Fluids & Electrolytes in Sports Nutrition

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What to expect...

- Water
- Electrolytes
- Fluid and Electrolyte Balance
- Temperature Regulation
- 5 Selected Research Studies
- Human Ecological Model
History

- Fluid and Electrolytes studied for decades
  - Primary research geared towards chronic diseases and illnesses
  - As the world of athletics expanded, so did sports nutrition research
- 1960's: University of Florida-Gators Football team
  - Gatorade- invented in 1966 by Dr. Robert Cade and his team of researchers

Fluid In Our Bodies

- Water makes up ~ 45-70% of body weight
- Typically, females are comprised of less fluid as a % of body weight compared to males
  - Why?
- Water contained in the following compartments:
  - Intracellular Compartment (fluid inside cells) → ~40% BW
  - Extracellular Fluid Compartment
    - Interstitial tissue fluid → ~16% BW
    - Intravascular/blood fluid → ~4% BW
Functions of Water

1. Provides the essential building material for cell protoplasm.
2. Protects body tissue like spinal cord and brain.
3. Control of the osmotic pressure and maintains a proper balance between water and electrolytes.
4. Main component of blood and is the major transportation mechanism.
5. Provides proper functioning of our senses.
6. Regulation of body temperature.

Temperature Regulation

- Energy released in the form of heat
- Body temperature ↑ and sweating occurs to cool down core body temp.
- In humid environments, sweating as a cooling mechanism is not as effective compared to sweating in dry environments
- Re-hydration becomes especially important in humid conditions
Rates of fluid ingestion alter pacing but not thermoregulatory responses during prolonged exercise in hot and humid conditions with appropriate convective cooling


Objectives

- To examine the effects of fluid replacement on temperature regulation and cycling performance under hot and humid conditions
Methods

- Six highly trained male cyclists (age 23± 4 years)
- Subjects completed a ramp protocol on an air-braked cycle ergometer for determination of peak power output
- Six 80km trials performed in a chamber in which subjects mounted their own bike
  - Simulated humidity conditions were not specified

Methods (Cont’d)

- Performed six 80 km timed trials with differing conditions:
  1. **familiarization trial** → to familiarize participant with procedures and also obtain estimated sweat losses during 80km trial.
  2. 0% sweat losses ingested
  3. 33% sweat losses ingested
  4. 66% sweat losses ingested
  5. 100% sweat losses ingested
  6. **WET trial** → subjects rinsed their mouth with 66% sweat loss, but did not ingest this volume of fluid
Measurements

- Rectal temperature
- Skin temperatures taken (mid calf, mid thigh, chest, subscapular region)
- Subjects asked to report their rating of perceived exertion (RPE), thermal comfort, and thirst comfort at 10 km intervals.
- Heart rate recorded every 2 min
- Power output, and temperatures measured at 1-min intervals
- Change in BW used to measure sweat losses
Results

- No significant differences in heat storage between the varying experimental conditions
- Thirst ↑ as distance ↑
  - (a sharper ↑ in WET and 0% trials noted)
- As % Peak power ↑, rectal temperature ↑
- ↓ performance times → ↑ rectal temperature
- Wet trials did not result in faster performance compared to when no fluid was ingested
- Temperature changes varied according to changes in % body mass and showed no direct relationship to sweat loss

Conclusions

- There is no direct relationship between temperature change and hydration status
- Athlete's bodies must compensate for effects of lower rates of fluid ingestion on heat conductance so that our bodies do not overheat.
  - The body may lower metabolic rate to lower core temp
  - This is why results showed no significant difference in heat storage temperatures even under varying levels of hydration
Fluid- Electrolyte Balance

- Body fluid balance maintained at ± 0.2% of total BW under thermoneutral conditions (when sweating is not provoked)
- When sweating occurs, plasma volume ↓, and plasma osmolality (blood concentration) ↑
  1. ADH (Antidiuretic Hormone) signals the kidneys to ↑ water retention
  2. renin-angitensin II- aldosterone system signals the kidneys to ↑ sodium (Na⁺) retention

