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The Effect of Physiology and Hydration Beliefs on Race Behavior and Postrace Sodium in 161-km Ultramarathon Finishers

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Purpose: To determine if beliefs about physiology and rehydration affect ultramarathon runners' hydration behaviors or if these beliefs increase the risk for exercise-associated hyponatremia (EAH). ***Methods:*** Participants of the 2011 161-km Western States Endurance Run completed a prerace questionnaire, prerace and postrace body-mass measurements, and postrace assessment of serum sodium ([Na+]). ***Results:*** Of 310 finishers, 309 (99.7%) completed the prerace questionnaire and 207 (67%) underwent postrace blood studies. Twelve (5.8%) finishers had asymptomatic EAH ([Na+] range 131–134 mmol/L). The most common hydration plan (43.1%) was drinking according to schedule, and these runners did so to replace fluid lost when sweating (100%) and to avoid dehydration (81.2%). Prerace drinking plan was not associated with postrace [Na+] or the development of postrace hyponatremia. There also were no group differences between those with and those without EAH for any other variables including planned energy intake or knowledge of fluid balance. Runners not planning to drink to thirst trended toward more influence from advertisements (P = .056) and were significantly more influenced by scientific organizations (P = .043) than runners with other drinking plans. Finally, runners who believe that EAH is caused by excessive drinking adopted a lower-volume drinking plan (P = .005), while runners who believe that EAH is caused by sodium loss via sweating reported more common use of sodium supplementation during the race (P = .017). ***Conclusions:*** Beliefs regarding the causes of EAH alter race behaviors including drinking plan and sodium supplementation but do not appear to affect the likelihood of developing EAH during a 161-km ultramarathon.

Keywords: fluid balance, health behavior, endurance, exercise, hyponatremia

Exercise-associated hyponatremia (EAH) is a potentially fatal condition of water imbalance characterized by a serum sodium ([Na+]) <135 mmol/L during or after prolonged exercise.[1] A complication of EAH is exercise-associated hyponatremic encephalopathy, in which cerebral edema results in increased intracranial pressure and risk of tonsillar herniation.[2] This preventable condition has been responsible for numerous deaths in the 3 decades since it was first recognized.[3]

The incidence of EAH in ultraendurance events has been found to be quite variable. A pooled analysis of 200 European ultraendurance athletes including swimmers, cyclists, runners, and triathletes found an EAH prevalence of 6%.[4] This is consistent with another study of 145 European ultrarunners reporting a prevalence of 5%.[5] However, studies of 161-km ultramarathons conducted in warmer North American climates have shown a much higher prevalence, ranging up to 30% to 51%.[6–8]

The overconsumption of hypotonic fluids is well established as a primary cause of EAH.[1,9–11] This may be exacerbated by nonosmotically stimulated vasopressin release from the posterior pituitary.[12,13] Drinking to thirst has been advocated as the hydration plan with the lowest risk for EAH development[14] while risking no decrease in performance.[15,16] Among athletes running shorter distance races (≤21 km), certain hydration-related beliefs have been linked to overdrinking.[17] It is unknown whether this relationship exists for participants in ultramarathons and whether these risky hydration beliefs have a measureable effect on [Na+] or the development of EAH.

There is a small body of literature that details hydration behaviors in ultramarathons.[18–22] Mean rates of fluid ingestion vary from 0.5 to 0.8 L/h, and in at least 1 study, the significant strong (r = –.58) relationship between fluid ingestion during the last half of a 160-km run and postrace [Na+] was shown to have a negative slope.[21] However, a recent large study of 669 ultramarathoners found a weak (r = .17) but significant relationship such

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that lowered [Na^+] was more common with weight loss.[8] The discordance of body-mass measurements and total body water during ultramarathons (that a 2–4% loss in body mass is required before a decrease in total body water) has previously been described.[23]

