Fluids, Electrolytes and Hydration
Team Physicians Course 2017
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Kaiser Permanente Sports Medicine Fellowship Program

With thanks to Stephen Simons, MD, FACSM
Objectives

• Discuss optimum hydration and effects of dehydration on performance
• Discuss best fluid replacement strategies
• Review electrolyte composition of various fluids
• Discuss “overhydrating”
Fluid content of body

- Total body weight (female)
  - 45% Solids
  - 55% Fluids

- Total body weight (male)
  - 40% Solids
  - 60% Fluids

- Total body water (TBW)
  - 2/3 Intracellular fluid (ICF)
  - 1/3 Extracellular fluid (ECF)
  - 80% Interstitial fluid
  - 20% Plasma
Fluid and electrolyte balance

Diagram showing the mechanisms of homeostatic regulation of fluid and electrolyte balance.
Optimum Hydration

• Water loss of 2% or more decreases performance
• Goal is to remain “euvolemic”
• Measuring body weight pre and post exercise helps estimate sweat rates
• Maintaining electrolyte balance, especially Sodium (Na), important
  – balance depends on water and sodium intake and loss
Sweat

• Major mechanism of heat dissipation during exercise
• Sweat rates vary with individuals and activities
• Contents
  – Water
  – Electrolytes—Na, K, Ca, Mg, Cl
• Na concentration may vary greatly
  – “Salty sweating”
Sweat

- Water loss varies with:
  - Individual variance
  - Exercise intensity
  - Ambient temperature and humidity
  - Body surface area and body weight
  - Clothing
  - Metabolic efficiency
  - Acclimatization
# Sweat Rates

<table>
<thead>
<tr>
<th>Sport</th>
<th>Condition</th>
<th>Sweat rate (L/Hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterpolo</td>
<td>Training (Male)</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>Competition (M)</td>
<td>0.79</td>
</tr>
<tr>
<td>Rowing</td>
<td>Summer training (M)</td>
<td>1.98</td>
</tr>
<tr>
<td></td>
<td>Summer training (F)</td>
<td>1.39</td>
</tr>
<tr>
<td>Basketball</td>
<td>Summer comp (M)</td>
<td>1.6</td>
</tr>
<tr>
<td>Soccer</td>
<td>Summer training (M)</td>
<td>1.37</td>
</tr>
<tr>
<td></td>
<td>Winter training (M)</td>
<td>1.13</td>
</tr>
<tr>
<td>American Football</td>
<td>Summer training (M)</td>
<td>2.14</td>
</tr>
<tr>
<td>Tennis</td>
<td>Summer comp (M)</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Summer comp (cramp prone M)</td>
<td>2.6</td>
</tr>
<tr>
<td>Half Marathon</td>
<td>Winter comp (M)</td>
<td>1.49</td>
</tr>
</tbody>
</table>

ACSM Position Stand on Exercise and Fluid Replacement 2007
Extreme Variability in Sweat Rates

- Mia Hamm
  - Soccer legend
  - 700 ml/hr
- Chris Legh
  - Professional Triathlete
  - 2 L/hr
- Adam Kennedy
  - Professional tennis player
  - 5 L/hr

Thanks to Bob Sallis, MD, FACSM
## Measuring Hydration Status

<table>
<thead>
<tr>
<th>Measure</th>
<th>Practicality</th>
<th>Validity (acute v chronic)</th>
<th>Euhydration Cut-off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Body Water</td>
<td>Low</td>
<td>Acute and Chronic</td>
<td>&lt; 2%</td>
</tr>
<tr>
<td>Plasma Osmolality</td>
<td>Medium</td>
<td>Acute and Chronic</td>
<td>&lt; 290 mOsmol</td>
</tr>
<tr>
<td>Urine Specific Gravity</td>
<td>High</td>
<td>Chronic</td>
<td>&lt; 1.020 g/ml</td>
</tr>
<tr>
<td>Urine Osmolality</td>
<td>High</td>
<td>Chronic</td>
<td>&lt; 700 mOsol</td>
</tr>
<tr>
<td>Body Weight</td>
<td>High</td>
<td>Acute and Chronic</td>
<td>&lt; 1%</td>
</tr>
</tbody>
</table>

ACSM Position Stand on Exercise and Fluid Replacement 2007
Measuring Hydration Status

- Thirst
- Dizziness
- Tachycardia
- Dry Mouth
- Skin Turgor
- Headache
Effects of Dehydration on Performance

• Increased strain and perceived exertion
  – Worse in hot environment
  – Worse with increase dehydration

• Dehydration (>2% BW)
  – Decreased aerobic capacity
  – Decreased mental/cognitive performance

• Dehydration (3-5%)
  – No change in anaerobic or muscle strength
Dangers of Impaired Fluid Balance

• Dehydration
  – Increased risk for exertional heat illness
  – Muscle cramps??
  – Rhabdomyolysis and Renal damage

• Hyper-hydration
  – Exercise induced hyponatremia
Exercise-Associated Hyponatremia

• First recognized in Comrades Marathon (South Africa, reported in 1971)
• Associated with over drinking of hypotonic fluids and/or excessive salt loss
Exercise-Associated Hyponatremia

• Athletes at higher risk:
  – women
  – older adults
  – smaller athletes who run slowly, sweat less and drink hypotonic fluids before during and after the race
  – CF gene carriers
  – football and tennis players who over hydrate to prevent cramps or get hypotonic IV hydration.
Exercise-Associated Hyponatremia

• Beware of diagnosing the endurance athlete with dehydration and encouraging hypotonic fluid replacement.

