Chapter 9
Lecture Slides
Introduction

- Water
- Electrolytes
- Temperature regulation
- Exercise performance in the heat
- Fluid, carbohydrate and electrolyte replacement
- Ergogenics
- Heat illnesses
- High blood pressure
Introduction

• Water and electrolytes
  – Critical to health
    • Cholera
    • Diarrhea with fluid and electrolyte losses
    • Oral rehydration solutions
  – Critical to exercise performance
    • Temperature regulation during exercise in the heat
    • Health
    • Performance
How much water do you need per day?

- Daily water needs are individualized
- Body water balance
  - Output
    - Small amount in feces and evaporation with breathing
    - Insensible perspiration (30% of water losses)
    - Urinary output (caffeine, alcohol, protein)
- Input
  - Beverages
  - Water in food
    - Metabolic water
    - Metabolism of 350 g of carbohydrate → 1 liter of water
### Water Intake

- Fluids: 2,000 ml (8 cups)
- Water content in food: 500 ml (2 cups)
- Water produced from metabolism: 300 ml (1.25 cups)

### Water Output

- Skin perspiration: 750 ml (3 cups)
- Lung respiration: 300 ml (1.25 cups)
- Urine: 1,650 ml (6.75 cups)
- Feces: 100 ml (0.4 cups)

**Total Water Intake**

2,800 ml
(approximately 11.5 cups)

**Total Water Output**

2,800 ml
(approximately 11.5 cups)
Water requirements

- AI established for water under normal environmental temperatures and activity levels
- AI for adults age 19 and over
  - Males: 3.7 liters (3.9 quarts)
  - Females: 2.7 liters (2.9 quarts)
What else is in the water we drink?

- **Natural geological formations**
  - Calcium, magnesium, iron, sodium

- **Industrial contaminants**
  - 700 contaminants, including pesticides
  - EPA has set national standards

- **Pipes in house**
  - Lead, copper

- **Intentionally added**
  - Fluoride
Water safety

• Cool Website
  • www.epa.gov/safewater
• The Environmental Protection Agency website. Click on Local Drinking Water Quality
Bottled water

• Wide variety of bottled waters
  – Vitamin; herbal; oxygen; fitness
• Most bottled waters meet high safety standards
• Nation’s two best-selling bottled waters are purified municipal water
  – Aquafina and Dasani
• Most bottled waters do not contain fluoride
• May be expensive
  – Gourmet water at $40 a bottle
Where is water stored in the body?
Body water compartments

- Intracellular water (60-65%)
- Extracellular water (35-40%)
  - Intercellular (interstitial) water
  - Intravascular water
  - Miscellaneous water
Body water

• Adult males
  – 60% of body weight
  – Greater amount of muscle (high water content)

• Adult females
  – 50% of body weight
    • Greater amount of body fat (low water content)

• Percentages of body water may vary
  – 70 percent in muscular individuals
  – 40 percent in obese individuals
How is body water regulated?

• Normohydration (euhydration)
  – Normal body water stores
• Dehydration
  – Process of losing body fluids
• Hypohydration
  – Low levels of body water
  – Hypohydration and dehydration used interchangeably
• Hyperhydration
  – Process of increasing body fluids
  – Above normal levels of body water
Body water regulation

• Maintain body water homeostasis
• Osmolality or tonicity of body fluids
  – Isotonic
  – Hypotonic
  – Hypertonic
• Body water flows from a hypotonic area to a hypertonic area
The antidiuretic hormone (Vasopressin)
How do I know if I am adequately hydrated?

- Thirst
- Urine color
  - Deep yellow may indicate hypohydration
    - Riboflavin vitamin may cause deep yellow urine color
- Body weight changes
  - Rapid body weight changes are due to body water loss or gain
What are the major functions of water in the body?

• Essential building material for cell protoplasm
• Protection of organs such as brain and spinal cord
• Maintenance of electrolyte balance and key cell functions
• Main constituent of blood
• Proper functioning of senses (eyes, ears)
• Regulation of body temperature
Can drinking more water or fluids confer any health benefits?

