Pol. J. Sport Tourism **2026**, *33(1), 26-30*
DOI: 10.2478/pjst-2026-0004

Original research papers

RISK OF RED-S SYNDROME AMONG INDIVIDUALS WHO REGULARLY ENGAGE IN PHYSICAL ACTIVITY

ANNA WIKTORIA MARTYNIUK[1], ANNA GALCZAK-KONDRACIUK[2], KAZIMIERZ CIOŁEK[3], KRYSTYNA GÓRNIAK[4]

Józef Piłsudski University of Physical Education in Warsaw, Faculty of Physical Education and Health, [1]Department of Fundamental Physiotherapy, [2]Department of Health Promotion, [3]Student Scientific Circle "Dietetyk", [4]Department of Physical Education Methodology

Mailing address: Anna Wiktoria Martyniuk, Department of Fundamental Physiotherapy, Józef Piłsudski University of Physical Education in Warsaw, 2 Akademicka Street, 21-500 Biała Podlasja, Poland,
e-mail: anna.martyniuk@awf.edu.pl

Abstract
Introduction. Regular physical activity increases energy expenditure and requires adequate energy intake to maintain physiological homeostasis. Inadequate energy intake can lead to low energy availability (LEA), which is a key factor in the development of relative energy deficiency in sport (RED-S), a syndrome affecting multiple systems in the human body. The aim of this study was to assess the risk of RED-S. The study was conducted among physically active young adults in Poland and involved the identification of dietary and behavioral factors associated with an increased risk of RED-S. ***Material and methods.*** A total of 151 participants (72 women, 79 men) aged 22.09 ± 2.2 years completed an online questionnaire assessing dietary habits, hydration, physical activity, and energy intake. Basal metabolic rate was calculated using the Mifflin-St. Jeor equation, and lean body mass was calculated using the James (1976) formula. Total energy expenditure was compared to the intake to estimate energy deficits. ***Results.*** Approximately 70% of participants had a negative energy balance, and most consumed four or fewer meals per day. Logistic regression showed that a negative energy balance significantly increased the risk of RED-S in both women (OR = 3.82) and men (OR = 8.50). In men, inadequate hydration and low meal frequency were also significant predictors. ***Conclusions.*** The results indicate that physically active young adults, especially men, may be at increased risk of RED-S due to poor eating habits. Better nutrition education and energy balance monitoring are recommended.

Keywords: diet, physical activity, RED-S syndrome, women, men, LEA

Introduction

Regular physical activity involves systematic body movement requiring energy expenditure, performed at least several times a week. It includes various forms of activity, such as walking, running, cycling, swimming, strength training, and fitness classes. It is widely recognized as one of the key elements of a healthy lifestyle, improving metabolic, cardiovascular, and psychological functioning [1, 2]. At the same time, an increase in training load increases the body's energy requirements, which means that proper nutrition plays an important role in maintaining the physiological balance of active individuals. When energy supply does not meet the increased demand resulting from physical activity, low energy availability (LEA) may occur. LEA occurs when, after subtracting the energy expended during training, there is too little energy left to carry out basic metabolic processes, regeneration, and maintain health. LEA is not the same as a negative energy balance – it can occur both with insufficient energy supply and with high training volume, even if the total calorie content of the diet does not appear to be low. Under LEA conditions, the body begins to conserve energy by lowering its metabolic rate and limiting physiological functions, which can lead to hormonal disorders, reduced immunity, mood disorders, and a gradual decrease in bone mineral density.

A negative energy balance, on the other hand, is a situation in which total energy expenditure exceeds the amount of energy supplied by food. Although a prolonged deficit can lead to weight loss, it does not always cause LEA – a small energy deficit can occur without any negative impact on health. The problem arises with a significant or chronic deficit, when energy availability falls below the level necessary to sustain metabolic processes, which is a direct path to the development of RED-S [3, 4].

Based on the latest consensus of the International Olympic Committee [4], relative energy deficiency in sport (RED-S) is a set of multi-organ disorders affecting metabolic, hormonal, immune, psychological, and bone health. The problem affects both competitive athletes and recreational exercisers, especially young adults, who often lack sufficient nutritional knowledge or engage in restrictive eating practices [3].

