

Hydration status and sodium concentration in the sweat of adult athletes from the Brazilian Rhythmic Gymnastics Team

Estado de hidratação e concentração de sódio no suor de atletas adultas da Seleção Brasileira de Ginástica Rítmica de conjuntos

Joana Medeiros Sales¹ , João Henrique Gomes¹ , Bruna Matins² , Camila Ferezin Resende² , Renata Rebello Mendes¹ 

1. Universidade Federal de Sergipe, Aracaju, SE, Brazil
2. Confederação Brasileira de Ginástica, Aracaju, SE, Brazil

ABSTRACT

Introduction: During physical exertion, body mass losses $\geq 2\%$ correlate with hyperthermia, decreased muscle perfusion, increased subjective perception of effort, and reductions in muscle hypertrophy, cardiac output, and thermoregulation; consequently, performance and health impairments are observed. **Objective:** To evaluate the pre-training hydration status, sweat rate (SR), post-training hydration status, and sodium concentration of athletes from the Brazilian National Rhythmic Gymnastics Team. **Methods:** A cross-sectional study was conducted with 11 adult gymnasts, experienced in the Rhythmic Gymnastic (10.7 years) and in the national team (3.4 years). Pre- and post-training hydration status was assessed by urine color and density. The dehydration rate (DR) was determined by the % body mass loss, and the SR by the fluctuation in body mass associated with food and beverage intake and urinary excretion during training. Sweat sodium concentration was assessed using the Gx Sweat Patch. **Results:** The average DR was 0.2%, and 90.9% of the athletes presented weight loss $< 2\%$. During training, the average SR was 322.8 ml/hour. Urine color and density indicated hypohydration pre-training (81.8% mild and 18.2% moderate). Post-training, 72.7% were moderately dehydrated and 27.3% mildly dehydrated. The sodium concentration in the gymnasts' sweat was low. **Conclusion:** Although fluid replacement during training prevented losses greater than 2% of body mass in most athletes, and sodium concentration was low, they were hypohydrated before and after the training session.

Keywords: dehydration; gymnastics; physical exercise; sweat; sodium.

RESUMO

Introdução: Durante o esforço físico, perdas de massa corporal $\geq 2\%$ correlacionam-se com hipertermia, menor perfusão muscular, maior percepção subjetiva de esforço, e reduções de hipertrofia muscular, débito cardíaco e termorregulação; consequentemente observam-se prejuízos de performance e saúde. **Objetivo:** Avaliar o estado de hidratação pré-treinamento, taxa de sudorese (TS), o estado de hidratação pós-treinamento e concentração de sódio de atletas da Seleção Brasileira de Ginástica Rítmica (GR). **Métodos:** Estudo transversal desenvolvido com 11 ginastas adultas, experientes na modalidade (10,7 anos) e na seleção nacional (3,4 anos). Os estados de hidratação pré e pós-treino foram avaliados pela cor e densidade da urina. A taxa de desidratação (TD) foi determinada pela % perda de massa corporal, e a TS, pela oscilação de massa corporal, associada à ingestão de alimentos e bebidas, e excreção urinária durante o treinamento. Avaliou-se concentração de sódio no suor através de adesivo Gx Sweat Patch. **Resultados:** A TD média foi 0,2%, e 90,9% das atletas apresentou perda de peso $< 2\%$. No treinamento, observou-se TS média de 322,8ml/hora. A cor e a densidade da urina indicaram que hipohidratação no pré-treinamento (81,8% grau leve e 18,2%, moderado). No pós- treinamento, 72,7% estavam em estado de desidratação moderada e 27,3%, leve. A concentração de sódio no suor das ginastas foi baixa. **Conclusão:** Embora a reposição de fluidos durante o treinamento tenha prevenido perdas superiores a 2% da massa corporal na maioria das atletas, e a concentração de sódio tenha se mostrado baixa, estas apresentaram-se hipohidratadas antes e após a sessão de treinamento.

Palavras-chave: desidratação; ginástica; exercício físico; suor; sódio.

Introduction

During physical exercise, approximately 75% of the energy produced is dissipated in the form of heat [1], with evaporation being the main mechanism promoting thermal homeostasis [2]. Therefore, fluid loss during sports is a common phenomenon among athletes, and, when fluid loss is not adequately replenished, it can harm not only their athletic performance but also their health [3-10].

It is believed that fluid losses approaching 1% of body mass can lead to a moderate reduction in performance [11], culminating in significant losses for elite teams, given that any drop in performance can lead to drastic changes in ranking [12]. However, the harmful effects of inadequate fluid replacement are most evident when the loss exceeds 2% of body mass, characterizing a state of dehydration [5,13,14]. In this situation, in addition to reduced muscle perfusion [15], increased subjective perception of exertion (RPE) [7], impaired muscle hypertrophy [9], and, consequently, a drop in performance, clinical manifestations such as reduced cardiac output, reduced thermoregulation, and hyperthermia [16] also stand out. Therefore, it is essential to fully replace the fluids lost during training or, at least, a sufficient amount to prevent the loss from exceeding 2% of body mass [14]. Given this, it becomes necessary to evaluate the sweat rate of athletes during efforts, especially in their specific training routines, since sweating can vary significantly according to factors inherent to the physical exercise to be performed [7].

According to Lopes-Torres *et al.* [2], long-duration exercise can increase the risk of dehydration in athletes due to greater exposure to elevated body temperature and, consequently, sweating. In this perspective, Rhythmic Gymnastics (RG) stands out as a modality that seeks “perfection” through the execution of body movements, handling of equipment, and musical accompaniment [17,18]. For athletes to perform exercises with excellence, they are subjected to high training volumes, which can reach 50 hours per week [19,20], which increases the risk of intra-workout dehydration and makes it difficult to reestablish euhydration at rest, due to the limited time between training sessions [13].

