Water Requirements and Fluid Balance

Chapter 8

Water Content of the Body

<table>
<thead>
<tr>
<th>Table 8.1</th>
<th>Distribution of Body Water in a Young 70-kg (154-lb) Man</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume [%]</td>
<td>Body mass [%]</td>
</tr>
<tr>
<td>Intake fluid</td>
<td>24</td>
</tr>
<tr>
<td>Loseable fluid</td>
<td>14</td>
</tr>
<tr>
<td>Insensible fluid</td>
<td>16.5</td>
</tr>
<tr>
<td>Blood plasmas</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Note: Water volume is a 2% of body mass.
Thermoregulation and Exercise in the Heat

- Increased muscular activity during exercise causes an increase in heat production.
- Thermoregulation is defined as the mechanisms that prevent excessive rise in body temperature

- Heat Production During Exercise
  - For every 1 L of O$_2$ consumed, about 4 kcal of heat is produced
  - Most of the heat produced is transferred to the body's core (not the skin)
    - Increase in core temperature is then sensed by thermoreceptors in the brain and corrective mechanisms begin

Thermoregulation and Exercise in the Heat

- Heat Storage During Exercise
  - Some storage of heat will occur during exercise
  - When heat loss = heat production, body temperature will plateau
  - However, during high-intensity exercise, no plateau may be observable
    - HP: 70W (Rest) to 1000W (Exercise)
    - This could potentially increase body temperature by 1°C (1.8°F) every 4 minutes
    - Thus, the body temperature could reach dangerous levels in only 12-15 min
  - Heat production is proportional to exercise intensity
  - Reference temps:
    - 36 to 38°C (96.8 to 100.4°F) normal (rest)
    - 38 to 40°C (100.4 to 104°F) normal (exercise)
    - > 40°C, dangers of heat exhaustion, heat stroke

Thermoregulation and Exercise in the Heat

- Environmental Heat Stress and Heat Loss by Evaporation of Sweat
  - Environmental heat stress determined by:
    - Ambient temperature, relative humidity, wind velocity, and solar radiation
  - If skin temp > ambient temp, heat is lost from the skin by physical contact:
    - Evaporation of sweat, convection, and conduction
  - If ambient temp > skin temp, heat is gained from the environment
    - Relative humidity also has large impact on the evaporation of sweat
Thermoregulation and Exercise in the Heat

– 1 L of water from the skin will remove around 573 kcal of heat
– The sweat rate would have to be between 1.6 to 2L/hour if all the heat produced was to be dissipated by evaporative heat loss alone
– A useful index of environmental heat stress is the wet bulb globe temperature (WBGT):
  \[ \text{WBGT} = 0.7 T_{wb} + 0.2 T_{bb} + 0.1 T_{db} \]
– Factors influencing sweat loss
  • Poorly ventilated clothing
  • Sweat drips, not evaporates, off skin
  • High intensity exercise maintained, causing increased body core temp & increased sweat (quicker dehydration)

Thermoregulation and Exercise in the Heat

<table>
<thead>
<tr>
<th>Table 8.3</th>
<th>Sweat Loss and Heart Rates After 60 Minutes of Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature</td>
<td>Humidity (%)</td>
</tr>
<tr>
<td>[°F]</td>
<td>(%)</td>
</tr>
<tr>
<td>73.1 (°F)</td>
<td>70</td>
</tr>
<tr>
<td>78.4 (°F)</td>
<td>30</td>
</tr>
<tr>
<td>83.5 (°F)</td>
<td>30</td>
</tr>
<tr>
<td>88.7 (°F)</td>
<td>90</td>
</tr>
<tr>
<td>93.9 (°F)</td>
<td>90</td>
</tr>
</tbody>
</table>

Exercise performed at about 60% to 70% VO2max under different environmental conditions.

Dehydration of 2% body mass sufficient to significantly impair exercise performance (equivalent of 1.5L water for a typical 70kg male athlete)

Thermoregulation and Exercise in the Heat

![Figure 8.3](image.png)

Figure 8.3 Plan of dehydration on heart rate and rectal temperature during 2 hours of cycling.
**Thermoregulation and Exercise in the Heat**

- Heat Loss by Radiation and Convection
  - Radiation: transfer of energy waves by emission from one object and absorption by another
  - Convection: Exchange of heat between a solid medium and one that moves
  - Heat loss via radiation and convection is the product of skin blood flow, the temperature difference between the core and the skin, and the ambient temperature

**Regulation of Body Temperature**

- Summary of thermoregulation during exercise in the heat
**Exercise Training, Acclimatization, and Temperature Regulation**

- Exercise training improves thermoregulation at an absolute workload.
  - But, training must be at a sufficiently high intensity to stress the thermoregulatory mechanisms
    - Typically > 70% VO\(_{2\text{max}}\)
  - Main adaptations:
    - Lower resting core temperature
    - Lower threshold for onset of sweating
    - Increase blood volume
    - Increase maximal cardiac output
  - Training in heat w/o fluids does not confer additional thermoregulatory adaptations (no dehydration adaptation)