The use of sodium supplementation during ultraendurance racing is common. A recent study documenting sodium intakes during a 161-km ultramarathon reported rates of 5 to 10 mg/kg/h,[22] although this included all sources of sodium—dietary, as well as supplemental. Some authors have suggested that ultraendurance athletes require approximately 1 g of sodium intake per hour to help maintain fluid and electrolyte homeostasis.[24,25] However, a study in ultraendurance triathletes failed to show significant changes in [Na^+] between groups who were given sodium supplementation of 600 to 700 mg/h or a placebo during the course of an approximately 12-hour race, although those supplementing with sodium did lose significantly less body mass during the race.[26] It was concluded that normal (or habitual) levels of dietary sodium intake were sufficient to protect against EAH during ultraendurance triathlons.

If prerace beliefs have measureable effects on race behavior or postrace [Na^+], then further hydration education may decrease the incidence of EAH among ultramarathon participants. Therefore, the main goal of this study was to describe hydration strategies during the 161-km Western States Endurance Run and to determine the relationships among hydration beliefs, race-related behaviors, and indices of fluid and electrolyte balance.

Methods

This observational study was performed at the 2011 Western States Endurance Run, a 161-km mountain-trail ultramarathon from Squaw Valley, CA, to Auburn, CA, that has been previously described.[6] The study was approved by the institutional review board at the VA Northern California Health Care System with waiver of consent. All race entrants were invited via e-mail to complete a Web-based prerace questionnaire approximately 22 days before the event and invited again 10 days before the event if they had failed to respond initially. Nonresponders were further invited to complete the questionnaire in person at registration the day before the race. The prerace questionnaire included questions about demographics, running experience, hydration and food-consumption plans during the race, and hydration beliefs.

Race finishers underwent body-mass measurement immediately before race start and immediately after crossing the finish line. All participants were weighed in lightweight running clothing and shoes on 1 of 4 calibrated digital scales (Health-o-Meter model 349KLX, Bridgeview, IL) placed on a firm, level surface. The same scale was used for both measurements on any individual athlete.

Blood samples were collected from willing runners immediately after crossing the finish line via venipuncture by professional phlebotomists, with subjects seated. Samples were centrifuged within 30 minutes and placed in a cooler before being transported to a local clinical laboratory where plasma samples were analyzed for [Na^+] (Beckman Coulter DXC 800 chemistry analyzer, Beckman Coulter, Brea, CA). Fluid intake rates were not measured.

Data are presented as mean ± SD. Characteristics of finishers completing the prerace survey and those completing both the survey and the blood analysis were compared with unpaired *t* tests (continuous data) and the chi-squared test (categorical data). Single-factor analysis of variance (ANOVA) determined differences in mean postrace [Na^+] in hydration-plan groups and among groups holding different physiological beliefs. A 2-tailed *t* test determined differences between those who did and those who did not use supplemental sodium. Statistical significance was set at $P < .05$.

Results

Of 310 finishers, 309 (99.7%) completed the prerace survey and 207 (66.8%) provided postrace blood samples. Table 1 presents characteristics of the finishers who completed the prerace survey, grouped by whether a blood sample was obtained. The 2 groups were similar for age, sex, finish time, 161-km ultramarathon experience, and body-mass change during the race. Of the 207 finishers who completed postrace blood studies, 12 (5.8.%) were found to have postrace hyponatremia ([Na^+] range 131–134 mmol/L), although all were asymptomatic.

In the prerace survey, runners were asked, "What is your drinking plan for the race?" and given a single choice of 5 responses ("as much as I can," "to keep my urine clear," "on a schedule," "when thirsty," and "other"). Many runners (43.8%) reported that they planned to drink according to a predetermined schedule, measured either by distance or time. Another 16.6% reported drinking to thirst. Figure 1 presents the distribution of hydration plans along with postrace [Na^+] for each group ($P = .98$).

