T test was used. For categorical variables, the Chi-square test was performed. The results are presented as an average with respective standard deviation, minimum and maximum and percentages.

To evaluate the correlation between continuous or ordinal variables, without normal distribution, the Spearman's correlation coefficient (ρ) was used. Statistical significance was assumed when the p value was less than 0.05.

Results

In the present study, 59 competitive athletes were evaluated, with a mean age of 11.97 ± 2.76 years, during the competitive period, with a weekly training volume of 13.59 ± 5.45 hours/week (Table 1).

With regard to the participants' nutritional intake, a mean of energy consumption of 1370.0 ± 4544.2 kcal/day was observed, in which the distribution of macronutrients does not correspond to the recommendations given the needs (Table 1).

In addition, the study sample had an energy expenditure of 501.8 ± 316.5 kcal/day, which corresponds to an EA of 35.8 ± 15.9 kcal/kg FFM/day compared to energy intake (Table 1).

Table 1. Age, training habits and energy consumption of the participants (n=59).

Age, training habits and energy consumption	**Mean ± SD**	**Min - Max**
Age (years)	11.97 ± 2.76	8 - 20
Age in the sport (years)	5.89 ± 2.71	1.8 - 16
Training (hours/day)	2.92 ± 0.79	2.0 - 5.0
Training (times/week)	4.54 ± 0.84	2 - 6
Training (hours/week)	13.59 ± 5.45	4 - 30
Energy intake (kcal/day)	1370.0 ± 454.2	613 - 2796
Energy expenditure (kcal/day)	501.8 ± 316.5	295.3 - 834.1
Energy availability (kcal/kg FFM/day)	35.8 ± 15.9	21.6 - 51.2
Protein (g/day)	63.6 ± 14.0	31 - 94
Carbohydrates (g/day)	165.5 ± 66.6	50 - 367
Fat (g/day)	51.1 ± 22.3	21 - 134

FFM: Fat-Free Mass, SD: standard deviation.

Overall, gymnasts had an average body weight of 37.0 ± 9.8 kg (25^{th} percentile) and an average height of 144.9 ± 12.4 cm (25^{th} percentile), corresponding to a BMI of 17.3 ± 2.2 kg/m² (25^{th} to 50^{th} percentile).

When analysing the body composition by electric bioimpedance, athletes showed a high percentage of fat-free mass (96.1 ± 1.7 %) and reduced fat mass (9.8 ± 2.0 %) (Table 2).

Table 2. Body composition of the gymnasts (n=59).

Body composition	Mean ± SD	Min - Max
Body mass (kg)	37.0 ± 9.8	21.0 - 58.0
Height (cm)	144.9 ± 12.4	116.4 - 168.8
Arm circumference (cm)	23.5 ± 3.0	18.2 - 31.5
Waist circumference (cm)	61.2 ± 5.3	51.0 - 74.0
Hip circumference (cm)	74.5 ± 9.2	60.2 - 97.9
Fat mass (%)	9.8 ± 2.0	5.45 - 14.99
Fat-free mass (%)	96.1 ± 1.7	91.88 - 98.35
BMI (Kg/m²)	17.3 ± 2.2	13.65 - 25.29
BMD estimated (g/cm²)	0.60 ± 0.08	0.42 - 0.90
BMD, *Z-score*	0.19 ± 0.36	-0.40 - 1.00

SD: standard deviation.

Analysing the adequacy of macronutrients intakes, 62.7% of the athletes consumed carbohydrates below the recommendations, 67.8% exceeded the protein recommendations and 62.7% were within the recommendations for fat intakes (Table 3).

Table 3. Gymnasts' macronutrients intakes according to the recommended.

Macronutrients intakes according to the recommended	**Below**, *n (%)*	**Adequate**, *n (%)*	**Above**, *n (%)*	***p***
Carbohydrates	37 (62.7)	22 (37.3)	0 (0)	< 0.05
Proteins	9 (15.3)	10 (16.9)	40 (67.8)	< 0.001
Fat	1 (1.7)	37 (62.7)	21 (35.6)	< 0.001

Regarding intakes of micronutrients, statistically significant differences ($p<0.05$) were observed in most micronutrients compared to the recommendations, with the exception of vitamin C ($p=0.196$), iron ($p=0.088$), and zinc ($p=0.329$) (Table 4). Intakes of vitamin D, vitamin E, vitamin K, calcium, magnesium and potassium were significantly below the recommendations (13.9 ± 6.2 vs. 60 µg/day; 591.0 ± 259.2 vs. 1300 mg/day; 165.2 ± 51.0 vs. 240 mg/day; 1920.4 ± 618.6 vs. 4500 mg/day, respectively) (Table 4).