Re-absorption of Water

1. increased re-absorption of water from kidney back into the bloodstream
2. Pituitary gland (Antidiuretic Hormone) stimulated to release ADH
3. ADH carried to kidney by the blood
4. lower Na⁺ concentration
5. high Na⁺ concentration detected in bloodstream
Re-absorption of Na⁺

1. Low blood pressure or low Na⁺ signals renin
2. Renin splits angiotensinogen to angiotensin I.
3. ACE splits Angiotensin I into Angiotensin II
4. Angiotensin II causes arterial walls to constrict and signals the adrenal glands to release aldosterone
5. Aldosterone causes kidneys to retain Na⁺ and Excrete K⁺

Fluid Needs

- 2004 DRI recommendations of water for a sedentary person:
  - 3.7 liters/day in males
  - 2.7 liter/day in females
- Fluid recommendations for athletes debated between reputable organizations
- American College of Sports Medicine recommendations:
  - Before exercise: 500mL (2 hours prior to exercise)
  - During exercise: drinking early and at regular intervals
Drinking Do’s & Don’ts

**DO**
- Do start exercise well hydrated
- Do weigh yourself
- Do drink during exercise
- Do ingest sodium during exercise
- Do follow your own plan
- Do drink plenty during meals

**DON’T**
- Don’t rely solely on water
- Don’t over drink
- Don’t gain weight during exercise
- Don’t restrict salt in your diet
- Don’t delay drinking during exercise

The above recommendations were adapted from the following resource:

Fluid Intake (Water only)

**Excess**
- Hyperhydration (unequal osmolality between cell membranes)
- Over saturation of cells depletes electrolyte stores
- Brain edema

**Deficiency**
- Dehydration
- Symptoms: dry mouth, sunken eyes, poor skin, cold hands and feet, weak and rapid pulse, rapid and shallow breathing, confusion, exhaustion, and coma.
- Loss of fluid constituting more than 10% of body weight may be fatal.

Loss of fluid constituting more than 10% of body weight may be fatal.
Electrolytes

<table>
<thead>
<tr>
<th>Electrolytes lost in sweat</th>
<th>Primary Dietary Food Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium (Na⁺)</td>
<td>Found in small amounts of all food. Most comes from table salt and processed foods.</td>
</tr>
<tr>
<td>Calcium (Ca⁺)</td>
<td>Dairy products, green leafy, legumes.</td>
</tr>
<tr>
<td>Magnesium (Mg⁺)</td>
<td>Nuts, legumes/beans, whole grain breads/cereals, green leafy vegetables.</td>
</tr>
<tr>
<td>Chloride (Cl⁻)</td>
<td>Found in a variety of foods but mainly from table salt.</td>
</tr>
</tbody>
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Electrolyte Needs

- Sodium (Na⁺): 1300-2300 mg/day
- Potassium (K⁺): 4700 mg/day
- Calcium (Ca⁺): 1300-2500 mg/day
- Magnesium (Mg⁺): 320-400 mg/day
- Chloride (Cl⁻): 2000-3600 mg/day

- Needs vary based on individual athlete.
- Higher amounts needed for "salty sweaters", and those who sweat excessively.

Electrolyte Intake

<table>
<thead>
<tr>
<th>Excess</th>
<th>Deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>◦ Disrupts the sodium/potassium balance</td>
<td>◦ Fatigue, dizziness, confusion, weakness</td>
</tr>
<tr>
<td>◦ High blood pressure (too high sodium)</td>
<td>◦ Lack of energy</td>
</tr>
<tr>
<td>◦ Impaired nerve conduction</td>
<td>◦ Negative effect on vital physiological functions</td>
</tr>
<tr>
<td>◦ Decreased energy production</td>
<td>◦ Muscle cramping</td>
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Influence of Hydration and Electrolyte Supplementation on Incidence and Time to Onset on Exercise-Associated Muscle Cramps

Objectives

- To determine the role of hydration and electrolyte supplementation in the prevention of exercise-associated muscle cramps.
- **EAMC** (electrolyte associated muscle cramps)
  - Common among physically active individuals
  - Temporarily disabling
  - Therefore its prevention is studied.