In addition to the risk of dehydration, athletes who have a higher concentration of sodium in their sweat, as well as female athletes, are considered more susceptible to hyponatremia [21] and its complications can be mild, such as vomiting, headache and altered mental status, or severe, characterized by encephalopathy and risk of death [22].

Despite the potential vulnerability of rhythmic gymnasts to dehydration and hyponatremia due to their high training volume and female biological sex, our searches did not find any studies evaluating water balance or sweat sodium concentrations among rhythmic gymnasts. Therefore, the present study aimed to characterize the pre-workout hydration status, sweating, and dehydration rates during a training session, as well as the sweat sodium concentration of adult athletes from the Brazilian National Team of Rhythmic Gymnastics.

Methods

Experimental design

This is an observational, cross-sectional study. Four visits were made to the National Rhythmic Gymnastics Training Center (TC), located in Aracaju, Sergipe. During the first visit, the project was presented to the Technical Committee, and the Institution's consent form was obtained for subsequent submission to the Research Ethics Committee of the Federal University of Sergipe. After approval (process no. 92652418.0.0000.5546), the remaining stages of the study were continued. During the second visit to the TC, the Informed Consent Form (ICF) was provided to all athletes of the adult team, and any questions were clarified. During the third visit, the ICF was received from the athletes interested in participating in the study. At this same stage, a semi-structured questionnaire was applied, and the bioelectrical impedance test was performed to characterize the participants' body composition. The fourth visit to the training center consisted of data collection: application of protocols to assess hydration status, intra-workout water balance, and sweat sodium concentration, including: a) urine color; b) urine specific gravity (density); c) bioelectrical impedance analysis; d) sweat collection patch; e) body mass fluctuation. Urinary parameters and bioelectrical impedance analysis were assessed pre and post-workout to analyze possible changes in hydration status resulting from training. Body mass analysis included pre- and post-workout weight measurement, quantification of fluids and/or food consumed during the training session, and quantification of urinary volume excreted during the training session. By controlling for these variables, changes in body mass allowed the calculation of the athletes' sweat rate and dehydration rate, which are the subjects of this study.

Participants

Eleven athletes from the Brazilian National Rhythmic Gymnastics Team (Table I) participated in the study. The inclusion criterion was membership in this team. The exclusion criteria were: a) athletes who were unable to complete a training session at their usual intensity, whether due to injury or any other reason; b) athletes exposed to behaviors or situations that favor dehydration, such as diuretic use, recent sun exposure, recent alcohol consumption, episodes of vomiting or diarrhea, etc.; c) athletes with metal objects in their bodies, such as pins and plates. Of the 13 athletes who comprised the team at the time of data collection, two were excluded due to injuries that prevented them from completing one or more training phases.

Table 1 - Characterization of the rhythmic gymnasts of the Brazilian National Team, participants in the study (n = 11)

Variables	Mean (SD)
Age	19 (1.5)
Years of experience in RG training (years)	10.7 (2.4)
Years of experience in RG competitions (years)	9.3 (2.1)
Years of experience in the Brazilian RG National Team (years)	3.4 (2.5)
Body Mass (kg)	55.0 (6.02)
Fat Mass (%)	10.4 (2.2)

Environmental conditions at the time of data collection

The training session during which the study was conducted took place in the morning at the Brazilian Rhythmic Gymnastics Team Training Center (TC), located in Aracaju, Sergipe, Brazil. The training center is equipped with air conditioning, and during the training session during which the study was conducted, the ambient temperature varied between 24°C and 28°C. In Aracaju, the average daily humidity was 74%.

Training characteristics on the day of data collection

The session was led by the Brazilian National Team's coaching staff, following the pre-competitive training routine. The session consisted of the following stages: a) non-standardized individual warm-up (10 minutes); b) ballet training (30 minutes); c) trunk and lower limb flexibility (10 minutes); c) training exercises based on physical difficulties and repetitions of isolated elements, such as dance steps, risks, exchanges, and collaborations (40 minutes); d) practice of the training routine, with and without music (138 minutes). This training session lasted a total of 240 minutes, including breaks for food and fluid intake. The researchers did not interfere with the organization of the training session or the quality and quantity of liquids and solids consumed during the session.

Adopted protocols

1. To characterize the participants

1.1 General characteristics of the participants: a semi-structured questionnaire was applied addressing age, time of experience in RG training, competitions, and participation in the Brazilian team.

1.2 Body composition: the Biodynamics (BIA 450), TBW brand, bioelectrical impedance device was used to assess body composition [23]. In the present study, the athletes followed the previous procedures required to perform bioelectrical impedance.

2. To assess the hydration status of gymnasts:

2.1. Urine color: In this method, it is taken into account that the lower the

individual's hydration level, the darker the urine will be [24]. In our study, urine collection was performed immediately before the start of training and immediately after the end of training, allowing for a comparison of hydration status at the two different times and any changes in it. For this evaluation, a qualitative analysis of urine color intensity was used using a Likert scale, which classifies hydration level based on urine color, according to the study by Armstrong *et al.* [25]. According to this scale, the colors corresponding to numbers 1 and 2 indicate “good hydration”; numbers 3 and 4 indicate “mildly dehydrated”; numbers 5 and 6, “moderately dehydrated”; and 7 and 8, “severely dehydrated”. The analysis was performed blindly to avoid possible bias in data interpretation.