According to World Health Organization guidelines, adults should engage in at least 150-300 minutes of moderate or 75-150 minutes of vigorous physical activity per week [5]. Despite this, a significant proportion of the population in European countries with stable economies do not even achieve the minimum recommended level of physical activity, which affects their overall health and energy balance [6]. Studies show that proper nutrition – including adequate energy intake [7], proper hydration [8], and adequate calcium intake [9] – is essential for the health of people who regularly participate in sports [10].

Insufficient energy intake, poor eating habits, and the lack of nutritional knowledge can lead to eating disorders, which

are more common in physically active groups. Epidemiological studies have shown that eating disorders occur in approximately 5.5% of teenage athletes [11], with women being more at risk than men [12]. At the same time, a high risk of disorders is also observed in men who train in weight-class sports and those that require low body weight [13].

Strategies to reduce energy intake, especially reducing protein, fat, and carbohydrate intake while increasing fiber intake, can lead to hormonal imbalances, decreased muscle mass, bone mineralization problems, and an increased risk of injury [14, 15]. Factors that increase the risk of RED-S also include pressure to maintain low body weight, inappropriate nutritional advice from coaches, and overly restrictive dietary practices [16, 17].

Recent publications also point to other factors contributing to the development of RED-S, such as training stress, environmental stress, chronic fatigue, sleep disorders, frequent infections, and undiagnosed health problems [18].

Given the growing interest in physical activity among young adults, as well as the risk of energy and nutritional disorders, an attempt has been made to assess diet as a potential risk factor for the development of RED-S in this population. Understanding the eating habits of active individuals can form the basis for the development of effective preventive measures.

The aim of the study was to assess the risk of RED-S syndrome among people who regularly engage in physical activity. The following research questions were posed:

1. Does gender determine the risk of RED-S syndrome in individuals who regularly engage in physical activity?
2. Which of the analyzed factors increase the likelihood of developing RED-S syndrome?

Material and methods

A total of 179 individuals participated in the study, including 86 women and 93 men. After applying inclusion criteria such as regular physical activity (at least 2-3 times a week), consent to participate in the study and use of the results for scientific purposes, 151 people, including 72 women and 79 men, were qualified for further analysis.

The average age of the subjects was 22.06 ± 2.18 and 22.11 ± 2.31 years, respectively, and they came from different parts of Poland.

A diagnostic survey method was used to collect data through questionnaires. Participants were treated ethically, in accordance with the guidelines of the American Psychological Association's Code of Ethics regarding anonymity and informed consent. The study was conducted in accordance with the generally accepted principles of scientific research set out in the Declaration of Helsinki. In accordance with Polish regulations, formal approval from the Ethics Committee was not required.

The study was conducted using a diagnostic survey method with an anonymous online questionnaire (Microsoft Forms). Participants were informed about the purpose of the study and the voluntary nature of participation. The questionnaire consisted of 32 closed and semi-open questions covering:

- sociodemographic data,
- type and frequency of physical activity,
- number and regularity of meals,
- hydration habits,
- consumption of calcium-rich foods,
- nutritional history.

The questionnaire was developed in-house based on nutrition and physical activity assessment standards used in population studies.

In order to determine the individual energy requirements of the participants, the basal metabolic rate (BMR) was calculated using the Mifflin-St Jeor equation, separately for women and men [19]. Next, the total daily energy expenditure (TDEE) was determined by taking into account the physical activity index (PAI), calculated according to the formula:

PAI = Total Daily Energy Expenditure (TDEE) / Basal Metabolic Rate (BMR).

The CPM values obtained were compared with the daily energy intake estimated on the basis of the dietary interview.

The lean body mass (LBM) of the study participants was calculated using James' equation [20]:

LBM (women) = 1.07 × body weight (kg) – 148 × [body weight / height (cm)]^2,

LBM (men) = 1.10 × body weight (kg) – 128 × [body weight / height (cm)]^2.

Although LBM was available, the data necessary to calculate energy availability (EA) – defined as the amount of energy remaining after subtracting the cost of physical activity from energy intake, expressed relative to lean body mass – were missing [3, 4]. According to current recommendations, EA is the gold standard for assessing RED-S risk, but its calculation requires accurate data on the energy cost of physical activity, which were not fully available. For this reason, energy balance (the difference between energy intake and CPM) was used as an alternative indicator, which is acceptable in epidemiological studies when EA cannot be measured accurately.

