7-2002

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Stuempfle, K., et al. "Hyponatremia in a Cold Weather Ultraendurance Race." Alaska Medicine 44.3 (July-September 2002), 51-5.

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Abstract
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Keywords
hyponatremia, ultraendurance, race diet, sodium consumption, ultramarathon

Disciplines
Other Medicine and Health Sciences | Sports Sciences

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ABSTRACT

We assessed the incidence and etiology of hyponatremia in the 100-mile (161 km) Iditasport ultramarathon. Subjects (8 cyclists, 8 runners) were weighed and serum sodium was measured pre- and post-race. Race diets were analyzed to determine fluid and sodium consumption. Subjects were split by post-race serum sodium concentration into hyponatremic and normonatremic groups for statistical analyses. Seven of 16 subjects (44%) were hyponatremic. The hyponatremic group exhibited a significant decrease in serum sodium concentration (137.0 to 132.9 mmol/L), and the normonatremic group experienced a significant decrease in weight (82.1 to 80.2 kg) pre- to post-race. The hyponatremic group drank more fluid per hour (0.5 versus 0.4 L/h) and consumed less sodium per hour (235 versus 298 mg/h) compared to the normonatremic group. In conclusion, hyponatremia is common in an ultraendurance race held in the extreme cold, and may be caused by excessive fluid consumption and/or inadequate sodium intake.

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INTRODUCTION

Hyponatremia, defined as a serum sodium level below 135 mmol/L, is a serious consequence of endurance events lasting longer than six hours (1). Possible signs and symptoms include lightheadedness, nausea, vomiting, malaise, exhaustion, altered mental status, headache, seizures, and in extreme cases, death (2).

Figure 1 shows the two leading theories that attempt to explain the hyponatremia associated with prolonged exercise (1,3,4). One theory suggests that hyponatremia is caused by an increase in total body water, resulting from excessive fluid consumption or a failure to excrete excess volume. The second theory suggests that a decrease in sodium content resulting from excessive sodium loss in sweat or inadequate sodium intake causes hyponatremia. These two theories are not mutually exclusive. Any combination of the factors displayed in Figure 1 could lead to the development of hyponatremia.

Numerous papers have been published on the occurrence of hyponatremia in triathletes (2,5-12), ultramarathoners (13-17), marathoners (18-20), Grand Canyon hikers (21,22), military recruits (23, 24), and subjects in laboratory studies (25,26). All of these events took place in mild to hot environments, and the studies did not include an analysis of race diets to determine both fluid and sodium consumption.

In this study, we assessed the incidence of hyponatremia in the Iditasport, a 100-mile (161 km) ultraendurance race held in Alaska each February. Additionally, race diets were analyzed to determine racers' fluid and sodium consumption.

METHODS

The study was approved by the McDaniel College Institutional Review Board. All 122 entrants in the 2000 Iditasport Human Powered Ultra-Mara-

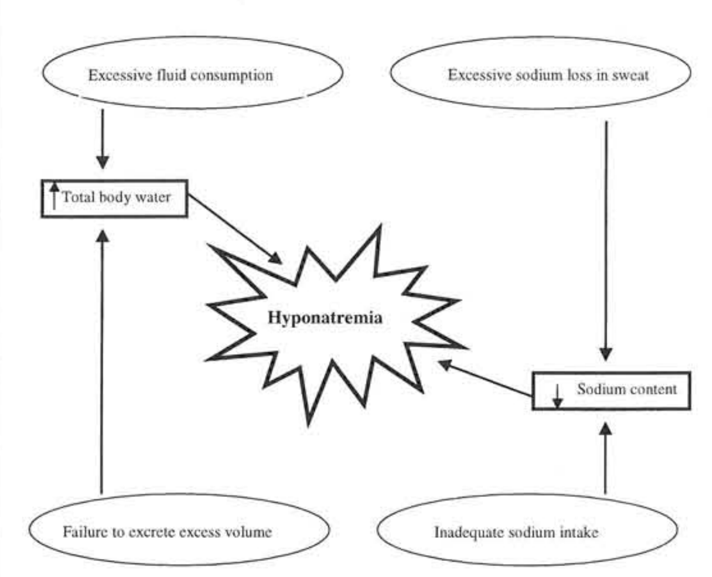

Figure 1. Possible causes of hyponatremia. Figure modified from Montain (1).