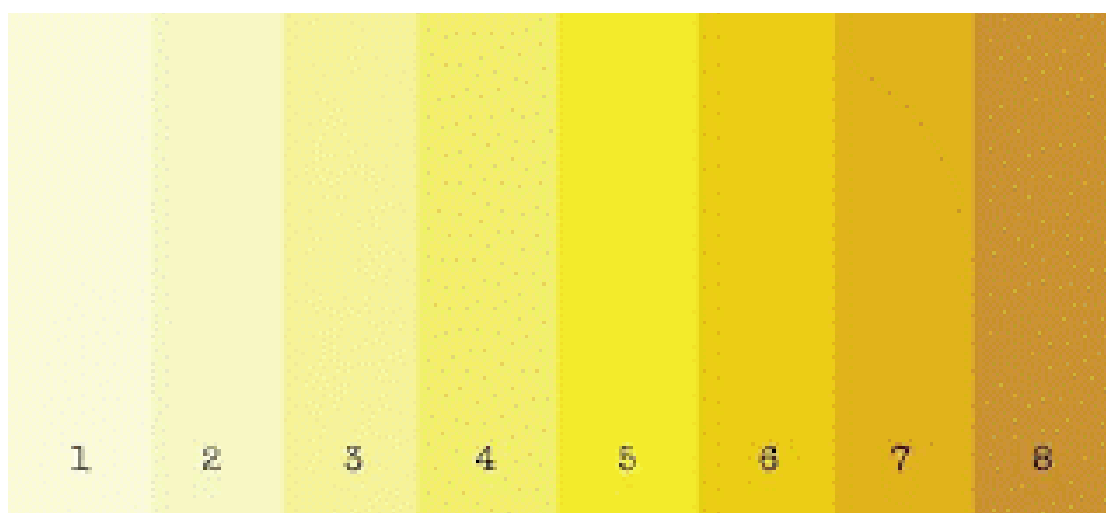


Figure 1 - Urine color scale for classifying hydration status, proposed by Armstrong *et al.* [25].

2.2. Urine density: In the present study, urine density was assessed using a portable Instrutherm refractometer, and the techniques adopted were in accordance with the manufacturer's instructions. Density identifies hydration status by measuring urine density and comparing it with the density of double-distilled water [26]. A result below 1010 g/L indicates good hydration, while a result between 1010 and 1020 g/L indicates minimal dehydration. From 1021 g/L onwards, the patient is significantly dehydrated, and severe dehydration is considered from 1030 g/L onwards [27]. In this case, this assessment was also administered immediately before and after training, allowing for the observation of possible changes caused by training.

2.3. Intra-workout Body Mass Change: In a review published by the International Society of Sports Nutrition [27] on current methods for assessing hydration in athletes, the authors classified the different methods according to criteria such as accuracy, cost, invasiveness, administrator skill requirements, and time required for implementation. The methods were ranked according to these criteria, with scores ranging from 1 to 5. In terms of accuracy, pre-

and post-training body mass fluctuation received a score of 4, second only to methods involving stable isotopes and neutron activation, whose execution times are unfeasible for elite teams. During training, changes in body mass may represent fluid loss through sweating, provided that fluid and food intake, urine and feces excretion are taken into account [27]. The assessment of sweating through body mass adopted the following procedure:

- a) the athletes' weight was measured immediately before the start of training;
- b) during the training session, the volume of fluids ingested, the weight of solid foods consumed, and the volume of waste excreted by the athletes were recorded;
- c) at the end of training, the athletes' weight was measured again.

To identify the sweating rate during the training session, the collected data were applied to the following equation:

Sweating rate = (Pre-exercise body weight – Post-exercise body weight) + Fluids consumed – Urine volume [27].

Furthermore, the athletes' weight loss rate was calculated, considering the importance of identifying the level of dehydration to determine the risk of presenting signs and symptoms resulting from negative fluid balance, based on current scientific literature.

Dehydration rate = (Pre-exercise body weight – Post-exercise body weight) X 100 / Pre-exercise body weight [27].

The scale used to measure body weight was a Welmy brand with an accuracy of 0.050 kg; to monitor liquid and solid consumption during the training session, a digital scale from the XH Import brand was used, with an accuracy of 0.001 kg; and to monitor urine excretion, specific collectors were adopted for this purpose, all with identification of each participant.

The athletes were instructed to consume liquids and solids ad libitum, without any interference from the researchers.

2.4. Bioimpedance analysis: According to the review by the International Society of Sports Nutrition [27], in which methods for assessing hydration in athletes were classified with scores ranging from 1 to 5, the use of electrical bioimpedance received a score of 3; however, the authors suggest that it may be an aid in assessing the distribution of body water in different compartments (extra and intracellular). Bioimpedance measures the resistance of a low-voltage electrical current through the body, which is transmitted by ions [23]. In the present study, bioimpedance testing was used before and after

training to assess possible changes in the amount of body water of athletes that occurred during the training session. The device used was Biodynamics (BIA 450).

2.5. Sodium concentration in sweat: In the present study, this parameter was assessed using the Gx Sweat Patch, a Gatorade sweat collector that identifies the amount of chlorine present in the fluid and, through its correlation with sodium, predicts the amount of sodium eliminated in sweat. The use of this tool was validated by three recent studies [28-30]. Sweat sodium concentrations < 500 mg/L were classified as “very low”; low: 500 to 800 mg/L; medium: 801 to 1100 mg/L; high: 1101 to 1500 mg/L; and very high: > 1500 mg/L.

3. To characterize the exercise intensity

Assessed through the subjective perception of exertion (RPE), obtained using the CR10 Borg scale [31]. Participants answered the following question: “How difficult do you think the exercise was?” RPE measurement was performed 30 minutes after training.

Statistical analysis

Descriptive statistics were used for data analysis. Variables were presented as mean, minimum, and maximum standard deviation, and others as absolute and relative frequencies. To compare variables in absolute values between pre- and post-training, normality and homogeneity were initially tested using the Shapiro-Wilk and Levene tests, respectively. Data that presented regular distribution were subjected to the paired t-test (parametric test): urine specific gravity, total water, extracellular water, intracellular water, and body mass. The chi-square test was used to compare data in relative frequencies. The urine color result was not normally distributed; therefore, a nonparametric test (Spearman’s test) was used to test for possible correlations. All analyses were performed with SPSS-22.0 software (IBM, SPSS Inc., Chicago, IL, USA). Significance was set at $p < 0.05$.