A negative or significantly reduced energy balance indicates an increased risk of low energy availability and thus RED-S syndrome [3, 4].

Based on the available recommendations, participants were divided into two risk groups:

1. <45 kcal/kg LBM/day – moderate or high risk of RED-S syndrome,
2. ≥45 kcal/kg LBM/day – no clinical risk.

The adopted threshold values correspond to the current energy criteria used in the assessment of RED-S risk, in accordance with the 2023 IOC consensus.

Hydration and calcium intake were calculated based on the specified food products and supplementation. Daily calcium intake was calculated based on the frequency of consumption of products using the KcalmarPro computer program. Intake standards were compared to the reference values found in "Nutrition standards for the Polish population and their application" [21].

BMI values were also assessed in relation to WHO standards.

The collected data were statistically analyzed using Statistica 13.3 software from StatSoft Polska.

The likelihood of RED-S syndrome was determined using a logistic regression model and odds ratio (OR), assuming a confidence interval (CI) of 0.95.

Results

The collected data indicate that 70.8% of women and 74.6% of men live in cities. Daily physical activity lasting 1.5 hours was undertaken by 50% of women and 62% of men, while the rest exercised 2-3 times a week. The most common physical activity was gym training (43% of women and 65.8% of men), followed by fitness classes (26.4% of women and 8.9% of men) and activities at home and outdoors (30.6% of women and 25.3% of men).

Nutritional status was assessed on the basis of body mass index (BMI), which in the study group was 21.61±2.38 for women and 23.93±2.52 for men. According to WHO criteria, in most ca-

ses the body composition was normal. Thinness was observed in 6.9% of women, normal body weight in 81.9% of women and 72.2% of men. Excessive body weight affected 11.2% of women and 25.3% of men, while 2.5% of men were obese.

In the group of men, the percentage of people with elevated BMI was higher, even though they reported more frequent physical activity and less frequent meals. This situation may be due to the greater muscle mass typical of men who train intensively at the gym, which increases BMI without necessarily indicating excessive body fat. In addition, a lower number of meals does not necessarily mean a lower energy balance – it is possible to eat larger portions or more caloric foods, which could also contribute to higher BMI values.

The information obtained shows that an irregular menstrual cycle was observed in 21% of the women surveyed.

An analysis of eating habits revealed that 70.7% of women and 75.8% of men consumed four or fewer meals per day. Vegetables were consumed daily by 84.7% of women and 75.9% of men, while fruit was included in the diet less than once a day by 49.9% and 51.7% of the participants, respectively.

The average calorie intake for women was 2531.8 ± 646.1 kcal, while for men it was 3574.2 ± 824.6 kcal, and the differences were statistically significant ($p < 0.001$).

When calculating the energy balance, which was the difference between total energy requirements and energy intake during the day, we found that approximately 70% of the subjects had a negative energy balance.

The average calcium intake in the group of women was 382.03 ± 384.4 mg, and in the group of men it was 522.59 ± 466.1 mg. Below the daily calcium intake standard were 93% of women and 82.2% of men.

The risk factors for developing RED-S syndrome in women and men are presented in Table 1.

Table 1. Risk factors for the development of RED-s syndrome

	Women n = 72			Men n = 79		
	OR	95% confidence interval (CI)	p	OR	95% confidence interval (CI)	p
Energy balance	3.82	1.04-14.04	0.04*	8.50	2.22-32.48	0.001*
Hydration	1.72	0.46-6.32	0.41	2.65	1.02-6.84	0.04*
Calcium intake	5.92	0.62-56.12	0.12	2.75	0.77-9.76	0.11
Frequency of physical activity	0.38	0.14-1.04	0.05*	0.98	0.38-2.48	0.96
Frequency of meal intake	2.23	0.73-6.81	0.15	2.59	0.98-6.85	0.05*

Note: OR (odds ratio) – odds ratio with a 95% confidence interval (CI), * – p ≤0 .05 – statistically significant difference.

