Analysis of hydration patterns of elite gymnasts. Intervention to improve performance

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Summary

Introduction: Male artistic gymnastics is a sport practiced individually with 6 different apparatus. It is a modality of high intensity and impact. Adequate hydration is important to avoid a decrease in performance and to reduce the risk of fatigue injuries.
Material and method: The hydration patterns of the Spanish artistic gymnastics team are analyzed during training, their individual liquid requirements are calculated, and a personalized hydration is prescribed, with the aim of improve performance. In the research, 9 male elite gymnasts participated. Each one completed 2 equal workouts separated by one week; the first with his usual hydration pattern (HAB) and the second one with an individualized hydration, according to the calculation of their needs with sport drink (POW). All were weighed, and measured the specific gravity and osmolality of urine, before and after training; At the end of each session a rated perceived exertion questionnaire (RPE) was passed and a performance test was carried out.
Results: It is observed that: i) POW significantly increased the drink intake in comparison to HAB during training (HAB: 0.57 ± 0.2 L, POW: 0.90 ± 0.2 L), ii) POW increased the number of pull-ups and total repetitions (HAB: 67.13 ± 4.9 repetitions, POW: 72.63 ± 5.7 repetitions), iii) HAB reduced body mass significantly after training iv) POW presented lower values of urine specific gravity after training and the% of body mass lost was negligible (HAB: 0.44 ± 0.2%, POW: 0.01 ± 0.1%), v) There were no differences in the urine osmolality, the PSE, the number of repetitions in hanging pikes and handstand push-ups between HAB and POW.
Conclusion: Individualized hydration for each athlete with the appropriate drink improves performance during training.

Key words:
Dehydration. Drink. Exercise. Water balance.

Análisis de los patrones de hidratación de gimnastas de élite. Intervención para mejorar el rendimiento

Resumen

Introducción: La gimnasia artística masculina es un deporte practicado de forma individual con 6 aparatos diferentes. Es una modalidad de alta intensidad e impacto. Una correcta hidratación es importante para evitar la disminución del rendimiento y reducir el riesgo de lesiones por fatiga.
Material y método: Se analizan los patrones de hidratación de deportistas de la selección española de gimnasia artística durante el entrenamiento, se calculan sus requerimientos individuales de líquido, y se pauta hidratación personalizada, con el objetivo de mejorar el rendimiento. En la investigación han participado 9 gimnastas de élite varones. Cada uno completó 2 entrenamientos iguales separados por una semana; el primero con su pauta habitual de hidratación (HAB) y el segundo mediante una hidratación individualizada, según el cálculo de sus necesidades con bebida para el deportista (POW). A todos se les pesó, y midió la densidad y osmolaridad de orina, antes y después del entrenamiento; al final de cada sesión se pasó un cuestionario de percepción subjetiva del esfuerzo (PSE) y se realizó un test de rendimiento.
Resultados: Se observa que: i) POW aumentó significativamente la ingesta de bebida respecto a HAB durante el entrenamiento (HAB: 0,57±0,2 L, POW: 0,90±0,2 L), ii) POW aumentó el número de dominadas y el total de repeticiones (HAB: 67,13±4,9 repeticiones, POW: 72,63±5,7 repeticiones), iii) HAB redujo la masa corporal de forma significativa después del entrenamiento iv) POW presentó valores inferiores de densidad de orina tras el entrenamiento y el% de pérdida de masa corporal fue insignificante (HAB: 0,44±0,2%, POW: 0,01±0,1%), v) No hubo diferencias en la osmolaridad de orina, la PSE, el número de repeticiones en flexiones de tronco y flexiones verticales entre HAB y POW.
Conclusión: La hidratación individualizada para cada deportista con la bebida adecuada mejora el rendimiento durante el entrenamiento.

Palabras clave:
Deshidratación. Bebida. Ejercicio. Equilibrio hídrico.

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Introduction

Men's artistic gymnastics is an individual sport performed with 6 different apparatus: floor, pommel horse, rings, vault, parallel bars and horizontal bar[1]. Each exercise lasts between 6 (vault) and 60 (floor) seconds[2], and the execution of each is crucial to the score obtained[1]. It is a high intensity, high impact sport which involves a great risk of injury[3]. This is a problem for these athletes, because they suffer approximately 2 injuries per year[3], causing them to lose many hours of training. The prevention of these injuries, therefore, especially those to the upper limbs4, is of paramount importance to the continuity of the training needed for maximum performance.

Many factors are responsible for the injuries incurred by those who practise this sport, the most relevant being incorrect technique in the execution of certain movements, the lack of protection available to the gymnast and fatigue[5,6].

Hydration status and fatigue are inversely related, meaning that it is vitally important to stay well hydrated during both training and competition in order to avoid a drop in physical performance and reduce the risk of injury[7,8].

Arnaoutis *et al.*[9] calculated the dehydration produced during training in five different sports: artistic gymnastics, swimming, canoeing, basketball and running, artistic gymnasts being those who finished training the most dehydrated, with a loss of 1.7 ± 0.07% body mass.