Results

Table II describes the differences in the study variables — body mass, body water, intracellular water, extracellular water, urine color, and urine specific gravity — before and after the training session. Total water and extracellular water levels showed a statistically significant increase. Regarding sweat sodium concentration, all athletes were diagnosed with low sweat sodium concentrations (< 500mg/L), according to the criteria of the patch supplier.

Table II - Results of the evaluation of hydration markers before and after training and recording of body mass

Variables	PRE			POST			p
	Mean (SD)	Min	Max	Mean (SD)	Min	Max	
Body mass (kg)	55.0 (6.3)	44.9	67.2	54.9 (6.5)	45.0	67.4	> 0.05
Total water (L)	34.5 (3.1)	29.5	40.5	35.3 (3.2)	31.5	42	< 0.05
Extracellular water (L)	14.1 (1.8)	12.0	17.4	14.8 (1.8)	12.7	18.1	< 0.05
Intracellular water (L)	20.4 (1.5)	17.5	23.1	20.5 (1.6)	18.4	23.9	> 0.05
Urine color*	4 (0.8)	3	6	5 (0.7)	4	6	> 0.05
Urine density (g/L)	1019.8 (6.8)	1011	1029	1020.6 (6.9)	1010.0	1030.0	> 0.05

* The median was used for urine color.

Table III illustrates the sweating and dehydration rates during the training session, as well as the RPE for the session. It is clear that, despite the low average dehydration rate, there was significant variation in the percentage of dehydration among the different athletes.

Table III - Sweat rate, dehydration rate and RPE related to training

Variables	Mean (SD)	Min	Max
Sweat rate (ml/hour of training)	322.8 (77.7)	186.0	419.8
Total sweat rate during the training session (ml)	1301.5 (312.0)	702.1	1706.3
Dehydration rate (% post-training body mass loss)	0.2 (0.9)	-0.6	2.0
Fluid intake during the training session (ml)	1340.0 (540.0)	712.0	2140.0
Urine volume excreted during the training session (ml)	167.1 (140.2)	0.0	510.0
RPE	3.1 (0.5)	2	4

Therefore, it is noteworthy that most participants maintained a level of dehydration considered to be free of health and performance risks (Figure 3). However, it is important to emphasize that all athletes arrived at training hypohydrated, based on the analysis of urinary variables, and most finished the training even more hypohydrated, as described in Figures 2 (team) and 3 (individual description).

Regarding the distribution of gymnasts according to the dehydration rate during the training session, it was observed that 81.8% of participants presented a loss of body mass of less than 1% of the initial body mass, while only 9.1% presented a loss between 1 and 2%, and 9.1% obtained a loss greater than 2%

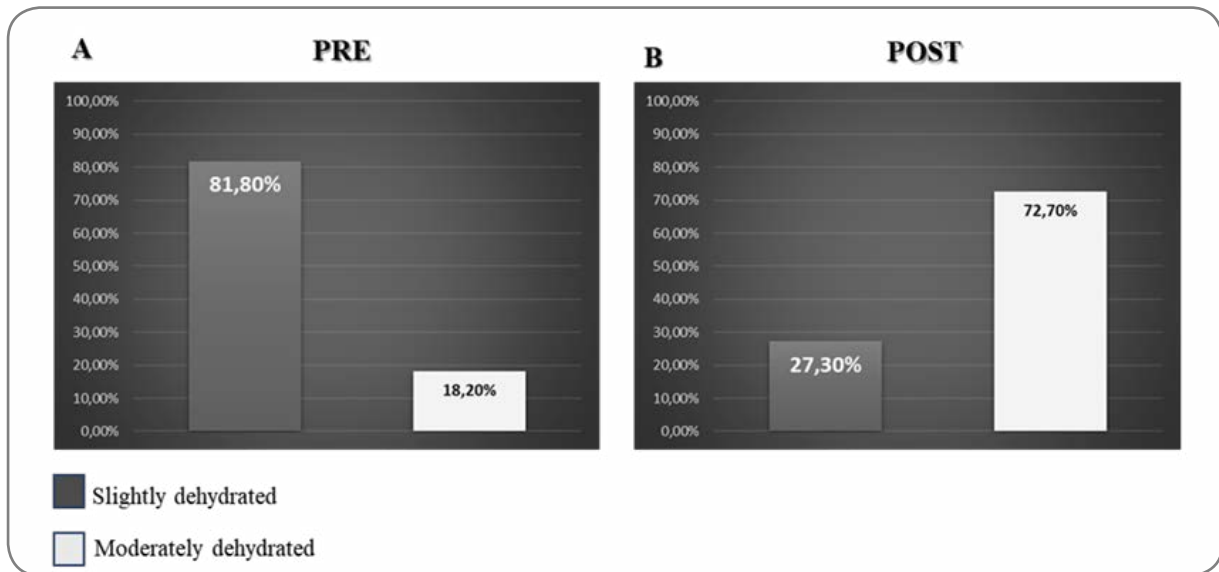


Figure 2 - Distribution of gymnasts according to pre- (A) and post- (B) training hydration status, according to urine color and density analysis

Table IV shows the gymnasts' hydration status before and after training, based on urine color and density. Note that five athletes (athletes 1, 2, 3, 6, and 11) maintained their initial classification categories, while another six (athletes 4, 5, 7, 8, 9, and 10) moved to categories with a higher degree of dehydration.

