Original Article

Is sodium a good hyperhydration strategy in 10k runners?

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ABSTRACT

The objective of the present study was to evaluate the effect of pre-exercise hyperhydration with sodium (PEHS), on the state of hydration and performance in runners of a 10K. Ten male runners (age 40.5 ± 9.7 yrs, weight 72.5 ± 8.4 kg, body fat 18.8 ± 4.5%) participated in the study and performed 10 km of street running under two different forms of prehydration: pre-exercise hydration (PEH), consisting of water intake *ad libitum*, and pre-exercise sodium hyperhydration (PEHS), consisting of sodium ingestion (12 mg of sodium for each 5 mL of water) diluted 1 h before the test. The variables evaluated were heart rate (HR), body temperature (BT), body mass (BM), blood pressure (BP), relative dehydration (RD), absolute dehydration (AD), total ingested water (TH_2O_{ING}), degree of dehydration (DD), sweating rate (SR), specific gravity of urine

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E-mail: desouza@ufs.br
Submitted for publication January 2018
Accepted for publication April 2018
Published *in press* July 2018
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2018.134.10

(SGU), urine pH, and performance time (PT). There was no difference between intervention groups in the variables HR, BT, BM, BP, SGU, urine pH, and PT. RD (0.76 ± 0.41 kg vs. 1.16 ± 0.43 kg; Cohen's d = 0.95; p = 0.042); AD (0.63 ± 0.36 kg vs. 0.99 ± 0.43 kg; Cohen's d = 0.90; p = 0.038); DD (0.63 ± 0.52% vs. 1.35 ± 0.56%; Cohen's d = 1.33; p = 0.009); SR (2255.03 ± 1297.25 mL vs. 3550.06 ± 1527.35 mL; Cohen's d = 0.91; p = 0.048) were lower in the state of PEHS. PEH presented greater TH_2O_{ING} (0.16 ± 0.12 mL vs. 0.34 ± 0.41 mL; Cohen's d = 0.59; p = 0.008). It was concluded that PEHS produces better hydration in runners during long distance running. **Keywords:** Sodium; Sports performance; Hypertonic saline solution.

Cite this article as:
de Souza, R.F., de Oliveira, L.S., de Matos, D., Moreira, O., da Silva, T., Chilibeck, P., Ferreira, A., Zanona, A.F., & Aidar, F.J. (2018). Is sodium a good hyperhydration strategy in 10k runners?. *Journal of Human Sport and Exercise*, *13*(4), 823-831. doi:https://doi.org/10.14198/jhse.2018.134.10

INTRODUCTION

Several sporting events occur in the summer season when temperature is high. The practice of physical exercise under these climatic conditions requires control and monitoring, since significant physiological demands result in dehydration, which compromises performance (Racinais et al., 2015).

Dehydration is caused by the low level of fluid (water, minerals, and organic compounds) in the body. During physical exercise, there is an increase in body temperature and blood flow to the skin, which causes heat loss through sweat evaporation (Sawka et al., 2007). Sweat is composed of water and electrolytes; excessive sweating combined with inadequate replacement during sports practice generates an imbalance that negatively impacts performance and health (Casa, Clarkson & Roberts, 2005).

Thus, many athletes intending to avoid or delay the dehydration state opt for pre-exercise hyperhydration (PEH) (Goulet et al., 2008). However, evidence suggests that sodium consumption in predetermined volumes may be more effective for stimulating water intake by increasing thirst (Morris et al., 2015).

The sensation of thirst is stimulated by vasopressin in response to plasma hyperosmolarity (Antunes-Rodrigues et al., 2004), which normally occurs during the dehydration state. However, by inducing hyperosmolarity with the infusion of hypertonic saline solution, vasopressin and thirst release occurs in hydrated individuals (Calzone et al., 2001).[7] It has been reported that sodium intake increases fluid intake *ad libidum* during exercise (Allen et al., 2013). In addition, the consumption of sodium solutions before exercise is a non-invasive mechanism to increase plasma volume (Hamouti et al., 2014). This can lead the individual to a greater intake of water and promote a state of hyperhydration.