Runners were further asked, "Why do you plan to drink this way?" and allowed multiple responses including "to avoid hyponatremia," "to avoid dehydration," "to replace fluid lost in sweat," "I believe more fluids help me run faster," "to avoid uncomfortable stomach symptoms," "because it is recommended to drink this way," or "other." Figure 2 displays the most common reasons that runners reported for selecting their specific drinking plans. "To replace fluid lost via sweating" (100%) and "wanting to avoid dehydration" (81.2%) were the most common responses.

The contributions of outside influences on hydration plans are presented in Table 2. The majority of runners indicated a high level of influence from personal experience and relatively little or no influence from advertising. Runners drinking according to a predetermined schedule reported a greater influence from advertising ($P = .056$) and scientific organizations ($P = .043$) than runners with alternative hydration plans.

Table 1 Comparison of Demographic and Performance Characteristics of Subgroup of Finishers Who Completed Both the Prerace Survey and Postrace Blood Sampling (n = 207) with Group of Finishers Completing the Prerace Survey (n = 309)

	Survey and blood sample	Survey	*P*
161-km ultramarathons completed (n)	4.8 ± 5.8	4.6 ± 7.8	.42
Age (y)	43.0 ± 9.6	42.7 ± 9.4	.76
Male sex (%)	81.3	81.5	.42
Race time (h)	25.2 ± 3.8	25.1 ± 3.8	.79
Body-mass change (%)	–1.6 ± 2.0	–1.6 ± 1.9	.73
Postrace [Na+] (mmol/L)	139.9 ± 3.1		

Note: Data presented as mean ± SD except when presented as percentage.

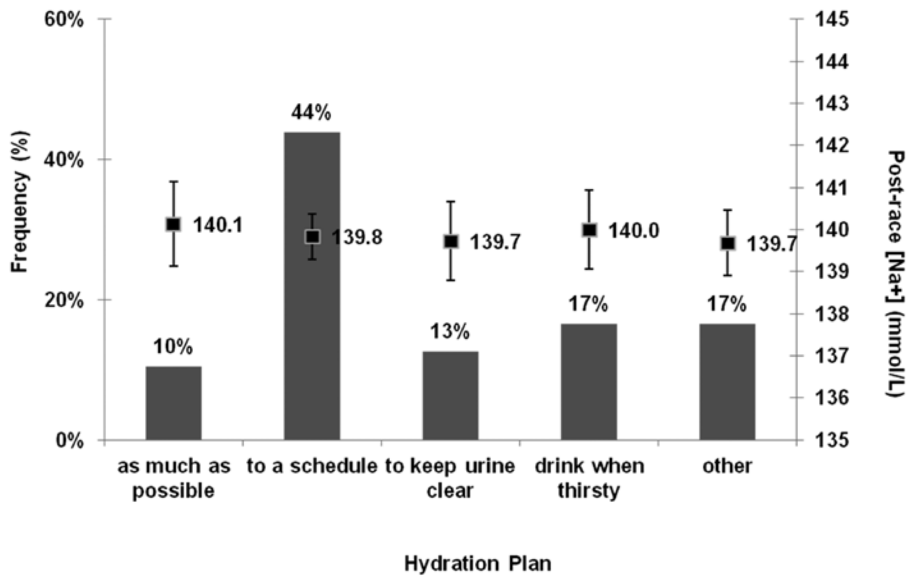

Figure 1 — Frequency of hydration plans and associated mean postrace [Na$^+$] (N = 207). Postrace [Na$^+$] did not vary significantly across groups (*P* = .98). Bars indicate 95% confidence interval for mean [Na$^+$] of hydration-plan group.

