Exercise-Associated Hyponatremia
Let’s Stop Adding Insult to Injury with Our Treatment

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Chief of PM&R, VA Northern California Health Care System
Director of Research, Western States Endurance Run
Chief Medical Officer, Ultra Medical Team

Disclosure: The contents presented herein do not represent the views of the Department of Veterans Affairs or the United States Government.
Feeling like a shadow of your former self?

The problem could be . . .

**low S**

When the moment is right ....will you be ready?

Poor endurance performance could be from . . .

**low S**
Ran 100 miles in 18 hours
• Took ~7000 mg supplemental sodium
• Serum [Na⁺] = 127

“I was drinking fluids like crazy and was taking 2 S!Caps per hour during the hottest part of the day.”

Weight up >3% at mile 90

Overview
• EAH defined
• Historical background
• Incidence
• Pathophysiology
• Risk factors
• Making the diagnosis
• Treatment
• Prevention

We are running experiments!
**Exercise-Associated Hyponatremia**

Occurrence of hyponatremia during or up to 24 hours after prolonged physical activity

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**EAH is Not a New Thing**

1981 – case report from 1981 Comrades (56 miles)  
Noakes et al., *S Afr Runner*

1984 – case report from 1982 WSER (100 miles)  
Lang, *UltraRunning*

1985 – 1st scientific paper on EAH - case series  
Noakes et al., *Med Sci Sports Exerc*

1986 – case reports from 1983 AMJA (50 & 62 miles)  
Frizzell et al., *JAMA*

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**Five Marathon Deaths**

- London 2007 (male)
- Washington DC 2002 (female)
- Boston 2002 (female)
- Chicago 1998 (female)
- Big Sur 1993 (female)
Canoe Marathon Death

Brad Ellis
• 30 years old
• Texas Water Safari
• 380 mile canoe race
• Died June 2012

Four (?) Military Deaths

• Marines 2001 (19 y male)
• Army 2000 (20 y female)
• Air Force 1999 (19 y male)
• Army 1997 (18 y male)

Police Officer Death

James McBride
• 25 years old
• Bicycle patrol training course – 12 miles, 3 gal!
• Died 2005
• Washington, DC
Grand Canyon Hiker Death

Susan Jane Linley
• 47 years old
• 5 hour, 10 km hike on South Kaibab Trail
• “drank a large amount of water”
• Died September 2008

Patrick Allen
• 17 years old
• High School Senior
• Bakersfield, CA
• Died 8/16/08

Zyrees Oliver
• 17 years old
• High School Senior
• Atlanta, GA
• Deceased 8/11/14
Walker Wilbanks
• 17 years old
• High School Junior
• Jackson, MS
• Deceased 8/25/14

“We are calling his official cause of death cerebral edema secondary to exercise-associated hyponatremia…. It was in no way a reflection of him being overhydrated or underhydrated. Walker did nothing wrong in preparation for this game. His coaches did nothing wrong in preparing him for this game. There’s concerns, I know, about whether he drank enough. There may be concern about whether he drank too much.... He did neither. This was a fluke – a freak event that occurred of him that could not be predicted, and most likely could not have been avoided.”

Dr. Joe Pressler, Walker’s UMMC physician
“....the evidence is firm that every single death from EAH is avoidable if athletes adhere to rational hydration strategies and avoid excessive and unneeded fluid intake.”

- The 2015 International EAH Consensus Group

Incidence of EAH

As high as.....

- 18% in Ironman triathlons
- 28% in marathons
- 50% in endurance cycling
- 51% in 100-mile ultramarathons

Exertional Heat Illness and Hyponatremia in Hikers

HOWARD D. SIEGEL, MD, MPH†
ELLEN SIEGEL, RN, CURN, MSc, RN, NSCA†
(SHERRI L. COLLINS, RN, RT, CMA) HOWARD BARZILAI, MD

- Incidence of EAH
- Reports 7 cases of symptomatic EAH in Grand Canyon National Park
- June – Sept 1993
The Pathophysiology

Exercise Associated Hyponatremia

- Inappropriate AVP secretion
- Excessive water intake
- Other factors:
  - Sweat sodium loss
  - Inability to mobilize sodium stores
  - ANP/BNP elevations
  - Rapid absorption of water from GI tract