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**Effects of Dehydration on Exercise Performance**

- Exercise performance can be impaired when an individual is dehydrated by as little as 2% body weight
- Losses around 5% can impair the capacity to do work by ~ 30%
Effects of Dehydration on Exercise Performance

- Mechanisms for adverse effects:
  - Reduction in blood volume
  - Decreased skin blood flow
  - Decreased sweat rate
  - Decreased heat dissipation
  - Increased core temperature
  - Increased rate of muscle glycogen use

Due to dehydration or simply exercise in the heat, VO2 max can decrease ~7%

Impaired thermoregulation directly related to reduced performance

Even low intensity exercise is negatively impacted by dehydration

Body temperature rises faster during exercise when dehydrated
Mechanisms of Heat Illness

Effects of Fluid Intake on Exercise Performance

- Pre-exercise hyperhydration
  - Has been hypothesized to improve thermoregulation by expanding blood volume and reducing plasma osmolarity
  - Protective effects of glycerol + water (1 g/kg b.w. in 1-2 L water)
- Fluid intake during exercise
  - Dehydration can be avoided by matching fluid intake to sweat loss
    - Difficult for the following reasons:
      - Sweat rates can exceed the amount of fluid ingestion that individuals can handle before GI distress
      - Sweat rates vary widely (Fig 8.10)
      - Thirst not a good indicator (Table 8.4)
      - Practicality

Effects of Fluid Intake on Exercise Performance

Figure 8.10 (Sweat rates for subjects who competed in a marathon held in cool-weather 12°C [54°F] conditions. The sweat rate was related to the running speed, but a large variation existed between individuals, even those running at the same speed. From K. McGaughey 1982)
Effects of Fluid Intake on Exercise Performance

Table 8.4 Fluid Losses and Intakes of Athletes

<table>
<thead>
<tr>
<th>Sport</th>
<th>Ambient Temperature (°C)</th>
<th>Sweat loss (ml/h)</th>
<th>Fluid intake (ml/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running</td>
<td>30-35</td>
<td>1,800</td>
<td>1,800</td>
</tr>
<tr>
<td>Cycling</td>
<td>10-15</td>
<td>2,500</td>
<td>800</td>
</tr>
<tr>
<td>Soccer</td>
<td>10-15</td>
<td>1,500</td>
<td>1,000</td>
</tr>
<tr>
<td>Basketball</td>
<td>20-25</td>
<td>1,800</td>
<td>1,800</td>
</tr>
</tbody>
</table>

• Fluid intake during exercise (cont’d)
  – Impact on performance

Figure 8.11 Effect of water intake on endurance capacity

- Small levels of CHO may improve performance (Fig. 8.12 and 8.13)
  - Too much will decrease absorption (Fig. 8.14)
- Fluid should be hypotonic compared to plasma
  - Some electrolytes might aid in replacing sweat losses but also increase absorption
- Electrolytes are added to sport drinks to:
  - Increase palatability
  - Maintain thirst
  - Prevent hyponatremia (low serum sodium concentration)
  - Increase water uptake
  - Increase fluid retention

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- Increase palatability
- Maintain thirst
- Prevent hyponatremia (low serum sodium concentration)
- Increase water uptake
- Increase fluid retention
Effects of Fluid Intake on Exercise Performance

![Graph showing the effects of different fluid intakes on exercise performance.](image)

**Figure 8.13** Effects of fluid intake on exercise performance. Bars represent the mean values of time (min) to complete the time trial (n=6).

Effects of Fluid Intake on Exercise Performance

![Graph showing small fluid, small fluid + CHO, and large fluid + CHO.](image)

**Figure 8.13** Effect of carbohydrate fluid intake on exercise performance. Bars represent the mean values of time (min) to complete the time trial (n=6).

Effects of Fluid Intake on Exercise Performance

![Graph showing exercise and hypotonic and hypertonic drinks.](image)

**Figure 8.14** Plasma volume changes during exercise with consumption of a hypotonic or hypertonic glucose-electrolyte drink. Bars represent the mean values of plasma volume (n=6).

Effects of Fluid Intake on Exercise Performance

![Graph showing the effects of fluid intake on exercise performance.](image)

**Figure 8.13** Effects of fluid intake on exercise performance. Bars represent the mean values of time (min) to complete the time trial (n=6).
Fluid intake during exercise (cont’d)

Fluid composition (cont’d):

- For exercise lasting less than 30 min
  - No real benefit for performance
- For exercise lasting greater than 1 hour
  - Sports drinks are recommended
  - Especially in hot humid environments
  - Sweat rate is dependant on environment, intensity and duration of exercise (Fig 8.15)

Main purpose of fluid ingestion is to maintain plasma volume which will improve thermoregulation and performance
**Fluid Requirements for Athletes**