Table IV - Classificação do estado de hidratação das ginastas nos momentos pré e pós-treinamento, de acordo com a cor e a densidade da urina

Participants	PRE			
	Urine Color	Category	Urine Density Range (g/L)	Category
Athlete 1	Color 3	Slightly dehydrated	1010-1020	Minimal dehydration
Athlete 2	Color 5	Moderately dehydrated	1021-1030	Significantly dehydrated
Athlete 3	Color 3	Slightly dehydrated	1010-1020	Minimal dehydration
Athlete 4	Color 3	Slightly dehydrated	1010-1020	Minimal dehydration
Athlete 5	Color 3	Slightly dehydrated	1010-1020	Minimal dehydration
Athlete 6	Color 3	Slightly dehydrated	1010-1020	Minimal dehydration
Athlete 7	Color 3	Slightly dehydrated	1010-1020	Minimal dehydration
Athlete 8	Color 3	Slightly dehydrated	1010-1020	Minimal dehydration
Athlete 9	Color 4	Slightly dehydrated	1010-1020	Minimal dehydration
Athlete 10	Color 4	Slightly dehydrated	1010-1020	Minimal dehydration
Athlete 11	Color 6	Moderately dehydrated	1021-1030	Significantly dehydrated

Table IV - Continuation

POST				
Participants	Urine Color	Category	Urine Density Range (g/L)	Category
Athlete 1	Color 4	Slightly dehydrated	1010-1020	Minimal dehydration
Athlete 2	Color 5	Moderately dehydrated	1021-1030	Significantly dehydrated
Athlete 3	Color 4	Slightly dehydrated	1010-1020	Minimal dehydration
Athlete 4	Color 5	Moderately dehydrated	1021-1030	Significantly dehydrated
Athlete 5	Color 5	Moderately dehydrated	1021-1030	Significantly dehydrated
Athlete 6	Color 4	Slightly dehydrated	1010-1020	Minimal dehydration
Athlete 7	Color 6	Moderately dehydrated	1021-1030	Significantly dehydrated
Athlete 8	Color 5	Moderately dehydrated	1021-1030	Significantly dehydrated
Athlete 9	Color 5	Moderately dehydrated	1021-1030	Significantly dehydrated
Athlete 10	Color 5	Moderately dehydrated	1021-1030	Significantly dehydrated
Athlete 11	Color 6	Moderately dehydrated	1021-1030	Significantly dehydrated

Critério de classificação de acordo com cor da urina: Armstrong *et al.* [25]; Critério de classificação de acordo com a densidade da urina: Casa *et al.* [26].

Discussion

The objective of this study was to characterize the pre- and post-training hydration status, sweating, and dehydration rates during the session, as well as the sweat sodium concentration of athletes from the Brazilian Rhythmic Gymnastics Team. Our main findings indicate that the athletes began the training session hypohydrated, and this fact, associated with the water loss experienced during training, even if small (average less than 1% of body mass), culminated in the maintenance of the hypohydration diagnosis for all participants at the end of the training. The sweat sodium concentration of all participants was considered low.

Maintaining a safe intra-workout weight loss percentage (< 2%) is essential for maintaining health and athletic performance [5]. Therefore, to avoid dehydration, water intake throughout exercise should be prioritized. However, in this study, the athletes arrived at training hypohydrated and maintained this state throughout the session (with no statistical differences). In other words, considering the average of the team evaluated, the amount of liquids consumed was sufficient to control the rate of dehydration, but not to restore body hydration levels to a state of euhydration.

There are some reports in the literature of results that differ from those found

in our study. Turner *et al.* [5] quantified the sweat rate of 14 squash athletes during a training session and found a prevalence of 79% of euhydrated athletes immediately before the start of training, based on urine osmolality analysis. In a study by Tarnowski *et al.* [5], conducted with elite female soccer players, it was found that 47.4% of the athletes were euhydrated before training.

In contrast, many studies point to a scenario similar to that identified in the present study. Ceylan and Santos [33] evaluated the hydration status and fluid intake of 22 under-15 judo athletes and, based on urine specific gravity analysis, found that 63.64% of the participants were significantly dehydrated before training. Similarly, in an investigation of the hydration status of taekwondo athletes, significant dehydration prevailed among participants in the pre-workout period [34]. Furthermore, Freire-Júnior *et al.* [35], in an evaluation of the water balance of female CrossFit practitioners, found that all participants began training dehydrated, even if to a minimal degree.

The differences in results across these studies, some of which indicate poor hydration and others adequate hydration pre-workout, may be related to the different training volumes and loads to which the athletes studied are subjected. According to Sawka *et al.* [13], high dedication of time to training sessions can lead to greater dehydration and less time between sessions, therefore reducing the athlete's opportunity to pursue rehydration strategies. In the case of the Brazilian RG team, evaluated in this study, the training and post-training physical therapy routine ends in the early evening and resumes in the early morning. Therefore, the interval for rehydration between sessions would be the early morning, a period during which athletes prioritize sleep, which may interfere with pre-workout hydration status.

In any case, the large number of studies that have identified a high prevalence of pre-workout hypohydration, including the findings of this study, may indicate the ineffectiveness of maintaining hydration beyond the training period. In this sense, it is essential to evaluate the focus of the guidelines found in consensus statements, position statements, and guidelines published for athletes. It is noted, then, that guidelines for fluid consumption "outside of training hours" are limited [36], which may further fuel the confusion.

The American College of Sports Medicine's position statement, "Nutrition and Athletic Performance" [37], presents measures to prevent dehydration during training, but is simplistic in recommending actions to maintain euhydration at other times of the day. Furthermore, some studies propose nutritional practices that are not feasible for many sports. For example, Kerkick *et al.* [36], in an update of the International Society of Sports Nutrition recommendations, propose the intake of 1,100 mL of fluids from waking up until the start of training. However, for the Brazilian RG team, whose training routine starts in the early hours of the day and can last up to ten hours a day [20], the adoption of this guideline is not factual.

The weakness of hydration guidelines beyond training hours is a problem that has persisted for years. The American College of Sports Medicine's position pa-

per on fluid replacement, “Exercise and Fluid Replacement” [13], addresses some general strategies for athletes to focus on fluid intake between two and four hours before training. However, this guidance does not apply to the routine of all sports, as athletes often have less than an hour between sessions, as is the case with the Brazilian RG team. For this reason, athletes, coaches, and other professionals seeking guidance in these documents may encounter a flaw in the literature currently used: the focus on intra-workout hydration and the lack of applicable guidelines for some sports outside of training.