Table 4. Gymnasts' micronutrients intakes compared with the RDA.

Daily consumption(per day)	**Mean ± SD**	**RDA**	**p**
Vitamin A (µg)	719.0 ± 489.8	700.0	< 0.001
Vitamin B3 (mg)	16.2 ± 6.0	12.0	< 0.001
Vitamin B6 (mg)	1.5 ± 0.6	1.0	< 0.001
Vitamin B12 (µg)	3.9 ± 2.6	1.8	< 0.001
Vitamin C (mg)	56.6 ± 68.0	45.0	0.196
Vitamin D (µg)	1.8 ± 1.3	5.0	< 0.001
Vitamin E (mg)	4.9 ± 2.2	11.0	< 0.001
Vitamin K (µg)	13.9 ± 6.2	60.0	< 0.001

Calcium (mg)	591.0 ± 259.2	1300.0	< 0.001
Iron (mg)	8.7 ± 2.9	8.0	0.088
Magnesium (mg)	165.2 ± 51.0	240.0	< 0.001
Manganese (mg)	1.3 ± 0.7	1.6	< 0.001
Potassium (mg)	1920.4 ± 618.6	4500.0	< 0.001
Selenic (µg)	68.0 ± 34.0	40.0	< 0.001
Sodium (mg)	1342.1 ± 587.3	1500.0	0.043
Zinc (mg)	8.3 ± 2.6	8.0	0.329
Fibre (g)	8.4 ± 3.8	26.0	< 0.001
Water (L)	1.3 ± 0.3	1.6	< 0.001

RDA: Recommended Dietary Allowances, SD: standard deviation.

Discussion and conclusions

Gymnasts are characterized by their aesthetic appearance and specific body composition profile, and it is frequently observed: low body weight, high lean mass and low fat mass as a result of high energy expenditure, and sometimes, insufficient energy intake.

The athletes of our study were aged between 8 and 20 years old and practiced gymnastics from very young ages. During the competitive period, they trained an average of 2.92 ± 0.79 hours per day.

Given the level of sport practice and the required energy expenditure, gymnasts demonstrated insufficient energy intake for the total energy expenditure, revealing a LEA (35.8 ± 15.9 Kcal/Kg FFM/day < 45 Kcal/Kg FFM/day) (Silva & Paiva, 2015). However, they were in a range of 30 to 45 Kcal/kg FFM/day, which in theory does not represent potential health impairments, but contributes to weight loss and influences body composition.

Gymnasts showed low body weight and height for their age (25th percentile) and a BMI between the 25th and 50th percentiles, although there were athletes above the 50th percentile, and one considered overweight for age belonging to the 90th percentile.

From the data obtained by electrical bioimpedance, all presented percentages of body mass below the reference values considered healthy for females (Rodriguez et al., 2009) and high percentages of lean mass.

These results are similar to other studies carried out with gymnasts of different nationalities, including Spanish (Martinez Rodriguez, 2020; Aguilo et al., 2021; Villa et al., 2021), which, despite small differences in age range and training volume, showed body compositions identical resulting from relative energy deficiency.

Despite this, there wasn't any athlete demonstrating negative effects on bone health (Rodriguez et al., 2009).

Considering the sport level of our participants, their nutritional intake is a very important factor given its role in sports performance, recovery, maintenance of physiological functions and in the risk of illness or injury (Silva et al., 2021). As such, it was intended to evaluate the adequacy levels in relation to macro and micronutrients in a competitive period.

The majority of athletes did not reach the carbohydrates recommendations (n=37, 62.7%), which is considered the main energy source of the organism (Rodriguez et al., 2009). These are the main substrate of the brain and are also responsible for the restoration of muscle and liver glycogen levels, presenting a fundamental role in the recovery after training/competitions (Nattiv et al., 2007; Thomas, Erdman, & Burke, 2016), but also in the performance of athletes during sports practice (Kerksick et al. 2017). As such, compliance with the recommendations is important.

