Sodium:
Good or Evil in Prolonged Exercise

Kristin J. Stuempfle, PhD
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May 30, 2017
Dietary Sodium
Sodium Supplements
- 161-km point-to-point race (Squaw Valley, CA to Auburn, CA)
- Single-track mountain trails
- Elevation: ~ 5500 m of cumulative ascent and 7000 m of cumulative descent
- Typical temperature range: 0 - 37°C
Do you plan to use sodium supplements during the race?

2011 WSER finishers

n=207

Mean Post-race [Na+] (mmol/L)

<table>
<thead>
<tr>
<th>Sodium supplementation</th>
<th>Runners (n)</th>
<th>Mean Post-race [Na+]</th>
</tr>
</thead>
<tbody>
<tr>
<td>no</td>
<td>21</td>
<td>139.1</td>
</tr>
<tr>
<td>yes</td>
<td>186</td>
<td>139.9</td>
</tr>
</tbody>
</table>
### Hydration strategies used by runners (%) in four segments of the 2013 WSER (n=272)

<table>
<thead>
<tr>
<th>Hydration Strategy</th>
<th>0-30 miles</th>
<th>30-56 miles</th>
<th>56-78 miles</th>
<th>78-100 miles</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thirst</td>
<td>52.6</td>
<td>44.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>51.5</td>
<td>57.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>67.0&lt;sup&gt;1,2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Maximum tolerated</td>
<td>13.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22.0</td>
<td>18.9</td>
<td>34.4&lt;sup&gt;1,3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Pre-determined schedule</td>
<td>27.4&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>15.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>29.6&lt;sup&gt;2,4&lt;/sup&gt;</td>
</tr>
<tr>
<td>Change in body weight</td>
<td>3.7&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>12.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>18.1&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Urine color</td>
<td>6.3</td>
<td>7.2</td>
<td>6.2</td>
<td>4.1</td>
<td>10.0&lt;sup&gt;2,3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Other</td>
<td>5.2</td>
<td>3.0</td>
<td>3.3</td>
<td>1.4</td>
<td>7.0&lt;sup&gt;1,4&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sodium Supplementation</td>
<td>82.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>95.5&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>90.6</td>
<td>84.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>95.6</td>
</tr>
</tbody>
</table>

*p*<0.05 between race segments with same letter considering the given hydration strategy  
*p*<0.01 between overall drinking strategies with same number

As advertised, prevent...

- Dehydration (by stimulating thirst and causing fluid retention)
- Exercise-associated hyponatremia
- Skeletal muscle cramps
- Nausea
Sodium deficit results in...

- Dehydration
- Exercise-associated hyponatremia
- Skeletal muscle cramps
Does Na\(^+\) prevent dehydration? Does Na\(^+\) prevent exercise-associated hyponatremia?

Does Na\(^+\) prevent muscle cramps? Does Na\(^+\) prevent nausea?
Does $\text{Na}^+$ prevent dehydration?

Does $\text{Na}^+$ prevent exercise-associated hyponatremia?

Does $\text{Na}^+$ prevent muscle cramps?

Does $\text{Na}^+$ prevent nausea?
Body Weight Change

Overhydration

Euhydration

Dehydration

-4 to -6%

0%
Why is -4 to -6% Body Weight Change Euhydration during an Ultramarathon?

Body mass loss does not reflect equivalent body water loss due to:

• Substrate use (glycogen, fat)
• Water released from glycogen
• Production of water during substrate metabolism
WSER 2013

Solid Line: Na⁺ supplements all segments

Dotted Line: No Na⁺ supplements any segment

No significant difference between groups
Solid Line: Na\(^+\) supplements and drinking max tolerated or to pre-determined schedule

Dotted Line: No Na\(^+\) supplements and drinking to thirst all segments

No significant difference between groups
• Weak positive relationship between Na$^+$ and weight change; ↑ Na$^+$, ↑ weight
• Na$^+$ intake accounted for only 3% of the variability in weight change
WSER 2014

Dietary analysis of 20 finishers

Total Na\textsuperscript{+} intake: food, fluid, Na\textsuperscript{+} supplements
Solid Line: finishers
Dotted Line: non-finishers

No significant difference between groups; weight change is not a distinguishing factor
% weight change among finishers: -6.8% to 3.1%

No significant correlation between weight change and finish time; weight loss does not necessarily impact performance
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
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<tbody>
<tr>
<td>Does Na(^+) prevent dehydration?</td>
<td>Not necessary</td>
</tr>
<tr>
<td>Does Na(^+) prevent exercise-associated hyponatremia?</td>
<td></td>
</tr>
<tr>
<td>Does Na(^+) prevent muscle cramps?</td>
<td></td>
</tr>
<tr>
<td>Does Na(^+) prevent nausea?</td>
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Does $\text{Na}^+$ prevent dehydration?