thon were invited to participate in the study at a mandatory informational meeting held two days prior to the race. Sixteen athletes (eight cyclists and eight runners) volunteered to be subjects and gave their written informed consent. All pre-race measurements were made at the informational meeting. Temperatures during the race ranged from -8° C to 4° C. The cyclists and runners competed on the same 100-mile (161 km) snowpacked course that winds through the Alaskan wilderness. Five checkpoints were located approximately every 15-20 miles (24-32 km), where food and fluid were available. In addition, athletes were required to carry 15 pounds (7 kg) of mandatory equipment at all times, including two liters of fluid in an insulated container, and 3000 kcal of food. Post-race measurements were made within 15 minutes of each athlete completing the race.

Pre- and post-race weight was measured using the Tanita Body Fat Monitor/Scale (TBF-622), accurate to ± 0.1 kg. Pre- and post-race blood samples were collected by routine venipuncture, with athletes in a sitting position. Duplicate hematocrits were measured immediately on the samples using standard procedures. Assays for serum sodium concentration were carried out at the Carroll County General Hospital Medical Laboratory in Westminster, MD with a Spectra Ion Selective Electrode analyzer using standard methods and the manufacturer's reagents on serum that was obtained by centrifugation, frozen immediately on dry ice, and stored at -20° C until thawed for analysis. Changes in plasma volume were calculated according to the formula of van Beaumont (27): % change plasma volume = $(100/100 - \text{hematocrit}_{pre}) \times 100\ (\text{hematocrit}_{pre} - \text{hematocrit}_{post})\ /\ \text{hematocrit}_{post}$, where hematocrit_{pre} and hematocrit_{post} are pre-race and post-race hematocrit samples, respectively.

Subjects carried out a complete dietary recall of food and fluid consumption immediately following the race. Competitors were required to carry all their garbage to the finish line, so during the dietary recall, it was possible to count the number and type of food wrappers in each subject's garbage bag. This process helped to ensure the accuracy of the dietary recall. The race diets were analyzed using the Nutritionist Five computer program (First Data Bank). Food items that were not listed in the Nutritionist Five program were added to the program using the nutrition facts from the food wrappers. Additionally, the recipes for specific foods that were available at checkpoints during the race were added to the program to assess the nutritional content.

Immediately following the race, subjects were interviewed to determine which, if any, hyponatremia (light-headedness, nausea, vomiting, malaise, exhaustion, altered mental status, seizures, headache) (2) or gastrointestinal (nausea, vomiting, diarrhea, cramps) (28) symptoms they experienced during the race.

Subjects were split by post-race serum sodium concentration into hyponatremic (serum sodium concentration < 135 mmol/L) and normonatremic (serum sodium concentration ≥ 135 mmol/L) groups (1) for statistical analyses. Comparisons between the hyponatremic and normonatremic groups were made using unpaired t-tests, while comparisons within each group (pre- and post-race measurements) were accomplished using paired t-tests. Statistical significance was set at $p \leq 0.05$ for all analyses.

RESULTS

Table 1 shows descriptive characteristics of the hyponatremic (serum sodium concentration < 135 mmol/L; n = 7) and normonatremic (serum sodium concentration ≥ 135 mmol/L; n = 9) groups. The hyponatremic group included three male cyclists, two male runners, one female cyclist, and one female runner, with an average finish time of 25.7 hours. The normonatremic group included four male cyclists and five male runners, with an average finish time of 29.2 hours. All subjects reported experiencing at least one symptom of hyponatremia, whereas 43% of the hyponatremic and 67% of the normonatremic group complained of gastrointestinal distress during the race.

Table 1. Descriptive characteristics; values expressed as mean ± SD.

	Hyponatremic (n = 7)	Normonatremic (n = 9)
Sex	5 male 2 female	9 male 0 female
Age (y)	35.9 ± 9.7	39.9 ± 11.2
Division	4 bike 3 foot	4 bike 5 foot
Finish time (h)	25.7 ± 8.3	29.2 ± 9.9
Hyponatremia symptoms	100%	100%
Gastrointestinal symptoms	43%	67%

As shown in Table 2, the hyponatremic group was significantly lighter than the normonatremic group both pre-race (71.0 versus 82.1 kg) and post-race (70.2 versus 80.2 kg). The normonatremic group exhibited a significant decrease in weight pre- to post-race (-1.9 kg). The hyponatremic group did not experience a significant change in weight.