The variables presented in the table, including negative energy balance, inadequate hydration, low calcium intake, increased frequency of physical activity, and low frequency of meal consumption, may contribute to the development of RED--S syndrome. The most significant factors for the development of RED-S syndrome in women were negative energy balance OR: 3.82 (CI: 1.04-14.04) and, to a lesser extent, high frequency of physical activity OR: 0.38 (CI: 0.14-1.04). In the group of men, negative energy balance OR: 8.50 (CI: 2.22-32.48) was the most significant factor in the development of RED-S syndrome. Inadequate hydration OR: 2.65 (CI: 1.02-6.84) and low frequency of meal consumption OR: 2.59 (CI: 0.98-6.85) also had a significant impact on the risk of RED-S syndrome in this group. Calcium intake was not significantly associated with the occurrence of RED-S syndrome in any of the study groups, despite high OR values (women: 5.92; men: 2.75).

Discussion

The results of the study indicate that a significant proportion of physically active young adults experience low energy availability, which is also confirmed by the results of international studies. It is particularly important that in the study group, men showed a higher risk of developing RED-S (Relative Energy Deficiency in Sport) than women, which undermines the stereotype of limiting this problem only to the phenomenon of the so-called "female athlete triad" [22].

The key risk factor for RED-S among women was a negative energy balance, while among men it was low meal frequency and insufficient hydration, which may be due to irregular eating patterns, higher training intensity, and underestimation of individual energy needs.

A diet with a negative energy balance not only leads to a reduction in body fat, but also to hormonal disorders, including a decrease in the levels of leptin, oxytocin, insulin-like growth factor IGF-1, triiodothyronine (T3), and thyrotropin-releasing hormone. This can also result in decreased estrogen levels and a negative impact on bone tissue development. As studies indicate [12, 24, 25], energy deficiency can lead to menstrual cycle disorders, lack of ovulation, and even functional amenorrhea [26, 27].

Our own research has shown that energy deficiency occurred in 75% of women and about 70% of men, which is higher than in the study by Koehler et al. [28], where low energy availability was observed in 56% of men and 51% of women. In turn, Slater et al. [29] report that 45% of women who exercise recreationally were at risk of a negative energy balance.

Another important element of proper nutrition among physically active individuals is hydration. It has a key impact on maintaining the body's performance, and its deficiency can lead to a decrease in training effectiveness and metabolic disorders. In a study by Abdulsalam et al. [30], improper hydration was observed in 56.6% of women and 43.4% of men. Similar results were obtained in this study – improper hydration was more common in women (62%) than in men (29%). The authors recommend regular fluid intake throughout the day and monitoring hydration based on, for example, urine color, emphasizing that adequate hydration during training is a mechanism that compensates for possible deficiencies during the day [31].

The WHO (2024) recommendations for healthy physical activity in adults suggest at least 2.5-3 hours of moderate physical activity per week. Meanwhile, a population study by the Robert Koch Institute in a group of 7,671 adults showed that only 20% achieve this level [16]. In our own study, this percentage was significantly higher – 50% of women and 62% of men exceeded the recommended level of activity, while the rest were within the WHO recommendations.

Regular physical activity should go hand in hand with healthy eating habits, including maintaining energy balance, proper hydration, and eating meals at appropriate intervals. It is recommended to eat at least three main meals and one or two snacks per day [32]. However, the results of our own research showed that most participants eat four or fewer meals per day, which is

consistent with the findings of Yerzhanova et al. [33] and Graji et al. [34].

An important part of the diet of active people are foods with high nutritional density, especially fruit and vegetables. Most of the respondents declared daily consumption of vegetables (84.7% of women and 75.9% of men), while fruit consumption was much less frequent – less than once a day for about half of the respondents (49.9% of women and 51.7% of men). Similar results were reported by Sprake et al. [35], highlighting the insufficient consumption of these products among physically active individuals.

Calcium is also an important component of nutrition in this group, as it is responsible, among other things, for the prevention of osteopenia and osteoporosis [36]. Calcium deficiency was common in the study population, amounting to 382 ± 384.4 mg in women and 522 ± 466.1 mg in men, which is significantly less than the nutritional recommendations. Similar values were obtained by Wrzosek et al. [37], and a systematic review by Balk et al. [38] confirmed that only populations in northern Europe achieve an average calcium intake of 1000 mg/day, while the rest of the world does not meet the standard. A deficiency of this element may increase the risk of developing osteoporosis, which leads to more frequent fractures, a reduced quality of life, and even increased mortality [39, 40].