Does $\text{Na}^+$ prevent exercise-associated hyponatremia?

Does $\text{Na}^+$ prevent muscle cramps?

Does $\text{Na}^+$ prevent nausea?
Blood [Sodium] (mmol/L)

- **Normonatremia**
  - 135 mmol/L

- **Hypernatremia**
  - 145 mmol/L

- **Hyponatremia**
  - 150 mmol/L

**EAH** = Blood sodium concentration < 135 mmol/L during or up to 24 h after prolonged physical activity
HYPONATREMIA

NORMONATREMIA

encephalopathy

pulmonary edema

Hyponatremia can be caused by sodium dilution and/or sodium depletion.

- Sodium Dilution: ↑ Water, Fluid retention
- Sodium Depletion: ↓ Sodium, Electrolyte losses
Hypovolemic Hyponatremia (Weight loss)

- Sweat Na loss
- Reduced Na intake
- Reduced Na mobilization from internal stores

Sodium depletion

Hypervolemic Hyponatremia (Weight gain)

- EAH
- Sodium dilution
- Absorption of fluids from GI tract
- Increased AVP
- Excessive fluid intake
- Water release from glycogen breakdown
- Sympathetic CNS, RAAS
EAH Spectrum

Sodium Dilution

Mixed Sodium Dilution and Sodium Depletion

- Sodium

+ Fluid

Sodium Depletion

+ Fluid and - Sodium
Sodium Dilution

- Overhydration
- Weight gain
- Clinically significant
- Symptomatic
- Life threatening

Mixed 
Sodium Dilution and 
Sodium Depletion

Sodium Depletion

+ Fluid

+ Fluid and - Sodium

- Sodium
No difference in post-race [Na+] between groups
2011 WSER finishers
n=207

Winger J et al IJSPP 2013
• Weak positive relationship between Na\(^+\) supplement intake rate and post-race Na\(^+\)
• ↑ Na\(^+\) supplement intake rate, ↑ post-race Na\(^+\)
• Na\(^+\) supplement intake accounted for only 6% of the variability in post-race Na\(^+\)
No significant differences in hydration or Na\(^+\) behaviors across 3 groups

<table>
<thead>
<tr>
<th>Hydration or Na(^+) Behavior</th>
<th>Hyponatremic (n=12)</th>
<th>Normonatremic (n=135)</th>
<th>Hypernatremic (n=8)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na(^+) supp. all segments (%)</td>
<td>41.7</td>
<td>55.6</td>
<td>62.5</td>
<td>0.59</td>
</tr>
<tr>
<td>No Na(^+) supp. any segment (%)</td>
<td>0</td>
<td>8.9</td>
<td>0</td>
<td>0.60</td>
</tr>
<tr>
<td>Drink to thirst all segments (%)</td>
<td>33.3</td>
<td>50.4</td>
<td>75.0</td>
<td>0.19</td>
</tr>
<tr>
<td>No Na(^+) supp. and drink to thirst all segments (%)</td>
<td>0</td>
<td>6.7</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>Na(^+) supp. intake rate (mg/h)</td>
<td>85 (34-181)</td>
<td>128 (50-254)</td>
<td>233 (182-349)</td>
<td>0.10</td>
</tr>
</tbody>
</table>

WSER 2014 Hoffman & Stuempfle. MSSE 2015
Na\textsuperscript{+} supplementation is not necessary to prevent the development of hyponatremia.
Sodium supplementation is not required to maintain serum sodium concentrations or to prevent hyponatremia.
Sodium Intake During an Ultramarathon Does Not Prevent Muscle Cramping, Dehydration, Hyponatremia, or Nausea

Martin D. Hoffman¹,²*, Kristin J. Stuempfle³ and Taylor Valentino⁴

- WSER 2014
- Dietary analysis of 20 finishers
- Total Na⁺ intake: food, fluid, Na⁺ supplements
Sodium supplementation has no effect on endurance performance during a cycling time-trial in cool conditions: a randomised cross-over trial

Samuel David Cosgrove and Katherine Elizabeth Black

Na⁺ supplementation had no effect on:

• Plasma [Na⁺] change pre- to post-race
• Performance
Does Na⁺ prevent dehydration?  
Not necessary

Does Na⁺ prevent exercise-associated hyponatremia?  
Not necessary

Does Na⁺ prevent muscle cramps?  

Does Na⁺ prevent nausea?
...DO THEY MENTION ANY WARNING SIGNS?

TOO MUCH WATER DANGEROUS TO RUNNERS

© 2005 WALT HANDELSMAN—NEWSDAY
Does $\text{Na}^+$ prevent dehydration?

Does $\text{Na}^+$ prevent exercise-associated hyponatremia?

Does $\text{Na}^+$ prevent muscle cramps?