The hyponatremic group exhibited a significant decrease in serum sodium concentration pre- to post-race (137.0 to 132.9 mmol/L) (Table 2). Six of the seven subjects had mild hyponatremia (post-race serum sodium concentration ranged from 132 - 134 mmol/L) (2), and one subject had severe hyponatremia (post-race serum sodium concentration = 129 mmol/L) (2). None of the athletes required medical attention. Both the hyponatremic and normonatremic groups exhibited a statistically insignificant decrease in hematocrit pre- to post-race (hyponatremic group: 42.4 to 39.8; normonatremic group: 42.9 to 41.2). Plasma volume increased in both the hyponatremic (+12.4 ± 19.3%) and normonatremic (+9.0 ± 20.0%) groups post-race.

A comparison of the race diets of the hyponatremic and normonatremic groups is shown in Table 3. No statistically significant differences were seen. However, the hyponatremic group consumed fewer kcal (212 versus 252 kcal/h), less sodium (235 versus 298 mg/h), and drank more liters of fluid (0.5 versus 0.4 L/h) compared to the normonatremic group.

DISCUSSION

This study represents the first report of the incidence of hyponatremia in a cold weather ultraendurance event. Hyponatremia occurred in 44% of the Iditasport athletes in this study, which is

Table 2. Pre- and post-race weight and blood values; values expressed as mean ± SD.

	Hyponatremic (n = 7)	Normonatremic (n = 9)
Pre-race weight (kg)	71.0 ±7.3[a]	82.1 ± 8.1
Post-race weight (kg)	70.2 ± 7.3[b]	80.2 ± 7.1[c]
Absolute weight change (kg)	-0.8 ± 1.0	-1.9 ± 2.4
Percent weight change (%)	-1.1 ± 1.5	-2.2 ± 2.6
Pre-race serum sodium (mmol/L)	137.0 ± 1.7	138.8 ± 2.9
Post-race serum sodium (mmol/L)	132.9 ± 1.9[d,e]	136.8 ± 1.2
Pre-race hematocrit	42.4 ± 3.5	42.9 ± 3.3
Post-race hematocrit	39.8 ± 2.3	41.2 ± 2.4

[a] $p \leq 0.05$ pre-race hyponatremic and normonatremic weight
[b] $p \leq 0.05$ post-race hyponatremic and normonatremic weight
[c] $p \leq 0.05$ pre-race normonatremic and post-race normonatremic weight
[d] $p \leq 0.05$ pre-race hyponatremic and post-race hyponatremic serum sodium
[e] $p \leq 0.05$ post-race hyponatremic and post-race normonatremic serum sodium

Table 3. Race diet; values expressed as mean ± SD.

	Hyponatremic (n = 7)	Normonatremic (n = 9)
Total kcal	5,481 ± 2,499	7,334 ± 5,322
Kcal/h	212 ± 64	252 ± 166
Percent carbohydrate (%)	69.0 ± 16.1	68.0 ± 14.4
Percent fat (%)	21.7 ± 16.4	22.4 ± 11.6
Percent protein (%)	9.1 ± 2.5	9.6 ± 4.1
Total Na^+ (mg)	6,216 ± 3,299	8,558 ± 4,730
Na^+/h (mg)	235 ± 92	298 ± 144
Total fluid (L)	11.9 ± 5.7	12.2 ± 4.0
Fluid/h (L)	0.5 ± 0.2	0.4 ± 0.2

a higher percentage than has been reported for athletes participating in triathlons or ultramarathons held in mild to hot environments. Speedy (2) and Hiller (6) reported that hyponatremia occurs in 18-27% of race participants, and others (7,8,16) have found that 9-36% of athletes who seek medical care are hyponatremic. It is interesting to note that the hyponatremic athletes were significantly lighter than the normonatremic athletes, and that the two female subjects in the study both developed hyponatremia. These results confirm the findings of others (1,2,29) that women and smaller individuals are more at risk for developing hyponatremia because they need to consume less fluid than larger individuals to dilute serum sodium to hyponatremic levels. All of the hyponatremic and normonatremic athletes in the present study experienced at least one of the signs and symptoms of hyponatremia. This is not surprising since the signs and symptoms of the condition (light-headedness, nausea, vomiting, malaise, exhaustion, altered mental status, headache, and seizures) (2) are very nonspecific.