The American Institute of Medicine, through the DRI (Dietary Reference Intakes), [38] recommends a daily intake of 2.3 liters of total water for women aged 14 to 18 and 2.7 liters of total water for women aged 19 to 30, the age groups in which the adult athletes of the Brazilian Rhythmic Gymnastics Team are included. It is believed that a starting point would be to introduce this water intake during the athletes’ rest periods.

This way, it is possible to estimate adequate fluid intake during non-workout periods, until further studies are conducted to assess the specific needs of these athletes, considering that, even at rest, they are still in the recovery process. This way, the harm caused by hypohydration, such as increased thermal and cardiovascular stress [5], could be minimized.

In the present study, the low prevalence of training-induced dehydration, identified as a loss of $\geq 2\%$ of body mass, may be due to the athletes’ reduced sweating (average 322.8 ml/h), as the International Society of Sports Nutrition [37] reports that the average sweat rate in athletes can range from 500 mL to 2,000 mL. It is necessary to consider that the athletes of the Brazilian Rhythmic Gymnastics Team receive nutritional monitoring, which allows guidance regarding intra-workout hydration. Furthermore, it is noteworthy that, previously, the athletes trained indoors without air conditioning. Approximately one month before the present study, the athletes began training in an environment with air conditioning, which, according to Sawka *et al.* [3], may have favorably affected sweating rate, given their previous acclimatization to heat at higher temperatures.

Gibson *et al.* [39] identified a similar scenario regarding water balance. In an evaluation of female soccer players, the average dehydration rate during training was 0.84%, which indicates risk-free weight loss. In a study by Badham *et al.* [9], during outdoor team sports training, an average dehydration rate of 1.3% was found, representing a moderate-risk classification.

In the study by Turner *et al.* [10], when evaluating fluid consumption during a training session of squash players, an increase in weight was identified; that is, the water balance was positive, representing an average weight gain of 1.22%. Finally, the study by Arnaoutis *et al.* [11] evaluated the hydration status of highly trained athletes from different sports, including gymnastics. In an evaluation of 10 athletes from this sport, hydration also exceeded sweating, resulting in a 1.7% weight gain. It is clear, then, that dehydration rates vary widely across scientific studies. Therefore, we believe it is necessary to evaluate the fluid balance of different sports and, when

possible, monitor athletes' intra-workout weight loss, as recommended by official guidelines [13].

Regarding the adoption of bioimpedance as a tool to assess water status changes during training, our study presented contradictory results compared to those demonstrated using other variables. The fact that we had: a) athletes who were hypohydrated before training (urinary variables); b) 0.2% average dehydration during training (body mass fluctuation); c) a higher prevalence of athletes in the moderate dehydration category after training leads us to hypothesize that post-training body water, measured by bioimpedance, would present values similar to those of the pre-training period, or even lower, depending on the statistical analysis; but not higher, as shown in the results of this study.

It is believed that this discrepancy is due to the limitations of the bioimpedance method for assessing acute changes in body hydration, as cited by Barley et. al. [27]. According to these authors, the use of bioimpedance may be an interesting strategy for assessing hydration during rest periods, after specific preparation the day before a session. However, at the time of this study, our searches revealed no studies that had used this tool to assess rhythmic gymnasts' performance at different points in their routines, which led us to test it in this setting. However, in the present study, we believe that the gymnasts' ad libitum fluid intake during training, especially the volumes consumed closer to the end of the session, may have influenced the results of the bioimpedance analysis of body hydration. This leads us to suggest further studies to verify the viability of this tool in training settings.

Finally, it is necessary to discuss the fact that, although most athletes presented adequate intra-workout hydration levels, one gymnast (9.1% of the sample) experienced water loss exceeding 2% of her body mass. The amount of sweat produced can vary depending on individual characteristics of the athlete—such as heat acclimatization, body weight, genetic predisposition, and metabolic efficiency—characteristics that substantially increase the risk of intra-workout dehydration [8]. Additionally, some athletes may experience gastrointestinal discomfort when attempting to replace high water losses during physical exertion [40] or may even face logistical difficulties in replenishing fluids, such as shorter breaks for nutrition during training sessions due to the athlete's greater attention to technical corrections proposed by the coaching team. In situations where fluid replacement is difficult, regardless of the cause, strategies to reduce fluid loss, such as ice in the oral cavity (colling), may be useful [41]. The low sodium concentration in the sweat of all participants in this study corroborates the scientific literature, as highly conditioned athletes acclimated to exercise in hot environments typically excrete sweat with sodium concentrations below 40 mmol/L, due to the greater capacity of the sweat glands for sodium conservation, especially during aerobic-dominant exercise. This capacity not only helps protect plasma volume but also reduces the risk of hyponatremia [42].

The greatest limitation of this study is its small sample size, a common occurrence when the sample is specific, such as national teams in certain sports. It is

also worth noting the limitation of this descriptive, cross-sectional study, applied to a specific setting, as outcomes may vary depending on the phases of training periodization and environmental conditions. However, we believe that these limitations do not invalidate the relevance of our findings, considering the scarcity of studies on the topic and the direct impact of hypohydration on athletes' performance and cardiovascular health. Furthermore, we believe that hypohydration resulting from low fluid intake outside of training hours is not exclusive to the Brazilian Rhythmic Gymnastics Team. Therefore, for future studies, we emphasize the need to develop effective strategies to ensure adequate hydration in the routines of athletes in various sports, including rhythmic gymnastics.

Conclusion

The adult gymnasts of the Brazilian rhythmic gymnastics team began their training session in a state of hypohydration and maintained this state until the end of the session. The prevalence of intra-workout dehydration was low, as was the concentration of sodium in sweat.

Conflicts of interest

No conflicts of interest.

Funding sources

No funding.