2004 Boston Marathon
Collapsed runners with EAH 7 of 16 (43%) with measurable AVP ex vivo proteolysis?

Non-Osmotic Stimuli for AVP Secretion

- Nausea with or without vomiting
- Hypovolemia
- Hypoglycemia
- Exercise
- Thermal stress
- Pain
- Drugs (nicotine, tricyclics)
- Rhabdomyolysis (via interleukin-6 release)
- High altitude
<table>
<thead>
<tr>
<th>Case</th>
<th>Age/</th>
<th>Sex</th>
<th>Activity</th>
<th>Pre-Tx</th>
<th>Serum [Na+]</th>
<th>Urine [Na+]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35</td>
<td>F</td>
<td>Hike</td>
<td>+</td>
<td>117</td>
<td>83</td>
</tr>
<tr>
<td>2</td>
<td>19</td>
<td>M</td>
<td>Hike</td>
<td>+</td>
<td>115</td>
<td>118</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>F</td>
<td>March (20 km)</td>
<td>-</td>
<td>123</td>
<td>82</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>F</td>
<td>Hike</td>
<td>+</td>
<td>121</td>
<td>74</td>
</tr>
<tr>
<td>5</td>
<td>18</td>
<td>F</td>
<td>March (8 km)</td>
<td>-</td>
<td>120</td>
<td>116</td>
</tr>
<tr>
<td>6</td>
<td>18</td>
<td>M</td>
<td>March</td>
<td>-</td>
<td>116</td>
<td>122</td>
</tr>
<tr>
<td>7</td>
<td>12</td>
<td>M</td>
<td>March (few km)</td>
<td>+</td>
<td>116</td>
<td>111</td>
</tr>
</tbody>
</table>

210 or 250 km cycling ride
Solid boxes = men
Open boxes = women

Inappropriate AVP secretion
Excessive water intake
Other factors:
Sweat sodium loss
Inability to mobilize sodium stores
ANP/BNP elevations
Rapid absorption of water from GI tract

Exercise Associated Hyponatremia


**Risk Factors**

**Individual Related**
- Excessive drinking
- Low body weight (female)
- Slow pace
- Inexperience
- NSAIDs (↑ action of AVP on kidneys)
- Elderly (↑ osmotic AVP secretion)
- Rhabdomyolysis (IL-6 stimulus for AVP secretion)

**Event Related**
- High fluid availability
- >4 h exercise
- Extreme heat
- Extreme cold

**Making the Diagnosis**

**Signs & Symptoms**

<table>
<thead>
<tr>
<th>Symptom</th>
<th>EXR</th>
<th>Shortness</th>
<th>AMS, HIPE, or SILENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue</td>
<td>Possible</td>
<td>Possible</td>
<td>Likely</td>
</tr>
<tr>
<td>Headache</td>
<td>Possible</td>
<td>Likely</td>
<td>Possible</td>
</tr>
<tr>
<td>Low Blood Flow Rate</td>
<td>Possible</td>
<td>Likely</td>
<td>Possible</td>
</tr>
<tr>
<td>Headache</td>
<td>Possible</td>
<td>Likely</td>
<td>Possible</td>
</tr>
<tr>
<td>Contraction</td>
<td>Possible</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Tiredness</td>
<td>Possible</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Confusion</td>
<td>Possible</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Shortness</td>
<td>Possible</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Nausea</td>
<td>Possible</td>
<td>Not present</td>
<td>Possible</td>
</tr>
<tr>
<td>Weakness</td>
<td>Possible</td>
<td>Likely</td>
<td>Possible</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Possible</td>
<td>Not present</td>
<td>Possible</td>
</tr>
<tr>
<td>Dizziness</td>
<td>Possible</td>
<td>Possible</td>
<td>Possible</td>
</tr>
</tbody>
</table>

EXR: exercise-related edema; AMS: acute mountain illness; HIPE: high altitude pulmonary edema; SILENCE: high altitude cerebral edema.
Death Valley National Park

MONITORING DEHUMIDIFICATION

The Effect of Water Loss on Performance

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Signs of Dehydration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>None</td>
</tr>
<tr>
<td>1% - 2%</td>
<td>Thirst, dry mouth</td>
</tr>
<tr>
<td>3% - 5%</td>
<td>Fatigue, nausea</td>
</tr>
<tr>
<td>&gt; 5%</td>
<td>Dizziness, confusion, weakness, high fever</td>
</tr>
</tbody>
</table>

Water Chart

<table>
<thead>
<tr>
<th>Water Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow</td>
<td>Dehydration</td>
</tr>
<tr>
<td>Orange</td>
<td>Moderate dehydration</td>
</tr>
<tr>
<td>Red</td>
<td>Severe dehydration</td>
</tr>
</tbody>
</table>

Welcome to Michigan Bluff Medical Aid Station

Mile 55

What Color is Your Pee?