There are few and inconclusive studies that evaluated the effects of sodium ingestion on PEH and consequently, on performance. Gigou et al. (2012) verified the efficacy of sodium hyperhydration (7.5 g Na^+) compared with euhydration in trained runners and triathletes. It was observed that pre-exercise sodium hyperhydration (PEHS) reduced heart rate and body temperature and presented less dehydration but without any effect on treadmill 18 km time trial performance. In contrast, Hamouti et al. (2014) found improved performance after salt PEH in cyclists during a time trial after 120 min of moderate-intensity cycling, and less plasma volume reduction was observed when salt was used compared to control; however there were no effects on thermoregulation.

Thus, the literature is slightly contradictory regarding the benefits of sodium ingestion during pre-exercise hydration. Therefore, the objective of this study was to evaluate the effect of sodium ingestion diluted in water on the state of pre-exercise hyperhydration and the performance of runners in a 10K. It was hypothesized that sodium ingestion during pre-exercise hydration would improve hydration status during exercise and subsequently improve performance.

METHODS

Ten volunteers in street race events, members of the Racing Club of the Federal University of Sergipe - Brazil, participated in this study. Inclusion criteria were male subjects, aged between 18 and 40 years, having a pace of 4 to 6 min/km, with an average weekly training volume of 30 ± 4.7km and without injuries in the last 6 months. Exclusion criteria were hypertensive individuals, those who did not complete the course, and those who were injured during the race.

Ethical approval for the study was received from the National Committee of Ethics in Research - CONEP, the National Health Council, and all participants signed a consent form that conformed to the ethical principles contained in the Declaration of Helsinki.

Procedures

All volunteers (age 40.5 ± 9.7 yrs, weight 72.5 ± 8.4 kg, height 1.74 ± 0.04 cm, body fat 18.8 ± 4.5%) performed on-track tests in the afternoon period under two different conditions: pre-exercise hydrated and hyperhydrated pre-exercise with sodium. There was a one-week interval between each intervention. For the pre-test euhydration protocol (PEH), the subjects ingested pure water at will (*ad libitum*) 1 h before the beginning of the test, allowing the emptying of the bladder. For the pre-exercise hyperhydration with sodium (PEHS), 12 mg of sodium for each 5 mL of water was added one hour before the start of the test. The subjects drank water whenever they were thirsty, allowing emptying of the bladder (Morris et al., 2015). On the day of PEHS, the local temperature at 17:00 pm was 28°C with a relative humidity of 75%. In the PEHS race the temperature was 28°C and the relative humidity was 77%. Before and after the interventions, urine samples were collected for analysis, and body weight, body temperature, blood pressure, heart rate and volume of water ingested during the tests were recorded.

Familiarization

One week before the study, all the participants were present at the track with the route that was used on the days of the interventions and carried out a light race for familiarization.

Hydration state

In order to verify the hydration status of the athletes, the following parameters were evaluated: total ingested water during the race (TH_2O_{ING}), body mass (BM), relative dehydration (RD) and absolute (AD), degree of dehydration (DD), specific gravity of urine (SGU), and urine pH.

Body mass, relative and absolute dehydration, rate of sweating, degree of dehydration, and body temperature

Body weight (BW) was measured by using a digital scale (Onida brand), with an accuracy of 100 grams, pre- and post-race; this was used as a reference for the calculation of the RD, AD, DD, and sweating rate (SR), using the following formulas:

RD = BWpre–BWpost
AD = (BWpre + Fi)–(BWpost + U), where Fi = fluid intake and U = volume of urine produced
DD = [(BWpre–BWpost)–U] / BWpre] × 100
SR= [(BWpre–BWpost) + Fi–(U + F)] / time of exercise (hour) × 60, where F = produced faecal volume.
(Burke and Hawley (1997); Horswill (1998)

BWpre= Body weight before race (Kg); BWpost= Body weight after race (Kg); Fi= Fluid intake (mL); U= Volume of urine produced (mL); F= Volume of faeces produced (g)

Body temperature was measured before and after the tests by using a digital thermometer (G-Tech brand) under the athlete's armpit for 60–120s.