Water serves different functions during exercise: it cools the body, helping to release the excess heat produced, supplies nutrients to the muscle cells, eliminates waste products and lubricates the joints[10].

Furthermore, it is an essential nutrient as it is involved in practically all the functions of the human body and, at about 60% of the body mass of adult males[11], represents its main component. So adequate water intake is essential.

Body water balance is maintained when the loss of water is offset by water and food intake plus endogenous water production by the metabolism[12], as shown in Table 1.

Dehydration can impair sports performance, with impairment intensifying the higher the % body mass loss during the activity[13], as shown in Table 2.

Table 1. Daily water consumption and loss in a sedentary person[12].

Daily water consumption (mL)		Daily water excretion (mL)	
Drinks	1500	Urine	1500
Food	1000	Faeces	200
Metabolic water	300	Lungs	350
		Skin (sweat)	750
Total	2800	Total	2800

Table 2. Symptoms of dehydration, according to the dehydration percentage[13].

% dehydration	Symptoms
1%	Thirst.
5%	Malaise, fatigue, loss of appetite.
7%	Difficulty salivating and swallowing.
>10%	Difficulty walking, lack of coordination and spasticity.
15%	Delirium, dry skin, difficulty drinking water.
>20%	The skin cracks and bleeds. Over this, death.

Table 3. Hydration status by urine density and osmotic concentration[21].

	Well hydrated	Euhydrated	Hypohydrated
Urine density	<1.013	1.013-1.029	>1052
Urine osmotic concentration (mOsm/Kg)	<442	442-1052	>1029

Although the effect of dehydration on performance in some types of sport has been measured[14-17], the consequences that a hydration status below optimal levels may have on artistic gymnastics has yet to be studied.

The objective of drinking during exercise is to prevent excessive dehydration (> 2% body mass) and alterations in electrolyte balance which may affect athletic performance[18].

Hydration status can be evaluated by calculating the change in body mass, the most realistic method[19], and analysing urine density and osmotic concentration, among other procedures[20]. Table 3 shows hydration status using the latter methods.

For athletes, sports drink is the most suitable liquid to prevent dehydration during exercise[21]. According to the consensus on drinks for athletes[22] of the Spanish Federation of Sports Medicine (FEMEDE), these should contain more than 80 Kcal/L and a maximum of 350 Kcal/L, with at least 75% of calories from high-glycaemic-index carbohydrates (glucose, sucrose, maltrodextrin). The concentration of carbohydrates should not be greater than 9% (90 g/L) and that of sodium should be between 460 mg/L (20 mmol/L) and 1150 mg/L (50 mmol/L).

Sodium intake is of great importance, because a decrease in blood sodium during physical exertion may lead to hyponatremia of the utmost gravity[22]. It also helps to improve hydration because it increases the sensation of thirst, meaning that the athlete keeps on drinking, and, moreover, it increases the amount of water retained in the body[11]. Meanwhile, carbohydrates help to maintain blood glucose levels and, therefore, help to save muscle glycogen, delaying the onset of fatigue[22].

The amount of fluid to ingest depends on the individual's sweat rate, the intensity and duration of exercise, the sports clothes worn, air movement and humidity, among other factors[19].

For all these reasons, it was considered important to carry out a study of the influence of hydration on performance in artistic gymnastics.

Objective

The objective of this study was:

- To analyse the hydration patterns of competition-level artistic gymnasts.
- To assess specific individual requirements in order to enhance sports performance.

Hypothesis

The hypothesis of this study was to verify that:

- Artistic gymnasts do not hydrate properly.
- Gymnasts improve their performance in training sessions with proper, individualised hydration, consuming sports drinks.

Material and method

The study involved 9 male sportsmen from the Spanish national artistic gymnastics team who train at the Madrid High Performance Centre; with an average age of 18.13±1.96, a height of 1.68±0.07 m, a body mass of 60.04±11.37 kg and 3.25±1.49 years' experience of high-performance training.

All the subjects passed a medical examination which included: medical, sports and dietary history, a clinical examination and blood and urine tests. They were informed about all aspects of the study and signed the consent form to take part in the study. They stated that they did not have any disease which might affect the results of the research.

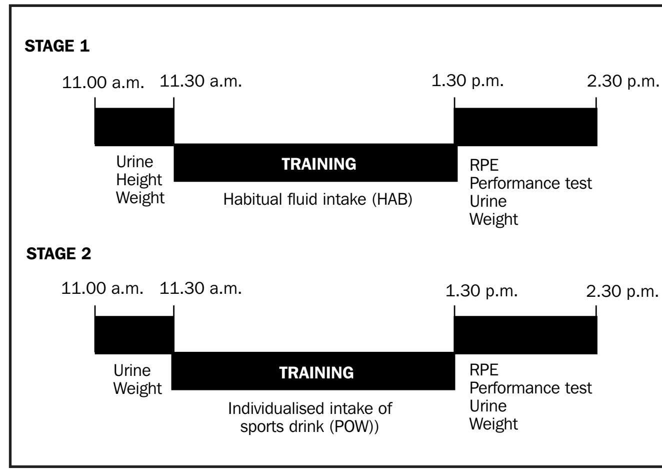
Procedures

The study was conducted using an experimental design with control group and pre-post measurement.