Authors' contributions

Conception and design of the research: Sales JM, Gomes JH, Mendes RR; Data collection: Sales JM, Martins B, Resende CF, Mendes RR; Análise e interpretação dos dados: Sales JM, Mendes RR; Statistical analysis: Gomes JH; Manuscript writing: Sales JM, Mendes RR; Critical review of the manuscript for important intellectual content: Sales JM; Gomes JH, Mendes RR

References

1. Hermend E, Chabert C, Hue O. Ultra-endurance events in tropical environments and countermeasures to optimize performances and health. *Int J Hyperthermia*. 2019;36(1):753-60. doi: 10.1080/02656736.2019.1635718
2. López-Torres O, Rodríguez-Longobardo C, Escibano-Tabernero R, Fernández-Elías VE. Hydration, hyperthermia, glycogen, and recovery: crucial factors in exercise performance - a systematic review and meta-analysis. *Nutrients*. 2023;15(20):4442. doi: 10.3390/nu15204442
3. Funnell MP, Mears SA, Bergin-Taylor K, James LJ. Blinded and unblinded hypohydration similarly impair cycling time trial performance in the heat in trained cyclists. *J Appl Physiol*. 2019;126(4):870-79. doi: 10.1152/jappphysiol.01026.2018
4. Linsell JD, Pelham EC, Hondula DM, Wardenaar FC. Hiking Time Trial Performance in the Heat with Real-Time Observation of Heat Strain, Hydration Status and Fluid Intake Behavior. *Int J Environ Res Public Health*. 2020;17(11):4086. doi: 10.3390/ijerph17114086
5. Périard JD, Eijssvogels T, Daanen HAM, Racinais S. Hydration for the Tokyo Olympics: to thirst or not to thirst? *Br J Sports Med*. 2021;55(8):410-11. doi: 10.1136/bjsports-2020-102803
6. Barley OR, Chapman DW, Abbiss CR. Reviewing the current methods of assessing hydration in

athletes. *J Int Soc Sports Nutr.* 2020 Oct 30;17(1):52. doi: 10.1186/s12970-020-00381-6.

7. Deshayes TA, Pancrate T, Goulet EDB. Impact of dehydration on perceived exertion during endurance exercise: A systematic review with meta-analysis. *J Exerc Sci Fit.* 2022 Jul;20(3):224-35. doi: 10.1016/j.jesf.2022.03.006

8. Dube A, Gouws C, Breukelman G. Effects of hypohydration and fluid balance in athletes' cognitive performance: a systematic review. *Afr Health Sci.* 2022;22(1):367-76. doi: 10.4314/ahs.v22i1.45

9. Badham L, Stern SE, O'Connor FK, Wijekulasuriya GA, Corcoran G, Cox GR, Coffey VG. Fluid intake is a strong predictor of outdoor team sport pre-season training performance. *J Sports Sci.* 2023;41(1):1-7. doi: 10.1080/02640414.2023.2191093

10. Turner O, Mitchell N, Ruddock A, Purvis A, Ranchordas MK. Fluid Balance, Sodium Losses and Hydration Practices of Elite Squash Players during Training. *Nutrients.* 2023;15(7):1749. doi: 10.3390/nu15071749

11. Arnaoutis G, Kavouras SA, Angelopoulou A, Skoulariki C, Bimpikou S, Mourtakos S, Sidossis LS. Fluid balance during training in elite young athletes of different sports. *J Strength Cond Res.* 2015;29(12):3447-52. doi: 10.1519/JSC.0000000000000400

12. Mendes RR, Prado JRS. Protocol to reduce the risk of unintentional doping caused by dietary supplements ingestion. *Rev Bras Fisiol Exerc.* 2023;22:e225468. doi: 10.33233/rbfex.v22i1.5468

13. Sawka MN, Burke LM, Eichner ER, Maughan RJ, Montain SJ, Stachenfeld NS. American College of Sports Medicine position stand. Exercise and fluid replacement. *Med Sci Sports Exerc.* 2007;39(2):377-90. doi: 10.1249/mss.0b013e31802ca597

14. Chevront SN, Kenefick RW. Dehydration: physiology, assessment, and performance effects. *Compr Physiol.* 2014;4(1):257-85. doi: 10.1002/cphy.c130017

15. Trangmar SJ, González-Alonso J. Heat, Hydration and the Human Brain, Heart and Skeletal Muscles. *Sports Med.* 2019;49(Suppl 1):69-85. doi: 10.1007/s40279-018-1033-y

16. Watanabe K, Stöhr EJ, Akiyama K, Watanabe S, González-Alonso J. Dehydration reduces stroke volume and cardiac output during exercise because of impaired cardiac filling and venous return, not left ventricular function. *Physiol Rep.* 2020 Jun;8(11):e14433. doi: 10.14814/phy2.14433

17. Silva R, Borges LP, Quintans LJ, Resende CF, Cadegiani FA, Gomes JH, Mendes RRM. Acute effects of a typical rhythmic gymnastic training day on physiological parameters in Olympic athletes. *Kinesiol.* 2022;54(2):278-87. doi: 10.26582/k.54.2.9

18. Debien PB, Timoteo TE, Gabbett TJ, Bara Filho MG. Training-load management in rhythmic gymnastics: practices and perceptions of coaches, medical staff, and gymnasts. *Int J Sports Physiol Perform.* 2022;17(4):530-40. doi: 10.1123/ijsp.2021-0279

19. Mendes RR. Nutrição aplicada à ginástica rítmica. In: Marcia Regina Aversani Lourenço, Roberta Gaio. (Org.). Escola de Treinadores de Ginástica Rítmica: Caderno Didático-pedagógico. 1ed. Curitiba: Bagai; 2024. v. 1, p. 43-64.