Blood Pressure

Blood pressure was measured with an aneroid sphygmomanometer (Tycos, USA)® and stethoscope (Littemann Quality, Germany). The BP measurement was performed with the volunteers seated and the left arm held at heart level. The median of three blood pressure measurements performed with an interval of 10 min between them was used for each volunteer. All measurements were performed by the same evaluator.

Heart rate and total performance time

The heart rate (HR) was measured by using the Dixtal model Superbright - DX 2455 model (Philips, The Netherlands), with a sensor positioned on the 3rd finger of the right hand, the reading being determined after stabilization of the signal. The devices have a receptacle to accommodate the distal portion of the finger, with one side containing a light source composed of two light emitting diodes (LED) and a photodetector on the other side. One LED emits red light (≅ 660 nm), and another emits infrared light (≅ 940 nm). A digital timer (Vollo® VL-512) was used to quantify the performance time (PT). The heart rate was assessed 3 minutes before the start of the race and 3 minutes after term.

Collection and analysis of specific gravity of urine and pH

In order to verify the specific gravity of the urine (SGU) and the pH, the athletes' urine was collected before and after the end of the test using a collecting vessel with a capacity of 40 mL. As an instrument of analysis, specific colorimetric tapes were used for urinalysis (Gold Analisa Diagnostica®, Belo Horizonte, Brazil).

Statistics

To verify the distribution of the sample, a test for normality and homogeneity was performed using the Shapiro–Wilk and Levene tests, respectively, considering the sample size. To analyse the variables HR, BT, BM, SBP, DBP, SGU, and urine pH a two-way repeated-measures ANOVA was used with Bonferroni's *post hoc* tests to analyse the factors time (pre-test vs. post-test) x conditions (PEH versus PEHS). Student's t-test was used to analyse the variables TH_2O_{ING}, PT, RD, AD, DD and SR, after the race. For verification of effect size, Cohen's d-test was used. All descriptive results were expressed as either means and standard deviations or mean absolute changes and 95% confidence intervals. Results were considered statistically significant at $p \leq 0.05$. Data were analysed by SPSS software 20.0.

RESULTS

Heart rate of the post-test in the PEHS condition (145 ± 18) was significantly increased by 33.1% when compared to that of the pre-test (97 ± 2, $p < 0.001$, Cohen's d = 8.42). The PEH post-test (156 ± 12) increased by 53.2% when compared with that of the pre-test (97 ± 2; $p < 0.001$; Cohen's d = 3.66). There was no condition x time interaction.

The systolic blood pressure of the PEH (132 ± 1) and the PEHS (140 ± 1) post-test conditions increased by 8.3% (121 ± 1, $p = 0.032$, Cohen's d = 1.17) and 6.8% (131 ± 1, $p < 0.001$, Cohen's d = 0.92), respectively, when compared with their respective pre-test values. Similarly, diastolic blood pressure in both PEH (89 ± 1) and PEHS (89 ± 1) increased by 15.7% (75 ± 1, $p < 0.001$; Cohen's d = 1.82) and 13.5% (77 ± 1, $p = 0.0035$, Cohen's d = 1.38). There were no condition x time interactions for blood pressure.

The urine specific gravity in the PEHS condition post-test (1.020 ± 4.08 g/mL) increased 1.38% when compared with the pre-test (1.009 ± 2.10 g/mL, $p < 0.001$; Cohen's d = 0.003). The PEH post-test (1.023 ± 2.58 g/mL) increased by 1.68% relative to the pre-test (1.006 ± 3.94 g/mL, $p < 0.001$, Cohen's d = 0.005). However, there was no condition x time interaction (Table 1).