The training sessions for data collection for the study were held one week apart at the same time on the same day of the week. The subjects ate and drank as normal, without any changes, and promised not to start taking nutritional supplements during the study. The research was divided into two different stages, as shown in Figure 1.

- STAGE 1 (HAB): The gymnasts were weighed 30 minutes before training (11 a.m.) with a body composition analyser and a first urine sample was taken. Training began at 11.30 a.m. They were asked not to urinate and to train for 2 hours as normal in terms both of intensity and type and quantity of drink. After training, their rate of perceived effort (RPE) was determined and they completed a sports performance test consisting of three different exercises. A second urine sample was taken and they were weighed again to calculate the percentage of dehydration.

Figure 1. Diagram of the methodology. RPE, rate of perceived effort.



- STAGE 2 (POW): The gymnasts were weighed 30 minutes before training (11 a.m.) with a body composition analyser and a first urine sample was taken. Training began at 11.30 a.m. They were asked not to urinate and to train at their habitual of intensity for 2 hours. They drank a drink specially designed for sportspeople in a quantity calculated on an individual basis according to each athlete's fluid needs (see 2.5 Calculation of fluid needs). The fluid they drank was Powerade® Powder, containing 7% carbohydrates and a sodium concentration (Na^+) of 22.62 mmol/L (520 mg/L). After training, their RPE was determined and they completed a sports performance test consisting of three different exercises. A second urine sample was taken and they were weighed again to calculate the percentage of dehydration.

Measurement of height

Height was measured using a stadiometer (Seca 213) on the first day of the study, before training began.

Urine osmotic concentration and density analysis

A urine sample was taken 30 minutes before the start of training and a second sample was taken in the hour following the end of training. The urine was collected in containers specifically designed for the purpose and these were labelled with the name of the athlete and a control digit.

Osmotic concentration was calculated using the freezing point method with an osmometer (OSMO STATION™ OM-6050). Density was measured using test strips (Combur 10 Test M) with an automatic urine analyser (URISYS 1800).

Dehydration analysis

The subjects were first weighed 30 minutes before starting to train and a second time after completing training. All measurements were taken after urinating, with the least amount of clothing possible (underwear). The dehydration percentage was calculated on the basis of body mass before and after training, using the following formula:

% dehydration= Mass BEFORE - mass AFTER/mass BEFORE x100

Calculating fluid requirements

Fluid requirements were calculated on the basis of the body mass of the athletes before and after training, and fluid intake during training.

The athletes drank from water bottles to make calculation easier. The bottles were weighed before and after training to calculate the difference and arrive at real fluid intake. The number of times the water bottle was refilled was taken into account if any of the athletes filled it up again. The bottles were weighed with an electronic balance (Kern PCB 6000-1). The following formula was used for the calculation:

Fluid requirements = (Mass BEFORE - Mass AFTER)
+ (Drink BEFORE-Drink AFTER)

Rate of perceived effort questionnaire

The scale used for the RPE of the athletes was the 10-point scale modified by Foster *et al.*[23]. This consists of a scale of 0 to 10, where 0 is zero exhaustion and 10 is a state of maximum exhaustion. The questionnaire was answered immediately after finishing training, the athletes pointing at their answers. Given that the two sessions were the same length, the RPE value was determined per session.

Performance analysis

Performance was measured at the end of each training session using a modified version of a specific artistic gymnastics test[24]. A circuit with different exercises (pull-ups, handstand push-ups and leg raises) was completed. Each exercise lasted 30 seconds and the number of repetitions each athlete did was counted. They were asked to carry out as many repetitions as possible using the suitable exercise technique, as shown in Figure 2. The time was calculated using a stopwatch (Geonaute W500) and 2 people observed the tests to count the repetitions.

Leg raises

Start: Hanging.
During: No swaying of the trunk and no bending of legs.
End: Legs parallel to the floor.