- Possible health benefits
  - Decreased risk of bladder cancer
  - Decreased risk of colon cancer
  - Suppression of appetite in weight control
    - The Volumetric Diet Plan

- Possible health risks
  - Alcohol in excess
  - Coffee for certain individuals
  - High-Calorie beverages and weight control
Electrolytes

What is an electrolyte?

• A substance in solution that conducts an electric current

• Electrolytes in the human body
  – Na; Cl; K; Ca; Mg; and others
  – Electrical currents in nerves and muscles
  – Activate enzymes to control metabolism
Sodium

• Symbol: Na (Natrium)

• DRI
  – AI = 1,500 milligrams (age 9-50)
  – UL = 2,300 milligrams
  – DV = 2,400 milligrams
    • Note: Larger amount than the UL
Sodium

- **Food sources**
  - Distributed widely in nature, but in small amounts in natural foods
  - Table salt: 1 teaspoon contains 2,000 mg of sodium
  - Processed foods may contain substantial amounts
  - To consume less
    - Drain and rinse vegetables
    - Use herbs or salt substitutes
<table>
<thead>
<tr>
<th>Food exchange item</th>
<th>Amount</th>
<th>Sodium (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Milk</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-fat milk</td>
<td>1 c</td>
<td>120</td>
</tr>
<tr>
<td>Cottage cheese</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creamed</td>
<td>1/2 c</td>
<td>320</td>
</tr>
<tr>
<td>Unsalted</td>
<td>1/2 c</td>
<td>30</td>
</tr>
<tr>
<td>Cheese, American</td>
<td>1 oz</td>
<td>445</td>
</tr>
<tr>
<td><strong>Vegetables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beans, cooked fresh</td>
<td>1 oz</td>
<td>5</td>
</tr>
<tr>
<td>Beans, canned</td>
<td>1 oz</td>
<td>150</td>
</tr>
<tr>
<td>Pickles, dill</td>
<td>1 medium</td>
<td>900</td>
</tr>
<tr>
<td>Potato, baked</td>
<td>1 medium</td>
<td>6</td>
</tr>
<tr>
<td><strong>Fruits</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Banana</td>
<td>1 medium</td>
<td>1</td>
</tr>
<tr>
<td>Orange</td>
<td>1 medium</td>
<td>1</td>
</tr>
<tr>
<td><strong>Starch</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bread, whole wheat</td>
<td>1 slice</td>
<td>130</td>
</tr>
<tr>
<td>Bran flakes</td>
<td>3/4 c</td>
<td>340</td>
</tr>
<tr>
<td>Oatmeal, cooked</td>
<td>1 c</td>
<td>175</td>
</tr>
<tr>
<td>Pretzels</td>
<td>1 oz</td>
<td>890</td>
</tr>
<tr>
<td>Meat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>Luncheon meats</td>
<td>1 oz</td>
<td>450</td>
</tr>
<tr>
<td>Chicken</td>
<td>3 oz</td>
<td>40</td>
</tr>
<tr>
<td>Beef, steak</td>
<td>3 oz</td>
<td>70</td>
</tr>
<tr>
<td>Tuna, low sodium</td>
<td>3 oz</td>
<td>35</td>
</tr>
<tr>
<td>Tuna, in oil</td>
<td>3 oz</td>
<td>800</td>
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<table>
<thead>
<tr>
<th>Fats</th>
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</thead>
<tbody>
<tr>
<td>Butter, salted</td>
<td>1 tsp</td>
<td>50</td>
</tr>
<tr>
<td>Margarine, salted</td>
<td>1 tsp</td>
<td>50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Canned foods and prepared entrees</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Spaghetti, canned</td>
<td>1 c</td>
<td>1,220</td>
</tr>
<tr>
<td>Turkey dinner, frozen</td>
<td>1</td>
<td>1,735</td>
</tr>
<tr>
<td>Chicken noodle soup</td>
<td>5 oz</td>
<td>655</td>
</tr>
<tr>
<td>Chicken noodle soup, low sodium</td>
<td>5 oz</td>
<td>120</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Restaurant fast foods</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Arby’s chicken breast fillet sandwich</td>
<td>1</td>
<td>1,220</td>
</tr>
<tr>
<td>McDonald’s Big Mac</td>
<td>1</td>
<td>1,010</td>
</tr>
<tr>
<td>Subway club (6 inches)</td>
<td>1</td>
<td>1,310</td>
</tr>
<tr>
<td>Taco Bell bean burrito</td>
<td>1</td>
<td>1,220</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condiments</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mustard</td>
<td>1 tbsp</td>
<td>195</td>
</tr>
<tr>
<td>Tomato catsup</td>
<td>1 tbsp</td>
<td>155</td>
</tr>
<tr>
<td>Soy sauce</td>
<td>1 tbsp</td>
<td>1,320</td>
</tr>
</tbody>
</table>
Food Labels - Electrolytes