Limitations of the study

The study has several limitations that should be taken into account when interpreting the results. First, instead of the recommended energy availability (EA), obtained from accurate data on energy expenditure during exercise, energy balance was used as a proxy indicator. Although energy balance allows for a general assessment of the relationship between energy intake and expenditure, it does not accurately reflect the amount of energy available for physiological processes. This may lead to an underestimation or overestimation of the risk of low energy availability (LEA), which is a significant limitation in the context of RED-S.

The second limitation is the fact that the survey form was completed independently by the participants. Self-reported data are subject to memory errors, conscious or unconscious distortion of responses, and inaccurate reporting of energy intake or physical activity. This may affect the reliability of the nutritional information obtained and the assessment of physical activity behaviors.

The third limitation is the use of the body mass index (BMI) as the primary anthropometric parameter. BMI does not take into account the proportions of muscle, fat, and bone mass, which is why it can lead to errors in the classification of nutritional status in physically active individuals. The use of body composition analysis, e.g., bioimpedance or DEXA, would enable a more accurate assessment of lean body mass and a better determination of RED-S risk.

Conclusions

1. Young adults who engage in regular physical activity are at risk of developing RED-S, mainly due to insufficient energy, fluid, and calcium intake.
2. Men are at particularly high risk of RED-S, which indicates the need to provide them with nutrition education to the same extent as women.
3. Training programs should be supplemented with education on energy availability, regular meals, and adequate hydration.
4. Coaches and specialists should monitor symptoms of RED-S in both women and men, avoiding a stereotypical approach based solely on the female athlete triad.
5. Further research involving larger populations and measuring actual energy availability (EA) is needed to more accurately assess the risk of RED-S.

References

1. Polańska S., Karykowska A., Pawelec Ł. (2024). Associations between chronotype and physical activity and well-being in adults. *Chronobiology international* 41(4), 521-529. DOI: 10.1080/07420528.2024.2321942
2. Luo X., Wang Y., Wang L., Shen Y., Ren M. (2024). Association between female androgen levels, metabolic syndrome, and cardiovascular disease: An NHANES Analysis (2013-2016). *International Journal of Women's Health* 16, 2087-2101. DOI: 10.2147/IJWH.S475149
3. Logue D.M., Madigan S.M., Melin A., Delahunt E., Heinen M. et al. (2020). Low energy availability in athletes 2020: An updated narrative review of prevalence, risk, within-day energy balance, knowledge, and impact on sports performance. *Nutrients* 12(3), 835. DOI: 10.3390/nu12030835
4. Mountjoy M., Ackerman K.E., Bailey D.M., Burke L.M., Constantini N. et al. (2023). 2023 International Olympic Committee's (IOC) consensus statement on Relative Energy Deficiency in Sport (REDs). *British Journal of Sports Medicine* 57(17), 1073-1097. DOI: 10.1136/bjsports-2023-106994
5. World Health Organization. (2024). *Physical activity.* Geneva: World Health Organization.
6. Kljajević V., Stanković M., Đorđević D., Trkulja-Petković D., Jovanović R. et al. (2022). Physical activity and physical fitness among university students—A systematic review. *International Journal of Environmental Research and Public Health* 19(1), 158. DOI: 10.3390/ijerph19010158
7. Bede F., Cumber S.N., Nkfusai C.N., Venyuy M.A., Ijang Y.P. et al. T. (2020). Dietary habits and nutritional status of medical school students: the case of three state universities in Cameroon. *The Pan African Medical Journal* 35, 15. DOI: 10.11604/pamj.2020.35.15.18818
8. Shirreffs S.M. (2009). Hydration in sport and exercise: water, sports drinks and other drinks. *Nutrition Bulletin* 34(4), 374-379. DOI: 10.1111/j.1467-3010.2009.01790.x
9. Kim K.M., Choi S.H., Lim S., Moon J.H., Kim J.H. et al. (2014). Interactions between dietary calcium intake and bone mineral density or bone geometry in a low calcium intake population (KNHANES IV 2008-2010). *The Journal of Clinical Endocrinology and Metabolism* 99(7), 2409-2417. DOI: 10.1210/jc.2014-1006
10. Sukur A., Lubis J., Fitrianto E.J., Hartono F.V., Jauhari M. et al. (2022). Nutritional status and adequacy of disabled athletes from Indonesia. *Journal of Physical Education and Sport* 22(12), 2939-2946. DOI: 10.7752/jpes.2022.12371
11. Mehta J., Thompson B., Kling J.M. (2018). The female athlete triad: It takes a team. *Cleveland Clinic Journal of Medicine* 85(4), 313-320. DOI: 10.3949/ccjm.85a.16137
12. Nazem T.G., Ackerman K.E. (2012). The female athlete triad. *Sports Health* 4(4), 302-311. DOI: 10.1177/1941738112439685
13. Teixidor-Batlle C., Ventura C., Andrés A. (2021). Eating disorder symptoms in elite Spanish athletes: Prevalence and sport-specific weight pressures. *Frontiers in Psychology* 11, 559832. DOI: 10.3389/fpsyg.2020.559832
14. Ghazzawi H.A., Alhaj O.A., Nemer L.S., Amawi A.T., Trabelsi K., Jahrami H.A. (2022). The prevalence of "at Risk" eat-