On the other hand, protein intake was above the recommendations in most athletes (n=40, 67.8%) which, given the low intake of carbohydrates, may prove to be an advantage for helping to store muscle and hepatic glycogen (Kerksick et al. 2017). Despite the protein intake being higher than recommended, there is no evidence that it can cause damage to health, namely liver and kidney health (Jäger et al., 2017).

Regarding fats, most gymnasts (n=37, 62.7%) had an intake within the recommendations. These are an energy source and help the absorption of fat-soluble components such as vitamins A, D, E and K.

Regarding the intake of micronutrients, the importance of adequate intake is highlighted due to its fundamental role for the proper functioning of the organism, being part of several metabolic pathways (Thomas, Erdman, & Burke, 2016).

During physical exercise, these are important in the phase of muscle synthesis and repair and end up having an influence on metabolic pathways (Rodriguez et al., 2009).

However, intakes of B vitamins, as well as vitamin C and calcium were exceeded, which may produce negative effects on gymnasts' health, especially bones, given its role in calcium absorption, and in muscle health, emphasizing the need to eat fortified foods to prevent injuries and /or diseases (Rodriguez et al., 2009).

From the micronutrients that exceeded the recommendations, none reached the maximum recommended dose, showing no concerns. Still in the analysis of nutritional intake, fibre intake was below the recommendations (8.4 ± 3.8 vs. 26 g/day), and hydration was found to be slightly below the needs.

In conclusion, gymnasts demonstrated an energy intake lower than their needs, as well as, LEA, justifying the low weight and height for their age and the low body fat mass. They also demonstrated inadequacies in the intake of macro and micronutrients, except for proteins and fats, that are above and within the recommendations,

respectively, and certain micronutrients, such as vitamins A, C and the B complex and the minerals iron and zinc.

From the point of view of bone health, gymnasts had high values of bone mineral density and were not at risk of osteoporosis.

The importance of food education for athletes and those around them should be highlighted with a clear intention to improving their nutritional intake, in order to promote health and well-being, as well as maximize the athlete's performance.

References

Aguilo, A., Lozano, L., Tauler, P., Nafría, M., Colom, M., & Martínez, S. (2021). Nutritional Status and Implementation of a Nutritional Education Program in Young Female Artistic Gymnasts. Nutrients, 13(5), 1399. Doi: 10.3390/nu13051399.

Amato, A., Proia, P., Caldara, G. F., Alongi, A., Ferrantelli, V., & Baldassano, S. (2021). Analysis of Body Perception, Preworkout Meal Habits and Bone Resorption in Child Gymnasts. International Journal of Environmental Research and Public Health, 18(4), 2184. Doi: 10.3390/ijerph18042184.

Jäger, R., Kerksick, C. M., Campbell, B. I., Cribb, P. J., Wells, S. D., Skwiat, T. M., … Antonio, J. (2017). International Society of Sports Nutrition Position Stand: protein and exercise. Journal of the International Society of Sports Nutrition, 14, 20. Doi: 10.1186/s12970-017-0177-8.

Jakše, B., Jakše, B., Mis, N. F., Jug, B., Šajber, D., Godnov, U., & Čuk, I. (2021). Nutritional Status and Cardiovascular Health in Female Adolescent Elite-Level Artistic Gymnasts and Swimmers: A Cross-Sectional Study of 31 Athletes.

Journal of Nutrition and Metabolism, 2021, 8810548. Doi: 10.1155/2021/8810548.

Jürimäe, J., Gruodyte-Raciene, R., & Baxter-Jones, A. D. G. (2018). Effects of Gymnastics Activities on Bone Accrual during Growth: A Systematic Review. Journal of Sports Science & Medicine, 17(2), 245–258.

Kerksick, C. M., Arent, S., Schoenfeld, B. J., Stout, J. R., Campbell, B., Wilborn, C. D., Taylor, L., Kalman, D., Smith-Ryan, A. E., Kreider, R. B., Willoughby, D., Arciero, P. J., VanDusseldorp, T. A., Ormsbee, M. J., Wildman, R., Greenwood, M., Ziegenfuss, T. N., Aragon, A. A., & Antonio, J. (2017). International society of sports nutrition position stand: nutrient timing. Journal of the International Society of Sports Nutrition, 14, 33. Doi: 10.1186/s12970-017-0189-4.