Coors Light - Hydrate
Pale Ale - Hydrate More
IPA - SEE MEDICAL
Guinness - GOOD
Guidelines for Treatment and Supporting Science

Frizzell et al. JAMA 1986
1983 AMJA 50 M & 100K ultramarathons
Max temp = 89ºF
Race guidelines: drink 300-350 ml/aid station = 15-18L (50 miles), 18-22 L (100 K)

Runner 1
24 yo med student
2nd in 100 K (8:36)
est. fluid intake = 20 L
~5 min post finish –
"stuporous and disoriented"
serum (Na+) = 123

Runner 2
45 yo physician
50 miles – 10:36
est. fluid intake = 24 L
~30 min post finish –
"disoriented and confused"
serum (Na+) = 118

Case Series with Differing Treatments for Symptomatic EAH and [Na+]<125

<table>
<thead>
<tr>
<th>Initial Treatment / Source</th>
<th>a</th>
<th>Blood (Na+)</th>
<th>Presentation</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hypertonic Saline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frizzell et al. JAMA 1986</td>
<td>1</td>
<td>118</td>
<td>disoriented and confused</td>
<td>dc'd after 8 hrs</td>
</tr>
<tr>
<td>Davis et al. J Emerg Med 2001</td>
<td>4</td>
<td>117-123</td>
<td>N/V, dizziness, confusion</td>
<td>dc'd from ED</td>
</tr>
<tr>
<td>Siegel et al. Am J Med 2007</td>
<td>2</td>
<td>123</td>
<td>unresponsive</td>
<td>&quot;rapid neurological improvement&quot; (&gt;2 hrs)</td>
</tr>
<tr>
<td><strong>Isotonic or Hypotonic Fluids</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frizzell et al. JAMA 1986</td>
<td>1</td>
<td>123</td>
<td>stuporous and disoriented</td>
<td>seizures, semicomatose 36 hrs, d/c 5th hospital day</td>
</tr>
<tr>
<td>Davis et al. J Emerg Med 2001</td>
<td>11</td>
<td>119-124</td>
<td>Multiple - N/V, dizziness, confusion, seizure (1)</td>
<td>5 admitted, 2 with seizures, 3 intubated, d/c after several days</td>
</tr>
</tbody>
</table>
Other Cases Reports Demonstrating Delayed Recovery from EAH Treatment with Isotonic Fluids


Siegel et al. Am J Clin Pathol 2009

2008 Boston Marathon

n=3
mental status changes
serum [Na+] = 126-133 tolerant of oral intake

Oral 9% saline (4 bouillon cubes in 4 oz water)

rapid recovery

Blood [Na+] (mmol/L)

2008 Boston Marathon
EAH treatment with oral 9% saline

From data of Siegel et al. Am J Clin Pathol 2009
WSER 2010 Treatment Trial

Subjects: neurologically asymptomatic finishers with EAH
Intervention: randomized to 100 ml 3% saline (51 mmol) oral or IV
Measurements: pre-treatment and 60 min post-treatment


Mechanism of Action

IV 3% HTS
(100 ml bolus x3 q 10 min)
1. Increases blood [Na⁺] 1-2 mmol/L for each 100 ml bolus
2. Expands plasma volume → removes volume-receptor stimulus for AVP secretion
3. Reduced AVP secretion → aquaretics and further increase in blood [Na⁺]

Blood [Na⁺]

IV Oral

Time: p=0.0009
Group: NS
Group x Time: NS

Body Mass (kg)

Pre-treatment
Post-treatment
55
60
65
70
75
80
85

Blood [Na⁺] mmol/L

Pre-treatment Post-treatment
0
1
2
3
4

Time: p<0.0001
Group: NS
Group x Time: NS

[AVP]p (pg/mL)

IV Oral

Time: p=0.005
Group: NS
Group x Time: NS

Plasma Volume Change (%)