Methods

- 13 healthy men (ages of 19-27) with a history of EAMCs.
- All subjects reported having a cramp in the plantar-flexor muscle group as a result from exercise within the past year.
- They were asked:
  - not to be physically active for 24 hours before.
  - to maintain a normal diet, hydration levels, and avoid alcohol and caffeine.
Methods

- Each participant completed 2 trials
  1. a hypo hydration trial
  2. carbohydrate-electrolyte trial.
- Trials were separated by 48 hours.
- Each trial was performed in a hot environment with 60% humidity.
- During each trial subjects experienced muscle cramps 56% of the time.

Methods

- During treadmill walking, participants were required to walk on their toes.
- Calf raises were performed on 9 cm. platforms.
- After recovery from the eccentric muscle action, subjects performed an explosive calf raise.
- The static position was then held for 5 seconds.
Results

- Seven subjects experienced a cramp in both conditions
- Two experienced cramps during the carbohydrate-electrolyte trial but not the hypo hydration trial.
- Subjects experienced cramps significantly earlier in the hypo hydration trial than the carbohydrate-electrolyte trials.

Results

- Exercise duration before onset was more than doubled in the carbohydrate-electrolyte trial.
- Consuming a carbohydrate-electrolyte beverage before and during exercise may delay the onset of EMAC.
- Dehydration and electrolyte loss are not the sole causes of EMAC
  - Some of the subjects still experienced cramps when they were hydrated and supplemented with electrolytes.
Discussion

- Small sample size, which only tested men.
- It appears that hydration and electrolyte supplementation did not influence the incidence of cramps.
- Exercise was so intense that hydration and electrolyte supplementation may not have had an opportunity to play a role in preventing EAMCs.

Sodium Replacement and Plasma Sodium Drop During Exercise in the Heat When Fluid Intake Matches Fluid Loss

Objectives

- To examine the effectiveness of sodium-containing sports drinks in preventing hyponatremia and muscle cramping during prolonged exercise in the heat.

Methods

- Randomized, crossover study of thirteen active men.
- Participants completed 4 trials of an exercise protocol in the heat consisting of 3 hours of exercise.
- During exercise, participants consumed 3 different types of drinks:
  1. carbohydrate-electrolyte with sodium
  2. another with less sodium
  3. colored and flavored water.
Methods

- The test consists of 30 minute intervals between cycling and walking uphill.
- The intensity was adjusted so participants had a heart rate of 130 to 140 beats per minute.
- Body mass was recorded at the beginning and immediately after.
- Body mass loss was replenished by an equal amount of the test drink.

Methods

- The second phase was 8 sets of 30 calf raises. Was used because this exercise exhibits glycogen depletion by 75%.
- The third phase included steep walking at a 12% grade on a treadmill for 45 minutes.
- Blood samples were taken immediately following analyzing changes in plasma volume and lactate levels.
Results

- When fluid intake matched body mass loss, relatively moderate amounts of sodium added to the hydration solution did not affect the decline in sodium concentration.
- Sodium supplementation did not increase serum sodium even when participants consumed a carbohydrate-electrolyte drink.

Results

- Sodium-containing drinks also caused a small increase in plasma osmolality.
- Four of the thirteen participants experienced pre-cramping signs with pain and stiffness in the gastrocnemius muscle.
Discussion

- A relationship between sodium supplementation and the prevention of exercise-associated muscle cramps cannot be established from the environmental and exercise factors of this study.
- Small Sample Size
- All Men

Exercise-Associated Hyponatremia in marathon Runners: A Two Year Experience

Davis DP, Videen JS, Marino A, Vilke GM, Dunford JV, Van Camp SP, Maharam LG. (2001) 
The Journal of Emergency Medicine. 21 (1) 47-57
Purpose

- The purpose of this study was to examine, define, and understand the pathophysiology, risk factors, and treatment of runners who were hyponatremic.