Table 1. Pre- and post-intervention values of heart rate, body temperature, body mass, blood pressure, urine specific gravity, and urine pH

	PEH		PEHS		
Variable	Change	95% CI	Change	95% CI	p
HR (bpm)	84	(69, 98)	48	(58, 87)	0.229
BT (ºC)	0.38	(−0.18, 0.94)	0.16	(−0.30, 0.62)	1.00
BM (Kg)	−1.16	(−8.72, 6.40)	−1.05	(−8.61, 6.51)	1.00
SBP (mmHG)	1.2	(0.1, 2.3)	1.7	(0.6, 2.8)	0.882
DBP (mmHG)	1.3	(0.5, 2.1)	1.00	(0.2, 1.8)	1.00
SGU (g/mL)	0.01	(12.89, 21.10)	0.01	(6.89, 15.10)	0.294
Urine pH (mol/dm^3)	0.70	(0.15, 1.24)	0.10	(−0.47, 0.67)	1.00

p = probability of significance <0.05, condition x time.
CI = confidence interval.
HR = heart rate; BT = body temperature; BM = body mass; SBP = systolic blood pressure; DBP = diastolic blood pressure; SGU = specific gravity of urine

When analysing post-race hydration variables between conditions (table 2), it was observed that total ingested water during the race (TH_2O_{ING}) was 52.9% lower in the PEHS condition (0.16 ± 0.12 mL) than in the PEH condition (0.34 ± 0.41 mL, *p* = 0.008, Cohen's d = 0.59). The relative dehydration in the PEHS condition (post-race) (0.76 ± 0.41) was 34.5% lower than that in the post-race PEH condition (1.16 ± 0.43; *p* = 0.042; Cohen's d = 0.95).

Similarly, the PEHS condition also presented a 36.4% reduction in absolute dehydration (0.63 ± 0.36 kg vs. 0.99 ± 0.43 kg, *p* = 0.038, Cohen's d = 0.90), 53.3% reduction in degree of dehydration (0.63 ± 0.52 kg vs. 1.35 ± 0.56 kg, *p* = 0.009, Cohen's d = 1.33) and 36.5% reduction in the sweating rate (2255 ± 1297 mL vs 3550 ± 1527 mL, *p* = 0.048, Cohen's d = 0.91) in relation to the PEH condition post-test. There was no difference between the total performance times (PEHS 48:11 ± 04:37 (min:s) vs PEH 49:37 ± 05:34 (min:s), p= 0.536, Cohen's d = 0.28).

Table 2. Post-intervention values of total ingested water, performance time, relative dehydration, absolute dehydration, degree of dehydration, and rate of sweating

	PEH vs PEHS		
Variable	Difference (PEHS – PEH)	95% CI	*p*
TH_2O_{ING} (L)	−0.12	(−0.21, −0.37)	0.008
PT (s)	-86.60	(-201.83, 375.03)	0.536
RD (Kg)	−0.41	(−0.80, -0.01)	0.042
AD (Kg)	−0.38	(−0.74, -0.02)	0.038
DD (%)	−0.72	(−1.23, -0.20)	0.009
SR (mL)	−1325.02	(−2633.79, −16.25)	0.048

p-value represents difference between conditions.
CI = confidence interval.
PEHS = pre-exercise hyperhydration with sodium; PEH = pre-exercise hydration; total ingested water (TH_2O_{ING}); performance time (PT); relative dehydration (RD); absolute dehydration (AD), degree of dehydration (DD), sweating rate (SR)

DISCUSSION

The present study evaluated the effect of pre-exercise hyperhydration induced by sodium ingestion diluted in water, on the state of hydration and performance of 10K runners. We hypothesized that PEHS may be beneficial for prevention of dehydration and improvement in performance.

Analysis of performance time (PT) verified that there was no difference between the conditions, in disagreement with the proposed hypothesis. In contrast, it was shown that the PEHS condition presented a better state of hydration when the post-test state of the variables total water intake during the test, relative dehydration, absolute dehydration, degree of dehydration, and sweating rate was assessed.