- Ensuring adequate hydration before exercise:
  - High fluid intake in the days before competition
    - Urine osmolality
    - Urine color
    - Body weight changes
  - Fluid intake increases as ambient temperature increases and activity level increases

**Fluid Requirement for Athletes**

- No. 1, 2 or 3 demonstrates hydration, if it is 7 or darker dehydration is present
**Fluid Requirement for Athletes**

- Ensuring Hydration during Exercise
  - Cannot rely on thirst mechanism
  - Fluid consumption should be sufficient so that body weight remains fairly constant
- Composition of Sports Drinks during Exercise
  - Rehydration is the most important factor rather than substrate availability
  - Some CHO and sodium is favorable
  - CHO: (20-60 g/L) Na: (20-60 mmol/L)

### Table 8.6 Compositions of Commonly Consumed Sport Drinks

<table>
<thead>
<tr>
<th>Drink</th>
<th>Carbohydrate (g/L)</th>
<th>Sodium (mmol/L)</th>
<th>Potassium (mmol/L)</th>
<th>Osmolarity (mOsm/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatorade</td>
<td>40</td>
<td>15</td>
<td>6</td>
<td>375</td>
</tr>
<tr>
<td>Gatorade V2</td>
<td>40</td>
<td>15</td>
<td>6</td>
<td>379</td>
</tr>
<tr>
<td>Powerade</td>
<td>40</td>
<td>24</td>
<td>4</td>
<td>296</td>
</tr>
<tr>
<td>Powerade LK</td>
<td>60</td>
<td>24</td>
<td>4</td>
<td>291</td>
</tr>
<tr>
<td>Powerade LK</td>
<td>80</td>
<td>24</td>
<td>4</td>
<td>291</td>
</tr>
</tbody>
</table>
**Fluid Requirement for Athletes**

- Rehydration after Exercise
  - Important for recovery especially when repeated bout of exercise are performed
  - Main factors influencing rehydration are volume and composition of fluid
    - Fluid should have some sodium and CHO
      - Increase absorption (Fig 8.21)
    - Avoid caffeine and alcohol (although the effects of alcohol are somewhat limited after exercise) (Fig 8.23)

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**Fluid Requirement for Athletes**

![](image1)

**Figure 8.21** Net fluid balance plotted against time after dehydration (loss of 1.5% of body weight) induced by mild exercise in a hot environment. Zero net fluid balance represents euhydration. Drink volume indicated was half of (50%) and total (100%) volume loss, and twice (200%) the sweat loss. The drink sodium concentration was either 32 mmol/l or 50

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**Fluid Requirement for Athletes**

![](image2)

**Figure 8.33** Percentage change in plasma volume with dehydration equivalent to 2% of body weight followed by ad libitum fluid intake with drinks containing 0%, 1%, 2%, and 4% butyric acid in a volume equivalent to a multiple of times the sweat loss. Note that plasma volume restoration was delayed with the 4% butyric acid drink.

*Rehydration after Exercise* - Important for recovery especially when repeated bout of exercise are performed. Main factors influencing rehydration are volume and composition of fluid. Fluid should have some sodium and CHO to increase absorption. Avoid caffeine and alcohol, although the effects of alcohol are somewhat limited after exercise.
**Fluid Requirement for Athletes**

Fluid requirement plays a key role in ensuring the health, safety, and overall physical performance of individuals participating in regular physical activity. The following are general recommendations on the amount and composition of fluids that should be ingested in preparation for, during, and after exercise or athletic activities.

1. Individuals should consume a nutritionally balanced diet rich in protein and carbohydrates before, during, and after physical activity to promote muscle recovery and energy production.
2. Fluid intake should be increased by 150% to 200% of the maintenance fluid requirements during intense exercise to prevent dehydration.
3. A large glass of cool water (600-900mL) should be ingested before long-distance exercise to help maintain body temperature and prevent heat-related illnesses.
4. Fluids containing electrolytes (e.g., sports drinks) should be consumed during exercise to replace lost electrolytes and maintain fluid balance.
5. A sports drink providing a mixture of water, electrolytes, and simple sugars is recommended for fluid replacement during exercise to optimize performance and hydration.
6. Athletes should drink fluids at a rate of 170-220mL of water per hour of exercise to maintain fluid balance.

**Fluid Requirement for Athletes**

<table>
<thead>
<tr>
<th>Pre-EX</th>
<th>Drink Volume (mL)</th>
<th>Body Weight (kg)</th>
<th>Loss (mL)</th>
<th>Rate (mL/hour)</th>
<th>Duration (min)</th>
<th>Rate (mL/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>66.5</td>
<td>495</td>
<td>70</td>
<td>220</td>
<td>60</td>
<td>20</td>
<td>30</td>
</tr>
</tbody>
</table>

Sweat Rate (mL/min):

Sweat Rate (mL/hour):

Recommended Fluid intake (mL/hour) to stay hydrated:

How much fluid should this person drink over the 65 minutes of exercise to remain hydrated?