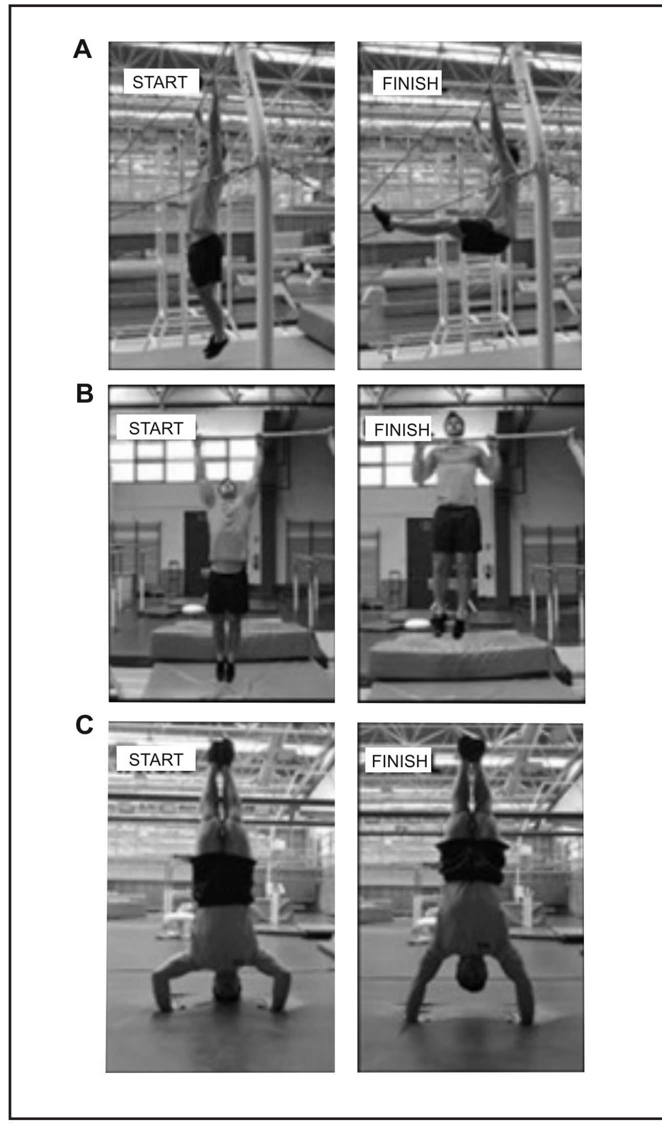
Pull-ups

Start: Hanging from arms.
During: No swaying.
End: The chin passes the bar.

Handstand push-ups

Start: Head touching the floor.
During: No swaying.
End: Fully extended.

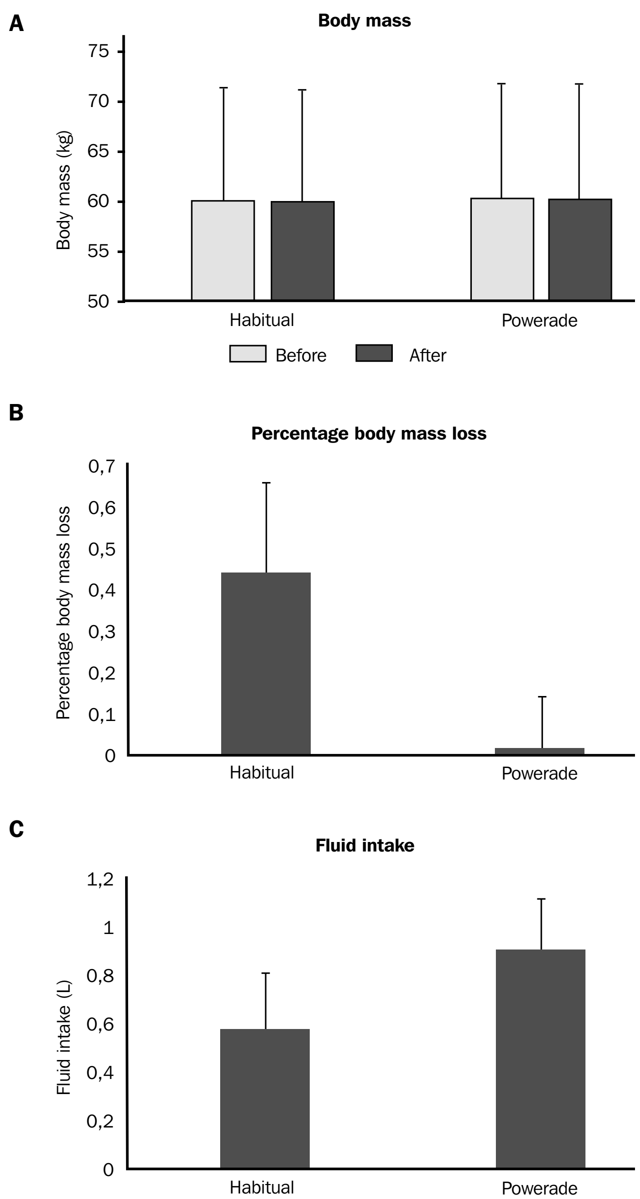
Figure 2. Complete repetition of a leg raise (A), pull-up (B) and handstand push-up (C).



Statistical analysis

The statistical analysis carried out focused on mean and standard deviation (SD) values. Because the number of subjects in the sample for the study was fewer than 30 (Pardo & Ruiz, 2004), a non-parametric statistics approach was chosen. For this reason, the Wilcoxon test for related measurements was used on the different variables of the study. The level of significance was taken as $p < 0.05$. All the statistics were calculated using SPSS software for Windows (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp).

Figure 3. Changes in body mass before and after artistic gymnastics training (A), % body mass loss at the end of training (B), fluid intake during training (C) by the different groups.