- Sodium is listed
  - Milligrams
  - % Daily Value
- Potassium and others may be listed
**TABLE 9.2** Nutrition facts label terms for sodium*

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium-Free or Salt-Free</td>
<td>Less than 5 milligrams per serving</td>
</tr>
<tr>
<td>Very Low Sodium</td>
<td>35 milligrams or less per serving</td>
</tr>
<tr>
<td>Low Sodium</td>
<td>140 milligrams or less per serving</td>
</tr>
<tr>
<td>Reduced-Sodium or Less Sodium</td>
<td>At least 25 percent less than the regular product</td>
</tr>
<tr>
<td>No Salt Added</td>
<td>Amount of sodium per serving must be listed</td>
</tr>
</tbody>
</table>

*Food labels must list the milligrams of sodium and the percent of the Daily Value, which is 2,400 mg.*
<table>
<thead>
<tr>
<th>Major electrolyte</th>
<th>Adequate intake</th>
<th>Major functions in the body</th>
<th>Deficiency symptoms</th>
<th>Symptoms of excess consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>1,500 milligrams</td>
<td>Primary positive ion in extracellular fluid; nerve impulse conduction; muscle contraction; acid-base balance; blood volume homeostasis</td>
<td>Hyponatremia; muscle cramps; nausea; vomiting; loss of appetite; dizziness; seizures; shock; coma</td>
<td>Hypertension (high blood pressure) in susceptible individuals</td>
</tr>
<tr>
<td>Chloride</td>
<td>2,300 milligrams</td>
<td>Primary negative ion in extracellular fluid; nerve impulse conduction; hydrochloric acid formation in stomach</td>
<td>Rare; may be caused by excess vomiting and loss of hydrochloric acid; convulsions</td>
<td>Hypertension, in conjunction with excess sodium</td>
</tr>
<tr>
<td>Potassium</td>
<td>4,700 milligrams</td>
<td>Primary positive ion in intracellular fluid; same functions as sodium, but intracellular; glucose transport into cell</td>
<td>Hypokalemia; loss of appetite; muscle cramps; apathy; irregular heartbeat</td>
<td>Hyperkalemia; inhibited heart function</td>
</tr>
</tbody>
</table>
Sodium

• **Major functions**
  – Principal electrolyte in extracellular fluids
    • Nerve impulse conduction
    • Initiate neural process of muscle contraction
  – Maintains normal body-fluid balance and osmotic pressure
  – Essential for control of blood volume and pressure
  – Component of sodium bicarbonate
    • Potential ergogenic effects
Sodium

• Deficiency and excess
  – Sodium is critical to life
  – Human body has a very effective regulatory feedback mechanism to maintain long-term control of sodium and water balance
  – Hypothalamic control of aldosterone release from the adrenal gland
  – Aldosterone stimulates kidneys to reabsorb sodium
    • ↑ aldosterone with low blood osmolality (low sodium levels)
    • ↓ aldosterone with high blood osmolality (high sodium levels)
  – Short-term deficiencies may impair exercise performance
Chloride

• Symbol: Cl

• DRI
  – Al = 2.3 grams, or 2,300 mg (age 9-50)
  – UL = 3.5 grams, or 3,500 mg
  – DV = 3,500 mg
Chloride

• Food sources
  – Dietary intake closely associated with sodium intake
  – 60% of common table salt

• Major functions
  – Works closely with sodium
    • Regulation of body water balance
    • Electrical potential across cell membranes
    • Helps form hydrochloric acid in the stomach
Chloride