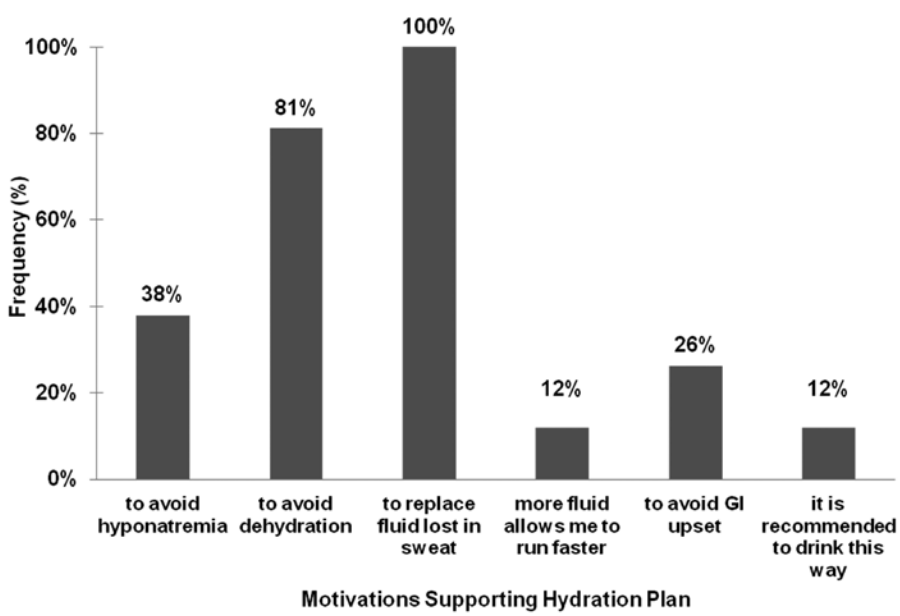

Figure 2 — Runners' reasons for choosing particular hydration plans as a percentage of total responding field (N = 309).

From survey data, cohorts were examined to determine the effect of beliefs on practices during the race. Among runners who responded that inadequate sodium intake is a cause of EAH (74.7%), the plan to use sodium supplementation was more common (P = .02). No significant difference in mean postrace [Na^+] was found between runners who planned to supplement with sodium and those who did not (Figure 3). Runners who indicated that EAH was primarily caused by excessive fluid intake (68.5%) adopted a thirst-based hydration plan more frequently than others (P = .005). No other postrace [Na^+] differences or body-mass changes among participants were found with regard to previous running experience, hydration beliefs, physiological knowledge, or hydration motivations.

Discussion

This study investigated the associations among beliefs, motivations, and influences that underlie hydration plans during ultramarathon participation and is the first study to relate these to physiological outcomes ([Na^+] and body-mass change). Previously, we demonstrated that certain hydration-related beliefs are reflected in the development of unsafe drinking plans during shorter running distances and in relatively inexperienced athletes (<3 y running experience).[17] The current study did not find any differences in the rates of postrace hyponatremia among participants with differing levels of knowledge regarding fluid-balance physiology (data not shown). In contrast to our previous study of much shorter races

Table 2 Runners' Reports of Levels of Influence of Various Sources on Their Hydration Plans

	Percentage Reporting Influence				
	1	2	3	4	5
Personal experience	<1	1	2	15	84
Recommendations from friends	14	17	24	33	14
Scientific authorities (individuals)	20	15	25	24	16
Scientific organizations	25	17	28	20	10
Race organizers	34	22	23	12	8
Advertisements	72	17	10	1	0

Note: Data reported as percentage of responding field (N = 309) indicating particular level of influence (1 = *no influence,* 5 = *heavy influence*).