WSER 2010 Treatment Trial
Subjects: neurologically asymptomatic finishers with EAH
Intervention: randomized to 100 ml 3% saline (51 mmol) oral or IV
Measurements: pre-treatment and 60 min post-treatment


IV 3% HTS
(100 ml bolus x3 q 10 min)
1. Increases blood [Na⁺] 1-2 mmol/L for each 100 ml bolus
2. Expands plasma volume → removes volume-receptor stimulus for AVP secretion
3. Reduced AVP secretion → aquaretics and further increase in blood [Na⁺]

Shifts osmotic gradient → reverses neurological symptoms
No risk of CPM

Mechanism of Action
Field Treatment

Scenario 1: An EAH diagnosis has been made by point-of-care sodium analysis.

Scenario 2: Point-of-care sodium analysis is not available, and the diagnosis of EAH is presumed.

Field Treatment (both scenarios)

**Fluids**

*Recommendation*: Hypotonic or isotonic fluid intake should be restricted in known or suspected EAH until urination begins.

*Recommendation Grade*: 1A

**Supplemental oxygen**

*Recommendation*: Respiratory symptoms should be supported with supplemental oxygen if available.

*Recommendation Grade*: 1B

**Appropriate transfer of care**

*Recommendation*: When transferring care, alert receiving caregivers of the diagnosis of EAH and appropriate management.

*Recommendation Grade*: 1B

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**Table 1. American College of Chest Physicians diagnosis scheme for grading evidence and recommendations in clinical practice**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
<th>Benefits or risks and burden</th>
<th>Methodological quality of supporting evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Strong recommendation, high-quality evidence</td>
<td>Benefits greatly outweigh risks and burdens</td>
<td>ICT-Evident (quantitative limitations or supporting evidence from observational studies)</td>
</tr>
<tr>
<td>1B</td>
<td>Strong recommendation, moderate-quality evidence</td>
<td>Benefits slightly outweigh risks and burdens</td>
<td>ICT-Evident (quantitative limitations or exceptionally strong evidence from observational studies)</td>
</tr>
<tr>
<td>2A</td>
<td>Weak recommendation, high-quality evidence</td>
<td>Benefits closely balanced with risks and burdens</td>
<td>ICT-Evident (quantitative limitations or supporting evidence from observational studies)</td>
</tr>
<tr>
<td>2B</td>
<td>Weak recommendation, moderate-quality evidence</td>
<td>Benefits closely balanced with risks and burdens</td>
<td>ICT-Evident (quantitative limitations or exceptionally strong evidence from observational studies)</td>
</tr>
<tr>
<td>2C</td>
<td>Weak recommendation, low-quality evidence</td>
<td>Uncertainty in the estimates of benefits, risks, and burdens; benefits, risks, and burdens may be closely balanced</td>
<td>Observational studies or case series</td>
</tr>
</tbody>
</table>

*ICT*: American College of Chest Physicians; *EPC*: evidence-based clinical trial.
**Known blood sodium**

*Recommendation:* Oral hypertonic saline solutions are an appropriate intervention in the field for cases of EAH when oral intake is possible.  
*Recommendation Grade:* 1B

*Recommendation:* Symptomatic biochemically confirmed EAH can be treated in the field with a 100-mL bolus of 3% hypertonic saline, which can be repeated twice at 10-minute intervals (3 doses in total) with the aim of acutely increasing serum sodium concentration by about 4 to 5 mmol/L and reversing cerebral edema in the setting of acute hyponatremia.  
*Recommendation Grade:* 1B

**Unknown blood sodium**

*Recommendation:* Hypotonic or isotonic fluids should be restricted in suspected EAH with consideration towards the potential harm that could result from fluid restriction if the diagnosis is incorrect.  
*Recommendation Grade:* 1C

*Recommendation:* IV hypertonic saline (100 mL bolus of 3% hypertonic saline, which can be repeated twice at 10-minute intervals) is an appropriate consideration in suspected EAH with neurological deterioration, whereas an oral hypertonic saline solution would be an appropriate consideration in suspected mild EAH.  
*Recommendation Grade:* 1C

**Immediate Medical Care in Hospital**

**Urgent sodium estimation**

*Recommendation:* With suspected EAH, and especially those with altered mental state, sodium estimation should be obtained as rapidly as possible after hospital arrival.  
*Recommendation Grade:* 1B