Does $\text{Na}^+$ prevent nausea?
Exercise-Associated Muscle Cramps

Dehydration/Electrolyte Imbalance
Neuromuscular junctions become hyperexcitable due to mechanical deformation and exposure to increased levels of excitatory extracellular constituents

Altered Neuromuscular Control
Muscular fatigue results in increased excitatory (muscle spindles) and decreased inhibitory (Golgi tendon organs) sensory input to CNS, resulting in increased motor neuron discharge to muscle fibers
No difference in Na$^+$ supplement intake rate in those with and without cramping
Only differences between 2 groups: prior history of cramping and post-race blood [CK]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Combined Cramping or Near Cramping</th>
<th>No Cramping</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior history of cramping (%)</td>
<td>81.7</td>
<td>52.1</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Na(^+) supplement use (%)</td>
<td>94.8</td>
<td>93.3</td>
<td>0.88</td>
</tr>
<tr>
<td>Na(^+) supplement intake (mg/h)</td>
<td>145 (59-295)</td>
<td>132 (62-235)</td>
<td>0.46</td>
</tr>
<tr>
<td>Minimum wt (% of start wt)</td>
<td>-3.0 (-4.3 to -2.0)</td>
<td>-3.1 (-4.1 to -2.1)</td>
<td>0.23</td>
</tr>
<tr>
<td>Post-race serum [Na(^+)] (mmol/L)</td>
<td>139 ± 4</td>
<td>140 ± 3</td>
<td>0.06</td>
</tr>
<tr>
<td>Post-race blood [CK] (IU/L)</td>
<td>19,458</td>
<td>11,862</td>
<td>0.0010</td>
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Sodium Intake During an Ultramarathon Does Not Prevent Muscle Cramping, Dehydration, Hyponatremia, or Nausea

Martin D. Hoffman¹,²*, Kristin J. Stuempfle³ and Taylor Valentino⁴

• WSER 2014
• Dietary analysis of 20 finishers
• Total Na⁺ intake: food, fluid, Na⁺ supplements
### Exercise-Associated Muscle Cramps

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<th>Altered Neuromuscular Control</th>
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<td>Muscular fatigue results in increased excitatory (muscle spindles) and decreased inhibitory (Golgi tendon organs) sensory input to CNS, resulting in increased motor neuron discharge to muscle fibers.</td>
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**Not supported by WSER data**
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<tr>
<td>-----------------------------------------------</td>
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<tr>
<td>Does Na$^+$ prevent nausea?</td>
<td></td>
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</tbody>
</table>
- Na⁺ supplement intake rate during same segment as symptoms
- No significant difference between groups

- Na⁺ supplement intake rate during segment before symptoms
- No significant difference between groups
• WSER 2009
• Dietary analysis of 16 runners
• Total Na⁺ intake: food, fluid, Na⁺ supplements
• No difference in total Na⁺ intake between runners with and without nausea and/or vomiting
• WSER 2014
• Dietary analysis of 20 finishers
• Total Na⁺ intake: food, fluid, Na⁺ supplements
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Sodium: Good or Evil in Prolonged Exercise

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Not necessary
• WSER 2006
• Ran 100 miles in 18 hours
• Took ~7000 mg supplemental Na⁺
• Serum [Na⁺] = 127
• Weight up >3% at mile 90
• Thirsty
• WSER 2013
• Dropped at 90 miles after 27.6 h
• Took > 8500 mg supplemental Na^+
• Serum [Na+] = 122
• Weight up >2% at mile 90
• Thirsty

• 2014 Grand Canyon “Rim-to-Rim-to-Rim”
• Ran/hiked 45 miles in 17 hours
• Took > 6500 mg Na$^+$
• Serum [Na$^+$] = 122
• Drank > 9 L, had post-treatment aquaresis
• Thirsty
Sodium: Good or Evil in Prolonged Exercise

Potentially Not necessary

Kristin J. Stuempfle, PhD
Gettysburg College
May 30, 2017
Recommendations

Thirsty? **Drink**!

Craving salt? **Eat something salty**!
Thank you
Solid Line: Na\(^+\) supplements all segments

Dotted Line: No Na\(^+\) supplements any segment

90 km and 161 km: No Na\(^+\) supplements lost more weight, but still in expected range
Solid Line: finishers
Dotted Line: non-finishers

No significant difference between groups; weight change is not a distinguishing factor
WSER 2013

% weight change among finishers: -6.8% to 3.1%

No significant correlation between weight change and finish time; weight loss does not necessarily impact performance
Noakes et al. PNAS 2005

- Negative slope
- ↑ weight, ↓ [Na+]
- EAH with overhydration

Hoffman et al. MSSE 2013

- Positive slope
- ↓ weight, ↓ [Na+]
- EAH with dehydration
• Open circles = symptomatic EAH

Symptomatic EAH most common with overhydration

Hoffman et al. MSSE 2013