ing disorders among athletes in Jordan. *Sports* 10(11), 182. DOI: 10.3390/sports10110182
15. Krebs P.A., Dennison C.R., Kellar L., Lucas J. (2019). Gender differences in eating disorder risk among NCAA Division I Cross Country and track student-athletes. *Journal of Sports Medicine* 5035871. DOI: 10.1155/2019/5035871
16. Krug S., Jordan S., Mensink G.B., Müters S., Finger J., Lampert T. (2013). Physical activity: results of the German health interview and examination survey for adults (DEGS1). *Bundesgesundheitsblatt, Gesundheitsforschung, Gesundheitsschutz* 56(5-6), 765-771. DOI: 10.1007/s00103-012-1661-6 [in German]
17. Besor O., Redlich N., Constantini N., Weiler-Sagie M., Monsonego Ornan E. et al. (2024). Assessment of Relative Energy Deficiency in Sport (REDs) risk among adolescent acrobatic gymnasts. *Journal of Personalized Medicine* 14(4), 363. DOI: 10.3390/jpm14040363
18. Jeukendrup A.E., Areta J.L., Van Genechten L., Langan-Evans C., Pedlar C.R. et al. (2024). Does Relative Energy Deficiency in Sport (REDs) syndrome exist? *Sports Medicine* 54(11), 2793-2816. DOI: 10.1007/s40279-024-02108-y
19. Mifflin M.D., St Jeor S.T., Hill L.A., Scott B.J., Daugherty S.A., Koh Y.O. (1990). A new predictive equation for resting energy expenditure in healthy individuals. *The American Journal of Clinical Nutrition* 51(2), 241-247. DOI: 10.1093/ajcn/51.2.241
20. James W.P.T. (1976). *Research on obesity: A report of the DHSS/MRC group*. London: Her Majesty's Stationery Office.
21. Jarosz M., Rychlik E., Stoś K., Charzewska J. (2020). *Nutrition standards for the Polish population and their application*. Warsaw: Institute of Food and Nutrition. [in Polish]
22. Marzuki M.I.H., Mohamad M.I., Chai W.J., Farah N.M.F., Safii N.S. et al. (2023). Prevalence of Relative Energy Deficiency in Sport (RED-S) among national athletes in Malaysia. *Nutrients* 15(7), 1697. DOI: 10.3390/nu15071697
23. Williams N.I., Helmreich D.L., Parfitt D.B., Caston-Balderrama A., Cameron J.L. (2001). Evidence for a causal role of low energy availability in the induction of menstrual cycle disturbances during strenuous exercise training. *The Journal of Clinical Endocrinology and Metabolism* 86(11), 5184-5193. DOI: 10.1210/jcem.86.11.8024
24. Williams N.I., Leidy H.J., Hill B.R., Lieberman J.L., Legro R.S., De Souza M.J. (2015). Magnitude of daily energy deficit predicts frequency but not severity of menstrual disturbances associated with exercise and caloric restriction. *American Journal of Physiology, Endocrinology and Metabolism* 308(1), 29-39. DOI: 10.1152/ajpendo.00386.2013
25. Lieberman J.L., DE Souza M.J., Wagstaff D.A., Williams N.I. (2018). Menstrual disruption with exercise is not linked to an energy availability threshold. *Medicine and Science in Sports and Exercise* 50(3), 551-561. DOI: 10.1249/MSS.0000000000001451
26. Coelho A.R., Cardoso G., Brito M.E., Gomes I.N., Cascais M.J. (2021). The female athlete triad/Relative Energy Deficiency in Sports (RED-S). *Revista Brasileira de Ginecologia e Obstetrícia: revista da Federação Brasileira das Sociedades de Ginecologia e Obstetrícia* 43(5), 395-402. DOI: 10.1055/s-0041-1730289
27. Skarakis N.S., Mastorakos G., Georgopoulos N., Goulis D.G. (2021). Energy deficiency, menstrual disorders, and low bone mineral density in female athletes: a systematic review. *Hormones* 20(3), 439-448. DOI: 10.1007/s42000-021-00288-0