**Assessment for cerebral and pulmonary edema**

*Recommendation:* A rapid assessment for signs and symptoms of cerebral edema and/or non-cardiogenic pulmonary edema should be made in all patients with possible EAH.  
*Recommendation Grade:* 1B

**Other laboratory testing**

*Recommendation:* When possible, urine for sodium and osmolality and blood for osmolality should be obtained before commencement of treatment.  
*Recommendation Grade:* 2C
Immediate Medical Care in Hospital

Fluid restriction
Recommendation: Oral and IV hypotonic or isotonic hydration should be avoided early in the management of EAH although it may be appropriate in certain clinical contexts once sodium correction has been initiated or hypovolemia is biochemically confirmed (by elevated blood urea nitrogen and urine sodium less than 30 mmol/L).
Recommendation Grade: 1B

Hypertonic saline
Recommendation: In hospital, severe biochemically confirmed or symptomatic EAH should be treated with a 100-mL bolus of 3% hypertonic saline, which can be repeated twice at 10-minute intervals (3 doses in total), with the aim of acutely increasing serum sodium concentration by about 4 to 5 mmol/L and reversing cerebral edema.
Recommendation Grade: 1A

Immediate Medical Care in Hospital

Supplemental oxygen
Recommendation: Supplemental oxygen to maintain an oxygenation saturation of 95% should be provided to treat hypoxemia from pulmonary edema when evident.
Recommendation Grade: 1B

Guidelines for Prevention and Supporting Science
How Much Fluid?

- ACSM Position Stand 2007
  - Prevent >2% weight loss
  - Fluid intake 400 – 800 ml/hr (“customized”)
  - ~3% body weight loss required to maintain euhydration when glycogen stores are utilized

Glycogen utilization ~0.5 kg
Water release from glycogen ~1.5 kg
Fat utilization ?

TOTAL >2.0 kg

2.0 kg/70 kg = 2.9%
Which Fluid?

- Hypotonic to blood
- Cannot prevent hyponatremia!

How do you get your sodium?
As advertised.......  
• Alleviation of cramping  
• Buffers to help stabilize the stomach  
• Protection against potentially fatal hyponatremia
Do we really need sodium during exercise?


Using sodium supplements and drinking to pre-determined schedule all segments (n=48)

Not using sodium supplements and drinking to thirst all segments (n=7)

- Ran 100 miles in 18 hours
- Took ~7000 mg supplemental sodium
- Serum [Na⁺] = 127
- Weight up >3% at mile 90
Exercise-associated hyponatremia with exertional rhabdomyolysis: importance of proper treatment

Marie D. Hoffman1, Kristin J. Stamper2, Barry Sullivan2, and Robert H. Wissel3

1Department of Physical Medicine and Rehabilitation, Department of Veterans Affairs, Northern California Health Care System, and University of California Davis Medical Center, Sacramento, CA. 2Health Sciences Department, Defiance College, Defiance, OH. 3Department of Surgery, Kaiser Permanente Santa Clara Medical Center, Santa Clara, CA.

Noakes et al. PNAS. 2005
Prevention

• Avoid Overhydration - drink to thirst!
• Avoid Excessive Sodium Supplementation
• Monitor Body Weight
• Educate Event Support and Medical Personnel

Key Points

• EAH can kill
• Prevent by avoiding overhydration
• Consider in differential diagnosis
• Treat with fluid restriction and HTS
Thank You!

mdhoffman@ucdavis.edu
June 1, 2011

Getting enough water is still the key hydration issue

Recent media reports have made the issue of fluids and hydration very confusing, which is too bad because it is actually a very straightforward issue.

During exercise, athletes should start drinking early and at regular intervals in an attempt to consume fluids at a rate sufficient to replace all the water lost through sweating (i.e., body weight loss), or consume the maximum amount that can be tolerated.
Prevention

Never gain weight and expect to lose up to 2-4% of body weight during prolonged endurance exercise. Drink to thirst!
A Michigan man accused of fatally stabbing his mother after she refused to give him money for drugs is expected to claim temporary insanity due to low sodium at his murder trial.

Court-appointed lawyer Timothy Kohler said Tuesday that 38-year-old Charles Foresi experienced brain dysfunction because he suffered from hyponatremia, or a lack of salt in bodily fluids outside the cells.