It is known that a well-hydrated body presents significant performance benefits, stabilizing body fluids (water, minerals, and electrolytes) and assisting in thermoregulation (Sawka et al., 2007). It was identified that sodium prehydration favoured the pre-competitive hyperhydrated state. Although the results of the present study agree with those of other studies (Morris et al., 2015; Johannsen et al., 2009), who also concluded that sodium hyperhydration did not improve sports performance, it could be that PEHS might be more beneficial if done over longer distances than 10 km when dehydration might become a more important factor.

Hydration helps to reduce effects of muscle fatigue (Nebot et al., 2015), yet it was observed that water intake during the test was lower in the PEHS condition than in the PEH, which demonstrates the efficacy of a prolonged state of hydration with less need for water replacement, thus proposing optimization of the test time and maintenance of the running pace to rehydrate during the passage through the hydration stations.

The relative and absolute dehydration were lower in the PEHS post-race when compared with PEH, which reinforces the evidence that the sodium-triggered state favoured hyperhydration of the runners (Gigou et al., 2012). Furthermore, there was higher water consumption in the PEH state during the race, which reinforces that the state of hyperhydration reduces thirst during the competition (Goulet et al., 2008). It was inferred that the sensation of thirst due to sodium intake occurred only before the start of the race in order to promote the state of hyperhydration.

The perception of thirst is sensitive to increased plasma sodium concentration and decreased blood volume. Thus, hydration with water reduces this sensation by altering the cellular osmolarity (Perrella, Noriyuki & Rossi, 2005). The need for water replacement depends on the intensity, duration of exercise, and ambient temperature. Humans naturally fail to replenish water loss at the same rate as it is eliminated.

During vigorous and prolonged exercise, the thirst sensation should not be identified as an indicator of fluid replacement, since thirst is already a result of minimal dehydration, thus hyperhydration can be an effective mechanism against thermal stress, delaying dehydration, and minimizing the increase in body temperature (Drummond, de Carvalho & Guimarães, 2007).

Although the hyperhydration state favoured thermoregulation during exercise, after 10 km of running, no changes in body temperature were observed in both forms of hydration. Conditions were made favourable by the hydration offered during the race. Similarly, BP did not differ between hydration conditions, demonstrating only the natural physiological increase due to elevated cardiac output and arterial vasodilation due to exercise performance (Monteiro & Sobral Filho, 2004). Thus, this result showed that intake of sodium diluted in water did not alter blood pressure.

The degree of dehydration was considered to have a low impact in both conditions, however lower rates of dehydration were observed when in the PEHS state, which may be beneficial for health, since 1–2% dehydration can raise body temperature up to 0.4 °C for each subsequent percentage of dehydration, 3% can reduce athletic performance, 4%–5% can decrease the capacity for prolonged exertion by 20%–30%, and above 6% can increase the risk of thermal fatigue, thermal shock, and in more severe cases, death (Coyle & Hamilton, 1990).

The specific gravity of the urine was not different between the conditions, but it was elevated at the end of the run in both conditions when compared to the initial state. Its value at the end of the run may be indicative of mild dehydration (1.010–1.020 g/mL) similar to body mass, which minimally changed - it is known that losses of greater than 2% body mass indicate a state of minimal dehydration (Casa et al., 2005); this did not occur in our study.

The sweating rate (SR) was lower in the PEHS than in the PEH state. However, both rates were higher than 2 L, which exposes participants to an accelerated process of water loss (Savoie, Asselin & Goulet, 2016). Although SR is expected to occur proportionally to fluid intake, the fact that PEHS has a lower SR may be related to sodium increasing net retention (Morris et al., 2015).

CONCLUSION

Pre-exercise hyperhydration with sodium assists in the maintenance of the hydration state of 10K runners. The state of hyperhydration does not improve performance time; however, it reduces the need for water intake during the running course and decreases relative and absolute dehydration, the degree of dehydration, and the rate of sweating.

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