28. Koehler K., Achtzehn S., Braun H., Mester J., Schaenzer W. (2013). Comparison of self-reported energy availability and metabolic hormones to assess adequacy of dietary energy intake in young elite athletes. *Applied Physiology, Nutrition, and Metabolism = Physiologie Appliquee, Nutrition et Metabolisme* 38(7), 725-733. DOI: 10.1139/apnm-2012-0373
29. Slater J., McLay-Cooke R., Brown R., Black K. (2016). Female recreational exercisers at risk for low energy availability. *International Journal of Sport Nutrition and Exercise Metabolism* 26(5), 421-427. DOI: 10.1123/ijsnem.2015-0245
30. Abdulsalam R., Alsadah A., Alkhuboli M., Muala D., Hussein A., Elmoselhi A.B. (2022). Hydration status assessment and impinging factors among university students in the UAE. *European Review for Medical and Pharmacological Sciences* 26(18), 6451-6458. DOI: 10.26355/eurrev_202209_29744
31. Olzinski S., Beaumont J., Toledo M., Yudell A., Johnston C.S., Wardenaar F.C. (2019). Hydration status and fluid needs of Division I Female Collegiate athletes exercising indoors and outdoors. *Sports* 7(7), 155. DOI: 10.3390/sports7070155
32. Frączek B., Krzysztofiak H., Krzywański J. (2019). *Sports nutrition*. PZWL Wydawnictwo Lekarskie. [in Polish]
33. Yerzhanova Y., Sabyrbek Z., Dilmachambetov E., Madijeva G., Milašius K. (2018). Mode and food habits of athletes of Kazakhstan. *Pedagogics, Psychology, Medical-Biological Problems of Physical Training and Sports* 22(6), 328-336. DOI: 10.15561/18189172.2018.0608
34. Graja K., Suchanecka M. (2018). Assessment of dietary habits and physical activity levels among individuals attending fitness clubs in Wrocław. *Rozprawy Naukowe AWF we Wrocławiu* 61, 61-76. [in Polish]
35. Sprake E.F., Russell J.M., Cecil J.E., Cooper R.J., Grabowski P. et al. (2018). Dietary patterns of university students in the UK: a cross-sectional study. *Nutrition Journal* 17(1), 90. DOI: 10.1186/s12937-018-0398-y
36. Liu Y., Le S., Liu Y., Jiang H., Ruan B. et al. (2022). The effect of calcium supplementation in people under 35 years old: A systematic review and meta-analysis of randomized controlled trials. *eLife* 11, e79002. DOI: 10.7554/eLife.79002
37. Wrzosek M., Woźniak J., Kozioł-Kaczorek D., Włodarek D. (2019). The assessment of the supply of calcium and vitamin D in the diet of women regularly practicing sport. *Journal of Osteoporosis* 2019, 9214926. DOI: 10.1155/2019/9214926
38. Balk E.M., Adam G.P., Langberg V.N., Earley A., Clark P. et al. (2017). Global dietary calcium intake among adults: a systematic review. *Osteoporosis International: a Journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA* 28(12), 3315-3324. DOI: 10.1007/s00198-017-4230-x
39. Rondanelli M., Faliva M.A., Barrile G.C., Cavioni A., Mansueto F. et al. (2021). Nutrition, physical activity, and dietary supplementation to prevent bone mineral density loss: A food pyramid. *Nutrients* 14(1), 74. DOI: 10.3390/nu14010074
40. Rohilla R., Therattil P. (2024). Optimising bone health in female athletes: A narrative review. *Sports Science & Health Advances* 2(2), 316-321. DOI: 10.60081/SSHA.2.2.2024.316-321

Submitted: October 25, 2025
Accepted: March 20, 2026