**Prevention – Avoid Overhydration**

*Recommendation:* Participants should focus on decreasing overdrinking during exercise by drinking according to thirst, and race organizers might consider reducing the overavailability of fluids (<3 km apart) along routes of exercise.

*Recommendation Grade:* 1B

**Prevention – Avoid Excessive Sodium Supplementation**

*Recommendation:* Excessive sodium supplementation is not recommended during physical activity lasting less than 18 hours.

*Recommendation Grade:* 2B
Prevention – Monitoring Body Weight

*Recommendation:* Body weight can be monitored in organized events, and in the presence of weight gain during exercise, fluid and sodium intake should be reduced until weight returns to 2% to 4% of body weight loss from baseline level.

*Recommendation Grade:* 1B

Prevention – Educate Event Support and Medical Personnel

*Recommendation:* Event support staff should be educated so they can provide proper hydration advice, and on-site medical and emergency medical service (EMS) personnel should be educated about proper recognition and treatment of EAH.

*Recommendation Grade:* 1B


1998 and 1999 Rock ‘N Roll Marathon (San Diego)

11 with severe EAH drank “as much as possible”

- 9 ≤[Na⁺] ≤ 125
- 3 were admitted

NS initially

HTS in ICU

2 developed seizures and altered mental status requiring intubation after arriving awake and oriented

3% HTS @100cc/hr

4 with severe EAH drank “as much as possible”

- [Na⁺] ≤ 117-131
- All treated in ED

no seizures

dc’d from ED without admission

1998 (retrospective)

1999 (prospective with treatment algorithm)
Cases from Boston and Marine Corps Marathons

2002 Boston and Marine Corps Marathons
n=2 women, 24 and 32 yo collapsed, unresponsive
serum [Na+] = 113 and 123
less than max dilute urine [Na+]>25 mEq/L
AVP measurable

2004 Marine Corps Marathon
n=2 delirium
serum [Na+] = 123

IV NS
full recovery

Entire Race
r=0.24, p=0.0027

Sodium Supplement Intake Rate (mg/hr)
Post-Race [Na+] (mmol/L)

Entire Race
r=-0.19, p=0.010

Change in Body Mass (%)
Symptom/Sign  

<table>
<thead>
<tr>
<th>Symptom/Sign</th>
<th>N (%)</th>
<th>N (%)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>2 (29)</td>
<td>15 (40)</td>
<td>0.44</td>
</tr>
<tr>
<td>Dizziness</td>
<td>4 (57)</td>
<td>28 (80)</td>
<td>0.20</td>
</tr>
<tr>
<td>Nausea</td>
<td>7 (100)</td>
<td>28 (80)</td>
<td>0.24</td>
</tr>
<tr>
<td>Vomiting</td>
<td>5 (71)</td>
<td>20 (54)</td>
<td>0.33</td>
</tr>
<tr>
<td>Anorexia</td>
<td>1 (14)</td>
<td>19 (54)</td>
<td>0.09</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>0 (4)</td>
<td>0.48</td>
<td></td>
</tr>
<tr>
<td>Thirst</td>
<td>1 (16)</td>
<td>18 (51)</td>
<td>0.12</td>
</tr>
<tr>
<td>Dry oral mucosa</td>
<td>1 (14)</td>
<td>16 (43)</td>
<td>0.15</td>
</tr>
<tr>
<td>Uncoordinated</td>
<td>2 (29)</td>
<td>11 (31)</td>
<td>0.63</td>
</tr>
<tr>
<td>Chills</td>
<td>2 (29)</td>
<td>12 (34)</td>
<td>0.57</td>
</tr>
<tr>
<td>Tingling</td>
<td>3 (43)</td>
<td>11 (31)</td>
<td>0.42</td>
</tr>
<tr>
<td>Cramps</td>
<td>0 (1)</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>Syncope</td>
<td>0 (8)</td>
<td>0.31</td>
<td></td>
</tr>
</tbody>
</table>

Resting pulse 83/min 92/min 0.67
Systolic blood pressure 120 mm/Hg 120 mm/Hg 0.90

...hypotension is much more common than heatstroke and is the most common cause of serious illness related to exercise in the heat. Early symptoms of hypotension and heat exhaustion are similar and do not allow distinction until mental status changes occur.

...hypotensive patients were hyperhydrated.

Reports 4 cases of symptomatic EAH in Grand Canyon National Park 1990-92
Grand Canyon EAH Cases by Month
2009-2014