The values are means±SD; n=8 subjects. * means statistical difference at $p < 0.05$.

Results

Of the 9 athletes who began the study, one could not attend the tests on the last day. The results correspond to the 8 athletes who completed the entire study.

Body mass

The changes in the gymnasts' body mass on the days of the study are shown in Figure 3a.

During the first stage of the study, with their habitual intake of fluid (HAB), the gymnasts' body mass dropped from 60.04±11.37 to 59.78±11.32 kg after training, with a mass loss of 0.44±0.22%. The difference was significant (p=0.040).

In the second stage, the gymnasts were given the suitable amount and composition of drink (POW), and the figures before and after training were 60.35±11.40 and 60.35±11,41kg, respectively, with a mass loss of 0.01±0.13%. No significant change was registered (p=0.931).

The body mass loss percentage between HAB (0.44±0.22%) and POW (0.01±0.13%) was significant (p = 0.025), and is shown in Figure 3b.

Fluid intake

The amount of fluid ingested was 0.57±0.24 L (HAB) and 0.90±0.22 L (POW). The difference was statistically significant (p = 0.025) and is shown in Figure 3c.

Urine density and osmotic concentration analysis

The changes in urine density on the days of the study are shown in Figure 4a.

The HAB values before and after training were 1.019±0.006 and 1.025±0.013, respectively. The results did not show a statistically significant difference (p = 0.317).

During the POW stage, the athletes' urine density decreased from 1.020±0.003 a 1.018±0.005. This difference did prove to be statistically significant (p=0.046).

The changes in the osmotic concentration of the athletes' urine on the days of the study are shown in Figure 4b.

The HAB values for this variable before and after training were 982.00±151.91 and 966.38±114.15 mOsm/kg, respectively. The results did not show a statistically significant difference (p = 0.674).

In the POW stage, the osmotic concentration of the subjects' urine dropped from 925.75±133.57 to 893.63±96.71 mOsm/kg. Again, the results did not show a statistically significant difference (p = 0.674).

Performance measurements

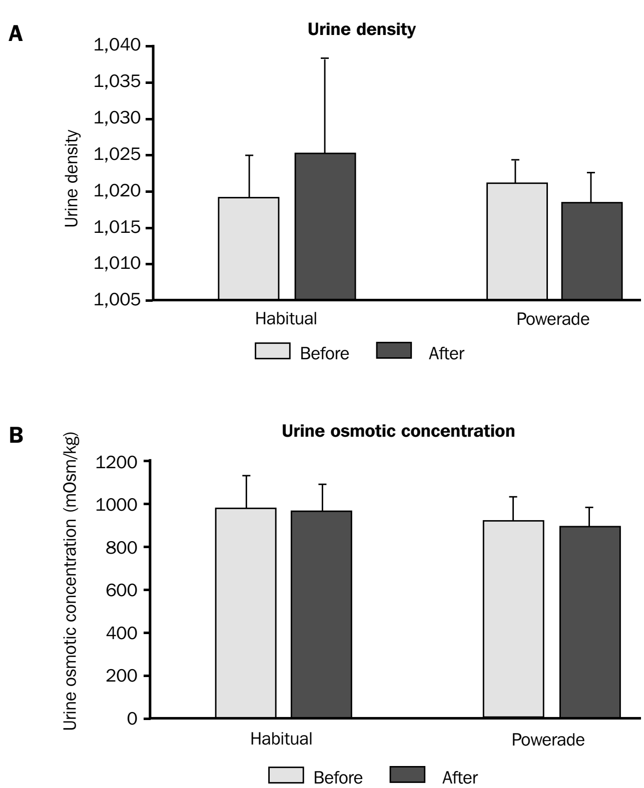
Figure 5a shows the number of repetitions of each exercise completed as a means of measuring performance.

The number of leg raise repetitions was 32.50±1.31 in HAB and 32.63±1.69 in POW. The result was not statistically significant (p=0.914).

The number of pull-up repetitions was 19.13±2.85 (HAB) and 21.88±3.27 (POW). The difference was statistically significant (p = 0.027).