Figure 1 shows the possible causes of hyponatremia, including an increase in total body water, resulting from excessive fluid consumption or a failure to excrete excess volume, and a decrease in sodium content, resulting from excessive sodium loss in sweat or inadequate sodium intake. The majority of reports (2,5,8-10,12-15,18,22-24) indicate that excessive fluid consumption is the most likely cause of hyponatremia, although others have suggested that a failure to excrete excess volume (7, 17,30) or excessive sodium loss in sweat (6,19,21) may be contributing factors.

We speculate that the hyponatremia seen in Iditasport athletes is caused by fluid overload and/or inadequate sodium intake. The normonatremic group exhibited a statistically significant weight loss (-1.9 kg) during the race, compared to the hyponatremic group that experienced a statistically insignificant weight loss (-0.8 kg). Others (9-11, 31) have reported that nonfluid weight loss during very prolonged exercise may account for as much as 2 kg of weight lost during the event. Sources of this nonfluid weight loss include loss of fat, glycogen, and water stored with glycogen. The corollary of this observation is that athletes who drink sufficiently to maintain their weight during an ultradistance event may in reality be overhydrated by 2 liters. This suggests that the hyponatremic Iditasport athletes may have had a fluid excess of 1.2 L, and that the normonatremic athletes were essentially euhydrated.

Both the hyponatremic and normonatremic groups exhibited a decrease in hematocrit and an increase in plasma volume following the race, although these changes were more pronounced in the hyponatremic group. These findings agree with the reports of others (5,9,10,23,25), and may be indicative of hyperhydration (9,10).

Race dietary analysis revealed that the hyponatremic group drank more liters of fluid per hour (0.5 L/h versus 0.4 L/h) and consumed less sodium per hour (235 mg/h versus 298 mg/h) than the normonatremic group, although the differences were not statistically significant. The ACSM recommends that athletes drink 0.6 – 1.2 liters of fluid per hour during exercise, with the addition of 0.5 – 0.7 g of sodium per liter for exercise lasting more than one hour (32). Using these guidelines and an average finish time of 27.6 h, the athletes in this study should have consumed 16.6 – 33.1 L of fluid and 8.3 – 23.2 g of sodium. Both the hyponatremic and the normonatremic groups consumed less fluid than the ACSM recommendations. However, the ACSM guidelines were established based on research from much shorter events than ultradistance competitions, and they are aimed at preventing heat injuries during events held in a hot environment. The guidelines may be inappropriately high for any ultraendurance competition (33,34), and most certainly are too high for an ultraendurance event held in Alaska in February. The hyponatremic athletes (6.2 g sodium) consumed less than the recommended amount of sodium, but the normonatremic athletes (8. 6 g sodium) were within the ACSM guidelines, suggesting that inadequate sodium intake may have been a contributing factor in the development of hyponatremia.

It seems unlikely that the other possible causes of hyponatremia shown in Figure 1 could account for the hyponatremia seen in Iditasport athletes. A failure to excrete excess fluid could be caused by excessive ADH, but it is known that ADH secretion is decreased in the cold (35). Hypothetically, hyponatremia can be caused by an excessive loss of sodium in sweat. There is little support for this theory in the literature for events occurring in hot environments (1), so it seems unreasonable to suggest that this is the cause of hyponatremia in an event held in the extreme cold, where athletes are instructed at a mandatory pre-race meeting to avoid sweating in an attempt to prevent hypothermia and frostbite.

In conclusion, hyponatremia occurred in 44% of the athletes competing in an ultraendurance event in the extreme cold. We speculate that the hyponatremia was caused by excessive fluid consumption and/or inadequate sodium intake.

ACKNOWLEDGEMENT

This study was supported by a grant from Gettysburg College.

Author's Note: These data were collected at the 2000 Iditasport Human Powered Ultra-Marathon. In 2001, the name of the race was changed to the Susitna100.

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