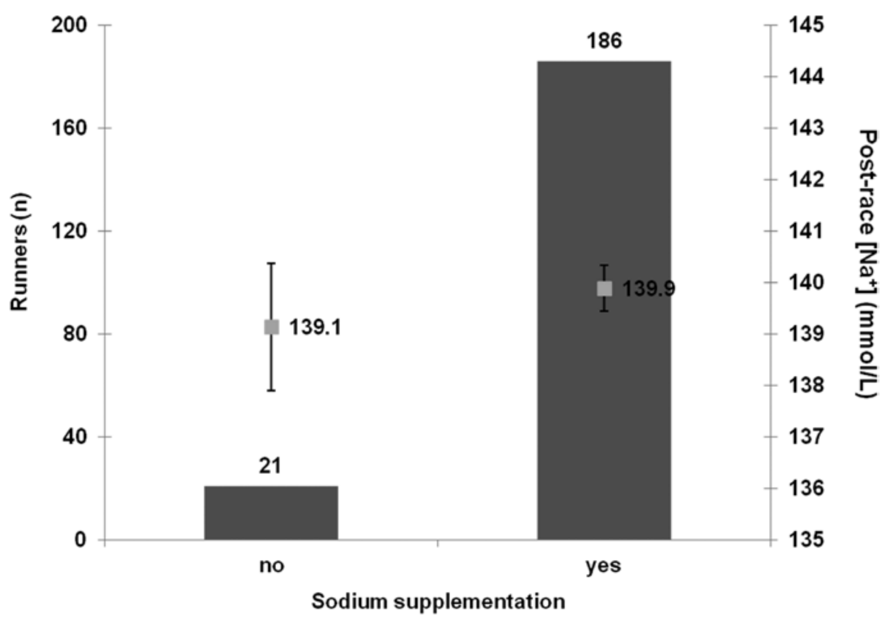

Figure 3 — Prevalence of race-day sodium-supplementation intention and postrace [Na^+] shown by supplementation group. Bars indicate 95% confidence interval for mean postrace [Na^+] among the 2 groups (N = 207). Postrace [Na^+] did not vary significantly (P = .27).

in which it was found that 57% of runners drank when thirsty,[17] the prevalence of this pattern of hydration in this cohort of runners was only 16.6% for reasons that remain unclear.

One of the main goals of the current study was to investigate the relationship between a priori hydration plans and postrace [Na^+]. It is theorized that the overhydration that frequently causes EAH is due to incorrect hydration education.[17,27] This relationship was not shown in the current sample of ultraendurance runners (Figure 1). This study did, however, capture a relationship between a priori hydration beliefs and behaviors during the race. For example, the runners who recognized the role that overhydration plays in the development of EAH chose drink-to-thirst hydration more frequently (P = .017) than did runners not holding this belief (data not shown). In observational studies of race distances from 21 to 100 km, drinking to thirst has been demonstrated to be safe and without apparent detrimental effect on performance.[16,28,29] Furthermore, education along with fluid limitation has previously been shown to be successful in decreasing rates of EAH in an ultradistance triathlon.[30] These findings suggest that efforts to educate ultramarathoners about the causes of EAH may decrease the prevalence of higher-volume-hydration plans without adversely affecting performance, but whether it will alter the incidence of EAH is unclear.

Finally, runners who believe that an insufficient sodium intake is a cause of EAH more commonly (P = .005) supplemented with sodium during the race. We found no differences for postrace [Na^+] between these groups (Figure 3), indicating that either the supplementation had no effect on postrace [Na^+] or, alternatively, that certain runners require supplementation to maintain a normal [Na^+]. This supports the findings of several studies that found that sodium supplementation was not required to maintain [Na^+] during endurance events.[22,26,31]

We found the prevalence of postrace hyponatremia during this race to be surprisingly low, which may reflect the more temperate conditions (0–28°C at nearby locations, mean 24.5°C) during the 2011 event when compared with usual temperatures at this race.[8] Compared with previous studies completed at this event[6,8] and a nearby 161-km mountain-trail race,[7] the low prevalence of EAH (5.8%) was unusual and likely increased the difficulty of establishing the relationships that this study investigated. If the postrace hyponatremia incidence had been closer to that previously observed at the Western States Endurance Run, the study would have been powered to find smaller differences in the data. The study was also limited by the usual difficulties of self-report survey data, although the participation rate was very high.

This study found that previously held beliefs were associated with hydration and sodium-supplementation behaviors during an ultramarathon. We also found that ultrarunners vary greatly in their hydration plans and that most do not drink only when thirsty but rather with the intent to replace lost fluid. It is interesting that the great variability in both hydration plans and sodium supplementation does not affect postrace [Na^+]. These findings should stimulate more effort to determine if prerace educational efforts by race organizers will decrease exercise-associated illnesses in ultramarathons.

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