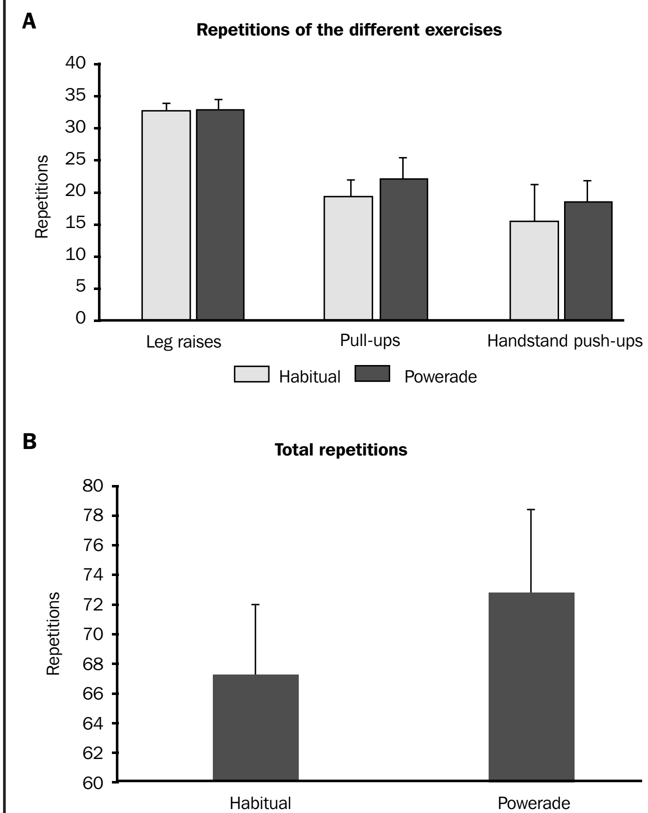
The number of handstand push-up repetitions was 15.50±5.55 in HAB and 18.13±3.60 in POW. The result was not statistically significant (p=0.207).

Figure 4. Urine density (A) and osmotic concentration before and after training in the different groups.



The values are means±SD; n=8 subjects. * means statistical difference at *p* <0.05.

Figure 5. Repetitions of the different exercises (A) and total repetitions (B) at the end of training in the different groups.



The values are means±SD; n=8 subjects. * means statistical difference at *p* <0.05.

The total number of repetitions carried out was 67.13±4.91 in HAB and 72.63±5.71 in POW. The difference was statistically significant (*p*=0.034) and is shown in Figure 5b.

Rate of perceived effort

The rate of perceived effort values were 6.25±1.39 in HAB and 6.75±1.49 in POW. The difference was not statistically significant (*p*=0.339) and is shown in Figure 6.

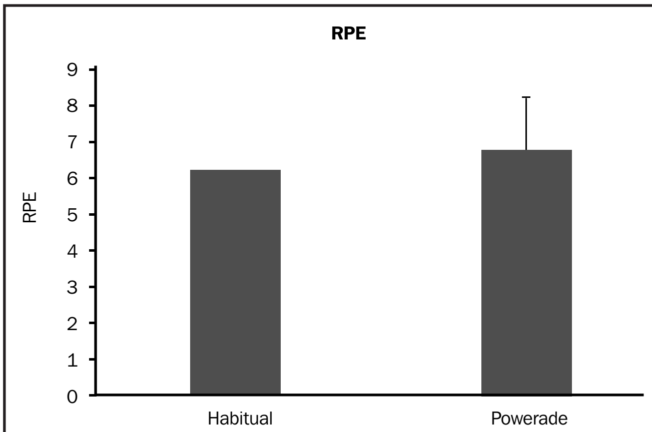
Tables 4 and 5 summarise the data presented above.

Discussion

In this study, we investigated hydration habits during regular training and calculated the right amount of the ideal drink for gymnasts to consume in order to assess any improvement in terms of performance on a second day of training.

The drink used in this study contains 7% carbohydrates and a concentration of Na^+ of 22.62 mmol/L (520 mg/L), fulfilling all the requirements to be called a sports drink according to the consensus of the Spanish Federation of Sports Medicine (FEMEDE)[22].

Figure 6. Rate of perceived effort (RPE) at the end of training by the different groups.



The values are means±SD; n=8 subjects.

Each participant was weighed before and after training to calculate the decrease in body mass during the exercise performed, this being the most realistic way[19] to find out the degree of fluid loss.

Table 4. Variables measured before and after training in the different groups.

Variable	Group	Before training	After training	*p*-value
Body mass (kg)	Habitual	60.04±11.37	59.78±11.32	0.040
	Powerade	60.35±11.40	60.35±11.41	0.931
Urine density	Habitual	1.019±0.006	1.025±0.013	0.317
	Powerade	1.020±0.003	1.018±0.005	0.046
Urine osmotic concentration (mOsm/kg)	Habitual	982.00±151.91	966.38±114.15	0.674
	Powerade	925.75±133.57	893.63±96.71	0.674

N.B.: The values are means±SD; n=8 subjects.

Table 5. Variables measured at the end of training in the different groups.

Variable	Habitual	Powerade	*p*-value
Leg raises (repetitions)	32.50±1.31	32.63±1.69	0.914
Pull-ups (repetitions)	19.13±2.85	21.88±3.27	0.027
Handstand push-ups (repetitions)	15.50±5.55	18.13±3.60	0.207
Total (repetitions)	67.13±4.91	72.63±5.71	0.034
Fluid intake (L)	0.57±0.24	0.90±0.22	0.025
Dehydration (%)	0.44±0.22	0.01±0.13	0.025
RPE	6.25±1.39	6.75±1.49	0.339

N.B.: The values are means±SD; n=8 subjects; RPE, Rate of perceived effort

In the HAB stage of the study, the gymnasts' lost 0.44±0.22% of body mass, meaning that they did not reach an excessive degree of dehydration (>2% body mass). These values are even lower than those described by Arnaoutis *et al.*[9], who cited a mass loss of 1.7±0.07%. The hydration pattern of the athletes taking part in the study was, therefore, acceptable.