• Symptoms occur with rapid decline in levels below 130 mmol/L

• Symptoms increase with rapidity of decline, the longer it remains low and the lower it goes.
Exercise-Associated Hyponatremia

- Symptoms at levels of 125 mmol/L or less:
  - Headache, vomiting, swollen hands and feet, restlessness, fatigue, confusion and disorientation (cerebral edema), wheezing (pulmonary edema)
- Progression of symptoms with levels below 120 mmol/L:
  - cerebral edema, seizure, coma, brainstem herniation, respiratory arrest and death.
Exercise-Associated Hyponatremia

Hyponatremia among Runners in the Boston Marathon

Christopher S.D. Almond, M.D., M.P.H., Andrew Y. Shin, M.D., Elizabeth B. Fortescue, M.D., Rebekah C. Mannix, M.D., David Wypij, Ph.D., Bryce A. Binstadt, M.D., Ph.D., Christine N. Duncan, M.D., David P. Olson, M.D., Ph.D., Ann E. Salerno, M.D., Jane W. Newburger, M.D., M.P.H., and David S. Greenes, M.D.

Exercise-Associated Hyponatremia

- 2002 Boston Marathon
  - 766 runners enrolled
  - 488 (64%) usable blood specimen
    - 13% Na<135mmol/l
    - 0.6% Na< 120

- Associated with:
  - Consumption of > 3 L fluid
  - Weight gain
  - Female
  - Low BMI
  - Race time > 4 hours

Fluid strategy-Pre exercise

- Goal is to start euhydrated
- If not euhydrated from prior exercise (<12 hour interval between activities), drink slowly at least 4 hours prior to exercise.
- If urine is dark or no urine output, drink more 2 hours prior to exercise
- Add salt to beverages or eat salty food
Fluid strategy-During exercise

- Goal is to prevent excessive dehydration (>2%BW)
- Fluid replacement should mirror losses (0.4-1.8 L/hr) and not be excessive, especially in exercise >3 hours
- Periodically drink, don’t drink at every water station
- Marathoners safe to drink 0.4-0.8 L/hr
- Slower, thinner athletes most at risk of over-hydration in activity > 3 hours.
- Salty sweaters need to replace electrolytes during exercise to avoid hyponatremia
Fluid strategy-Post exercise

• Goal is to fully replace fluid and electrolyte deficits
• If mild deficits, normal eating and drinking will replace losses
• If more moderate deficits, more aggressive replacement is warranted (~12 hours)
  – 1.5 L Fluid/kg weight loss
• Replacing fluid without sodium leads to excessive urine production and delayed euhydration
• IVF should be used only when losses exceed >7% BW with inability to ingest oral fluids
  – No benefit vs. oral rehydration
Sports Drinks

VS

Gatorade

Powerade
<table>
<thead>
<tr>
<th>Drink</th>
<th>Carbohydrate</th>
<th>Sodium</th>
<th>Caffeine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Gatorade</td>
<td>6%</td>
<td>110</td>
<td>0</td>
</tr>
<tr>
<td>Powerade</td>
<td>7%</td>
<td>53</td>
<td>0</td>
</tr>
<tr>
<td>Coca-Cola (12 oz)</td>
<td>13%</td>
<td>45 mg</td>
<td>34 mg</td>
</tr>
<tr>
<td>5 hour energy (2 oz)</td>
<td>0</td>
<td>18 mg</td>
<td>200 mg</td>
</tr>
<tr>
<td>Starbucks Caffe Americano (16 oz)</td>
<td>1%</td>
<td>15 mg</td>
<td>225 mg</td>
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<tr>
<td>Red Bull (8.4 oz)</td>
<td>9%</td>
<td>200 mg</td>
<td>80 mg</td>
</tr>
<tr>
<td>Chocolate milk (8 oz)</td>
<td>8%</td>
<td>150 mg</td>
<td>5 mg</td>
</tr>
</tbody>
</table>
Summary

• Proper hydration is important to good performance
• Dehydration negatively impacts performance
• Rehydration should be performed orally when possible
• Salty sweaters are at risk of hyponatremia if not replacing electrolyte losses
• Sports drinks are a good way of replacing losses, but often don’t contain the recommended electrolyte concentrations.
Bibliography