Methods-Subjects

- All runners who visited any of the San Diego Emergency Rooms for hyponatremia in the 1998 & 1999 Suzuki Rock 'N Roll Marathon
- 53 runners -1998 race
  - 21 patients hyponatremic
  - 11 severely hyponatremic.
- Ten runners -1999 race
  - 5 hyponatremic patients
  - 4 severely hyponatremic.
Methods-Protocol

- Data included all emergency room evaluations and findings, blood draw times, i.v fluid administration, and SNa (serum sodium) values.

- Interviews were conducted with the hyponatremic patients to find out their own beliefs and strategies regarding hydration before, during, and after the race.

Results

- All patients said that they tried to have as much fluid as possible during and after the race.

- The 1999 race included an early use of HTS (Hypertonic saline) and concluded for a significantly faster rate of SNa correction for the severe hyponatremic patients compared to the 1998 patients who did not use HTS.

- Severe hyponatremics were significantly less likely to be tachycardic or hypotensive, more likely to be female, and more likely to be using NSAIDS.
Conclusion

- **Pros**
  - 2 years worth of data collection (larger sample size with no bias on age, gender, or athletic ability).
  - Data was collected by hospital staff (reputable agents)
  - Independent and dependent measures

- **Cons**
  - Small sample size
  - Multiple staff taking measurements (clinician error)

Supplements

- Powders, tablets, drinks, strips, food
Rehydration After Exercise In the Heat: A Comparison of 4 Commonly Used Drinks


Purpose

- The purpose of this study was to compare 4 commonly used rehydrating drinks to see which one was more efficient in fluid and sodium loss replenishment along with comparing their taste and feeling of fullness.
Methods- Subjects

- 8 volunteers (4 men/4 women)
- Characteristics consisted of age, height, body mass, body fat, and peak oxygen consumption

Methods- Protocol

- In all trials sweat samples were collected during exercise, or dehydration periods. The samples were used to measure sodium, potassium, and chloride.
- Subjects were asked to keep a dietary journal and exercise routines.
- Venous blood samples were also collected before the trials, 30 minutes after the trial, at the end of rehydration, and every hour for 4 hours postrehydration.
- Urine samples were taken as well.
- Subjects were also asked their perceptions on the beverages given at the end of the rehydration period.
Conclusion-Results

- The subject’s pre-exercise body mass was the same for all trials with a significant body mass decrease in all trials following the exercise period.
- Mean sweat sodium, potassium, and chloride concentrations did not change much during the trials.
- Subjects lost around 3.5% of their body water content during exercise and post perspiration.
- Hydration status of the subjects was significantly lower than the pretrial levels for Evian, San Benedetto, and Apfelschorle.
- Sweat electrolyte losses did not differ between trials but sodium and potassium intake did.

Conclusion-Results

- Subjects stayed in a negative sodium balance the entire follow up period and only with Apfelschorle did subjects have a positive potassium balance.
- All trials showed that there was a decrease in plasma volume post exercise.
- Subjects felt Gatorade and Apfelschlore were the sweetest while Gatorade was the saltiest as well. There was no difference found in the drinks being more fulfilling or pleasant than the other.
Discussion

- The article stated that recovery of fluid balance can only be attained with significant quantities of sodium being ingested post exercise.
- The article stresses that it is important to restore fluid and electrolyte balances.
- Choosing a drink should be specific to the demands of the athlete.

Pros/Cons

- **Pros**
  - Compared multiple beverages
  - Examined efficiency and subject liking
  - Detailed explanation of fluid and electrolyte balance
  - Used exercise (sweat samples) and dietary intake to measure and compare data

- **Cons**
  - Small study size
  - Compared drinks that aren’t commonly known/used
Wrapping it up…

Human Ecological Theory

- As peers, coaches, dietitians, and nutritionists, we represent the microsystem
- It is important to be able to convey information to athletes
- How can we relay our research to athletes?
  - Gain their trust
  - Display validity and reliability
  - Relate to them

References