20. Fernandes I, Gomes JH, Oliveira L, Almeida M, Claudino JG, Resende C, et al. Monitoring of the training load and well-being of elite rhythmic gymnastics athletes in 25 weeks: a comparison between starters and reserves. *Sports (Basel).* 2022;10(12):192. doi: 10.3390/sports10120192

21. Sims ST, Kerkick CM, Smith-Ryan AE, Janse de Jonge XAK, Hirsch KR, Arent SM, et al. International society of sports nutrition position stand: nutritional concerns of the female athlete. *J Int Soc Sports Nutr.* 2023;20(1):2204066. doi: 10.1080/15502783.2023.2204066

22. Hew-Butler T. Exercise-associated hyponatremia. *Front Horm Res.* 2019;52:178-89. doi: 10.1159/000493247

23. Sossou I, Silva GEM, Oliveira CEP, Moreira OC. Bioimpedância elétrica na avaliação da composição corporal: uma revisão dos princípios biofísicos, diferentes tipos, aspectos metodológicos, validade e aplicabilidade de suas medidas [Internet]. RBONE – Revista Brasileira de Obesidade Nutrição e Emagrecimento. 2022 [citado 2025 Ago 12];16(102):596-604. <https://www.rbone.com.br/index.php/rbone/article/view/2051>

24. Fernández-Elías VE, Martínez-Abellán A, López-Gullón JM, Morán-Navarro R, Pallarés JG, De la Cruz-Sánchez E, Mora-Rodríguez R. Validity of hydration non-invasive indices during the weightcutting and official weigh-in for Olympic combat sports. *PLoS One.* 2014;9(4):e95336. doi: 10.1371/journal.pone.0095336

25. Armstrong LE, Maresh CM, Castellani JW, Bergeron MF, Kenefick RW, LaGasse KE, et al.. Urinary indices of hydration status. *Int J Sport Nutr.* 1994;4(3):265-79. doi: 10.1123/ijns.4.3.265

26. Casa DJ, Armstrong LE, Hillman SK, Mountain SJ, Reiff RV, Rich BS, *et al.* National athletic trainers' association position statement: fluid replacement for athletes. *J Athl Train.* 2000;35(2):212-24.
27. Barley OR, Chapman DW, Abbiss CR. Reviewing the current methods of assessing hydration in athletes. *J Int Soc Sports Nutr.* 2020;17(1):52. doi: 10.1186/s12970-020-00381-6
28. Baker LB, Model JB, Barnes KA, Anderson ML, Lee SP, Lee KA, *et al.* Skin-interfaced microfluidic system with personalized sweating rate and sweat chloride analytics for sports science applications. *Sci Adv.* 2020;6(50):eabe3929. doi: 10.1126/sciadv.abe3929
29. Baker LB, King MA, Keyes DM, Brown SD, Engel MD, Seib MS, *et al.* Sweating rate and sweat chloride concentration of elite male basketball players measured with a wearable microfluidic device versus the standard absorbent patch method. *Int J Sport Nutr Exerc Metab.* 2022;32(5):342-49. doi: 10.1123/ijsnem.2022-0017
30. Baker LB, Seib MS, Barnes KA, Brown SD, King MA, Chavez PJD, *et al.* Skin-interfaced microfluidic system with machine learning-enabled image processing of sweat biomarkers in remote settings. *Adv. Materials Tech.* 2022;7(11). doi:10.1002/admt.202200249
31. Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, Parker S, *et al.* A new approach to monitoring exercise training. *J Strength Cond Res.* 2001;15(1):109-15
32. Tarnowski CA, Rollo I, Carter JM, Lizarraga-Dallo MA, Oliva MP, Clifford T, *et al.* Fluid balance and carbohydrate intake of elite female soccer players during training and competition. *Nutrients.* 2022;14(15):3188. doi: 10.3390/nu14153188
33. Ceylan B, Santos L. Fluid intake, hydration status and body mass changes in U-15 judo athletes during a training day. *Acta Scientiarum - Health Sciences.* 2022;44(1). doi: 10.4025/actascihealthsci.v44i1.57233
34. Belfort FG, Amorim PRS, Silva CE, Gonçalves CFF, Niquini PR, Silva RP, *et al.* Fluid balance during taekwondo training. *Revista Brasileira de Medicina do Esporte.* 2021;27(1):70-74. doi:10.1590/1517-869220212701113775
35. Freire-Júnior F, Santos HMLL, Silva Santos GLL, Melo-Marins DM, Silva AAS, Reis GS, *et al.* Fluid balance in women during a session of high intensity functional training. *Revista Brasileira de Ciência e Movimento,* 2015;23(4):38-45.
36. 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
37. Thomas DT, Erdman KA, Burke LM. American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. *Med Sci Sports Exerc.* 2016;48(3):543-68. doi: 10.1249/MSS.0000000000000852. Erratum in: *Med Sci Sports Exerc.* 2017 Jan;49(1):222. doi: 10.1249/MSS.0000000000001162
38. IOM. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate [Internet]. 2005 [citado 2025 Ago 12]. Disponível em: <https://nap.nationalacademies.org/catalog/10925/dietary-reference-intakes-for-water-potassium-sodium-chloride-and-sulfate>
39. Gibson JC, Stuart-Hill LA, Pethick W, Gaul CA. Hydration status and fluid and sodium balance in elite Canadian junior women's soccer players in a cool environment. *Appl Physiol Nutr Metab.* 2012;37(5):931-7. doi: 10.1139/h2012-073
40. Jeukendrup AE. Training the Gut for Athletes. *Sports Med.* 2017;7(Suppl 1):101-10. doi: 10.1007/s40279-017-0690-6
41. Burke LM, Jeukendrup AE, Jones AM, Mooses M. Contemporary Nutrition Strategies to Optimize Performance in Distance Runners and Race Walkers. *Int J Sport Nutr Exerc Metab.* 2019;29(2):117-29. doi: 10.1123/ijsnem.2019-0004
42. Murray B. Stofan, J. Hyponatremia in athletes [Internet]. Sports Science Exchange. 2003 [citado 2025 Ago 15];(16)1. Disponível em: <https://www.gssiweb.org/sports-science-exchange/article/sse-88-hyponatremia-in-athletes>