Even so, individualised hydration (POW) worked better for the gymnasts than their habitual intake, with a body mass loss percentage of 0.01±0.13% (practically zero), as opposed to 0.44±0.22% in HAB. This result may be due to the greater intake of fluid in POW, 0.90±0.22 L *versus* 0.57±0.24 L in HAB, each gymnast following the personal recommendations given.

The urine density and osmotic concentration values in both HAB and POW before and after training fell within the ranges of euhydration, although were far from the 'well hydrated' values considered in this study.

It should be noted that urine density decreased significantly during training in POW. This may be due to the intake of a greater amount of fluid. Meanwhile, density increased slightly in HAB, without reaching a significant level, probably due to a lower intake of fluid.

Arnaoutis *et al.*[9], who also measured urine density in gymnasts, found that it rose from 1.022±0.004 to 1.024±0.008 after training, probably due to dehydration of 1.7% of body mass. In contrast, while the increase in density in HAB from 1.019±0.006 to 1.025±0.013 was greater, the decrease in body mass was much lower: 0.4%. In both studies, the variable possibly increases due to the decrease in body mass. The difference in the density increase between the two studies may be because there is great variation between individuals.

Although the osmotic concentration and density figures fall within the range of euhydration, both before and after training, they are by no means consistent with adequate hydration. Therefore, hydration during training may not be enough to maintain proper body water balance, meaning that importance should be placed on hydration throughout the day.

The exercises used to analyse the gymnasts' level of performance were taken from Sleeper *et al.*[24]. The three exercises considered the most specific to artistic gymnastics were chosen. The duration of each exercise was cut by half to take into account the fatigue resulting from training.

The total number of repetitions was significantly higher in POW than in HAB. This may be because muscle glycogen was saved in POW as a result of increasing blood glucose through the carbohydrates contained in the drink ingested in this stage.

The performance of gymnasts in a state of dehydration has never been studied, so the results were compared with weight training, given that most of the muscle groups are involved and performance is also measured using the number of repetitions.

Haff *et al.*[25] increased performance through sports drink intake before and during a one-hour session with 16 sets of 10 repetitions involving isokinetic exercise of the hamstrings and quadriceps. In Kraft et al's study[26], 3% dehydration prior to strength training consisting of 3 sets at an intensity of 12 RM to failure and 2 minutes rest between sets, with exercises involving the whole body (bench press, lateral pulldown, military press, bicep curl, tricep extension and leg press), led to significantly fewer repetitions. Therefore, adequate hydration can increase the work performed during training sessions, because the right kind of drink is consumed and dehydration is prevented.

The rate of perceived effort in POW was higher than in HAB, though not sufficiently so as to reveal statistically significant differences, possibly because the athletes did not reach a state of excessive dehydration at any stage.

Carvalho *et al*.[27] compared the RPE of basketball players who drank sports drink or water during training. Those who drank the sports drink felt less fatigue, though not sufficiently so as to yield statistically significant differences, as in this study.

In contrast, in Kraft et al's aforementioned study[26], the RPE of the group which was dehydrated to 3% body mass significantly increased. These data do not coincide with those from this research, possibly because the body mass loss percentage in HAB (0.44±0.22%) was not as high as in this study.

Limitations

- The placebo effect may have come into play when carrying out the performance tests, with the gymnasts feeling motivated as a result of consuming a drink which they were not used to.
- To ratify the results of the study, it would be desirable to prolong the duration of the two stages of the study, taking into account the athletes' hydration throughout the day.

Conclusion

- The habitual hydration pattern of artistic gymnasts during training is acceptable.
- Individualised hydration regimes for each gymnast are the best way to maintain body water balance during training.
- Suitable hydration significantly improves performance in artistic gymnastics.

Practical applications

The data from this study indicate that individualised hydration for gymnasts is the best hydration approach to maintain body water balance and enhance performance.

Therefore, the multidisciplinary team of professionals working with the gymnast should consider this form of hydration, the characteristics of which are quite easy to define using data on body mass loss and fluid intake.

Gymnasts do not tend to be ideally hydrated when they start training. Therefore, the general recommendations for fluid intake before training, which consist of about 5-10 mL/kg body mass, 2-4 hours beforehand[20], should be taken into account. The gymnasts should continue to drink after training, replenishing 125-150% of the fluid lost and ingesting an adequate amount of sodium in order to retain the fluid drunk and stimulate the sensation of thirst[20], always adapting these recommendations to the needs of each individual.

Conflict of interest

The authors declare that they are not subject to any type of conflict of interest.