Marfell-Jones, M. J., Stewart, A. D., & de Ridder, J. H. (2012). International standards for anthropometric assessment. Wellington, New Zealand: International Society for the Advancement of Kinanthropometry.

Martínez-Rodríguez, A., Reche-García, C., Martínez-Fernández, M. D. C., & Martínez-Sanz, J. M. (2020). Valoración del estado dietético-nutricional, la composición corporal, el comportamiento alimentario y la percepción de la imagen en deportistas de gimnasia rítmica [Assessment of nutritional-dietary status, body composition, eating behavior, and perceived image in rhythmic gymnastics athletes]. Nutricion Hospitalaria, 37(6), 1217–1225. Doi: 10.20960/nh.03141.

Meng, K., Qiu, J., Benardot, D., Carr, A., Yi, L., Wang, J., & Liang, Y. (2020). The risk of low energy availability in Chinese elite and recreational female aesthetic sports athletes. Journal of the International Society of Sports Nutrition, 17(1), 13. Doi: 10.1186/s12970-020-00344-x.

Nattiv, A., Loucks, A. B., Manore, M. M., Sanborn, C. F., Sundgot-Borgen, J., Warren, M. P., & American College of Sports Medicine (2007). American College of Sports Medicine position stand. The female athlete triad. Medicine and Science in Sports and Exercise, 39(10), 1867–1882. Doi: 10.1249/mss.0b013e318149f111.

Parm, A. L., Jürimäe, J., Saar, M., Pärna, K., Tillmann, V., Maasalu, K., … & Jürimäe, T. (2012). Bone mineralization in rhythmic gymnasts before puberty: no longitudinal associations with adipocytokine and ghrelin levels. Hormone Research in Paediatrics, 77(6), 369–375. Doi: 10.1159/000339002.

Rodriguez, N. R., DiMarco, N. M., Langley, S., American Dietetic Association, Dietitians of Canada, & American College of Sports Medicine: Nutrition and Athletic Performance (2009). Position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and athletic performance. Journal of the American Dietetic Association, 109(3), 509–527. Doi: 10.1016/j.jada.2009.01.005.

Silva, M.R. G. (2015). Ingestão nutricional e composição corporal (3ª edição). Porto: Edições Universidade Fernando Pessoa. ISBN: 978-989-643-134-1.

Silva, H. H., Silva, M. G., Cerqueira, F., Tavares, V., & Medeiros, R. (2022). Genomic profile in association with sport-type, sex, ethnicity, psychological traits and sport injuries of elite athletes. The Journal of Sports Medicine and Physical Fitness, 62(3), 418–434. Doi: 10.23736/S0022-4707.21.12020-1.

Silva, H. H., Tavares, V., Neto, B. V., Cerqueira, F., Medeiros, R., & Silva, M. G. (2023). FAAH rs324420 Polymorphism: Biological Pathways, Impact on Elite Athletic Performance and Insights for Sport Medicine. Genes, 14(10), 1946. Doi: 10.3390/genes14101946.

Silva, M. R., & Paiva, T. (2015). Low energy availability and low body fat of female gymnasts before an international competition. European Journal of Sport Science, 15(7), 591–599. Doi: 10.1080/17461391.2014.969323.

Silva, M. R., & Paiva, T. (2016). Poor precompetitive sleep habits, nutrients' deficiencies, inappropriate body composition and athletic performance in elite gymnasts. European Journal of Sport Science, 16(6), 726–735. Doi: 10.1080/17461391.2015.1103316.

Tamolienė, V., Remmel, L., Gruodyte-Raciene, R., & Jürimäe, J. (2021). Relationships of Bone Mineral Variables with Body Composition, Blood Hormones and Training Volume in Adolescent Female Athletes with Different Loading Patterns. International Journal of Environmental Research and Public Health, 18(12), 6571. Doi: 10.3390/ijerph18126571.

Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. Journal of the Academy of Nutrition and Dietetics, 116(3), 501–528. Doi: 10.1016/j.jand.2015.12.006.

Villa, M., Villa-Vicente, J. G., Seco-Calvo, J., Mielgo-Ayuso, J., & Collado, P. S. (2021). Body Composition, Dietary Intake and the Risk of Low Energy Availability in Elite-Level Competitive Rhythmic Gymnasts. Nutrients, 13(6), 2083. Doi: 10.3390/nu13062083.