Bibliography

1. Jemni, M. *The science of gymnastics*. New York. Routledge; 2013. p. 3-8.
2. Jemni M, Friemel F, Lechevalier JM, Origas, M. Heart rate and blood lactate concentration analysis during a high-level men's gymnastics competition. *J Strength Cond Res*. 2000;14(4):389-94.
3. Kolt GS, Kirkby RJ. Epidemiology of injury in elite and subelite female gymnasts: a comparison of retrospective and prospective findings. *Br J Sports Med*. 1999;33(5):312- 8.
4. Caine DJ, Nassar L. Gymnastics injuries. *Med Sport Sci*. 2005;48:18-58.
5. Marshall SW, Covassin T, Dick R, Nassar LG, Agel J. Descriptive epidemiology of collegiate women's gymnastics injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. *J Athl Train*. 2007;42(2):234-40.
6. Oppliger RA, Magnes SA, Popowski LA, Gisolfi, CV. Accuracy of urine specific gravity and osmolality as indicators of hydration status. *Int J Sport Nutr Exerc Metab*. 2005;15(3):236-51.
7. Goulet E. Pre-exercise hyperhydration: comments on the 2007 ACSM position stand on exercise and fluid replacement. *J Exerc Physiol Online*. 2008;11(2):64-74.
8. Rahnama N, Reilly T, Lees A. Injury risk associated with playing actions during competitive soccer. *Br J Sports Med*. 2002;36(5):354-9.
9. Arnaoutis G, Kavouras SA, Angelopoulou A, Skoulariki C, Bismpikou, S, Mourtakos S, *et al*. Fluid balance during training in elite young athletes of different sports. *J Strength Cond Res*. 2015;29(12):3447-52.
10. Gil, A. *Tratado de nutrición*. Tomo IV. Nutrición clínica. Madrid. Médica Panamericana; 2010. p. 187-208.
11. Agostoni CV, Bresson JL, Fairweather-Tait S, Flynn A, Golly I, Korhonen, H, *et al*. Scientific opinion on dietary reference values for water. EFSA *Journal*. 2010;8(3):1458-507.
12. Merchant A. Características de las de soluciones hidroelectrolíticas y su aplicación durante la actividad física. Una revisión bibliográfica. efdeportes. (revista electrónica) 1999 (consultado 0905/2017). Disponible en: http://www.efdeportes.com/efd14/hidro.htm
13. Chicharro JL, Vaquero AF. Fisiología del ejercicio. Madrid. Médica Panamericana; 2010. p. 677.
14. Baker LB, Dougherty KA, Chow M, Kenney WL. Progressive dehydration causes a progressive decline in basketball skill performance. *Med Sci Sports Exerc*. 2007;39(7):1114-23.
15. Cheuvront SN, Carter R, Sawka MN. Fluid balance and endurance exercise performance. *Curr Sports Med Rep*. 2003;2(4):202-8.
16. Montain SJ, Coyle, E. Influence of graded dehydration on hyperthermia and cardiovascular drift during exercise. *J Appl Physiol*. 1992;73(4):1340-50.
17. Nuccio RP, Barnes KA, Carter JM, Baker LB. Fluid Balance in Team Sport Athletes and the Effect of Hypohydration on Cognitive, Technical, and Physical Performance. *Sports Med*. 2017;47(10),1951-82.
18. Sawka MN, Montain SJ, Latzka WA. Hydration effects on thermoregulation and performance in the heat. *Comp Biochem Physiol A Mol Integr Physiol*. 2001;128(4):679-90.
19. 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.
20. Thomas DT, Erdman KA, Burke LM. Position of the Academy of Nutrition and Dietetics, dietitians of Canada, and the American College of Sports Medicine: Nutrition and athletic performance. *J Acad Nutr Diet*. 2016;116(3):501-28.

21. Armstrong LE, Maresh CM, Castellani JW, Bergeron MF, Kenefick RW, LaGasse KE, *et al.* Urinary indices of hydration status. *Int J Sport Nutr Exerc Metab*. 1994;4(3):265-79.
22. Palacios N, Franco L, Manonelles P, Manuz, B, Villegas JA. Consenso sobre bebidas para el deportista. Composición y pautas de reposición de líquidos. Documento de consenso de la Federación Española de Medicina del Deporte. *Arch Med Deporte*. 2008;15(126):245-58.
23. 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.
24. Sleeper MD, Kenyon LK, Casey E. Measuring fitness in female gymnasts: the gymnastics functional measurement tool. *Int J Sports Phys Ther.* 2012;7(2):124-38.
25. Haff GG, Koch AJ, Kuphal KE. The effects of supplemental carbohydrate ingestion on intermittent isokinetic leg exercise. *J Sports Med Phys Fitness.* 2001;41(2):216-22.
26. Kraft JA, Green JM, Bishop PA, Richardson MT, Neggers YH, Leeper JD. Impact of dehydration on a full body resistance exercise protocol. *Eur J Appl Physiol.* 2010;109(2):259-67.
27. Carvalho P, Oliveira B, Barros R, Padrão P, Moreira P, Teixeira VH. Impact of fluid restriction and ad libitum water intake or an 8% carbohydrate-electrolyte beverage on skill performance of elite adolescent basketball players. *Int J Sport Nutr Exerc Metab.* 2011;21(3):214-21.