• Deficiency
  – Very rare
  – Losses during exercise-induced sweating parallel those of sodium
Potassium

• Symbol: K (Kalium)

• DRI
  – AI = 4.7 grams, or 4,700 mg (age 14 and above)
  – UL = None
  – DV = 3.5 grams (Note: less than the AI)
Potassium

• Food sources
  – Found in most foods
  – Especially abundant in fruits, vegetables, meat, milk
<table>
<thead>
<tr>
<th>Food</th>
<th>Amount</th>
<th>Milligrams of potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skim milk</td>
<td>8 oz glass</td>
<td>410</td>
</tr>
<tr>
<td>Yogurt, low-fat</td>
<td>1 c</td>
<td>530</td>
</tr>
<tr>
<td>Cheese, cheddar</td>
<td>1 oz</td>
<td>28</td>
</tr>
<tr>
<td>Meat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicken breast</td>
<td>1 oz</td>
<td>70</td>
</tr>
<tr>
<td>Beef, lean</td>
<td>1 oz</td>
<td>100</td>
</tr>
<tr>
<td>Fish, flounder</td>
<td>1 oz</td>
<td>160</td>
</tr>
<tr>
<td>Starch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bread, whole wheat</td>
<td>1 slice</td>
<td>65</td>
</tr>
<tr>
<td>Cereal, Cheerios</td>
<td>1 oz</td>
<td>110</td>
</tr>
<tr>
<td>Fruit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Banana</td>
<td>1 medium</td>
<td>460</td>
</tr>
<tr>
<td>Orange</td>
<td>1 avg</td>
<td>260</td>
</tr>
<tr>
<td>Apple</td>
<td>1 avg</td>
<td>35</td>
</tr>
<tr>
<td>Vegetables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potato, baked</td>
<td>1 avg</td>
<td>780</td>
</tr>
<tr>
<td>Broccoli</td>
<td>1 stalk</td>
<td>270</td>
</tr>
<tr>
<td>Carrot</td>
<td>1 medium</td>
<td>275</td>
</tr>
</tbody>
</table>
Potassium

• Major functions
  – Important intracellular electrolyte
  – Works with sodium and chloride
    • Electrical impulses
  – Glucose transport into cells
  – Glycogen metabolism
Potassium

• Deficiency and excess
  – Deficiency and excess are rare
  – Like sodium, potassium balance is regulated by aldosterone, but in a reverse way
    • High serum K stimulate aldosterone release
    • Aldosterone ↑ excretion of K into urine
    • Low serum K decreases aldosterone release
    • Increases K absorption by the kidney
  – Hypokalemia (fasting; diarrhea)
    • Muscular weakness; irregular heartbeat; death
  – Hyperkalemia (excess supplement use)
    • Cardiac arrhythmias; death
Sodium and potassium balance

• Sodium and potassium balance
  – 1. Low sodium concentration
  – 2. Leads to a decrease in blood volume
  – 3. Which stimulates kidney to release renin
  – 4. Which produces a form of angiotensin
  – 5. That stimulates the adrenal glands
  – 6. Which secrete aldosterone
  – 7. Which increases sodium resorption in kidney
  – 8. But increases potassium excretion
  – 9. Therefore, with low potassium, aldosterone synthesis and release is decreased
  – 10. Which decreases potassium excretion
Regulation of Body Temperature

What is normal body temperature?

• Core temperature
  – Internal temperature
    • Oral
    • Rectal
    • Esophageal
    • Gastrointestinal tract (capsule)
  – Normal range: 97-99°F (36.1-37.2°C)
  – Typical oral temperature: 98.6°F = 37°C

• Shell temperature
  – Skin and underlying tissues
  – May vary with ambient temperature
What are the major factors that influence body temperature?

\[ H = M \pm W \pm C \pm C \pm R - E \]

- **H** = Heat balance
- **M** = Resting metabolic rate
- **W** = Work done (exercise)
- **C** = Conduction
  - Direct physical contact
- **C** = Convection
  - Movement of air or water over body
- **R** = Radiation
  - Radiation of heat from or to the body
- **E** = Evaporation
  - Heat loss of vaporization; sweat and respiratory heat loss
How does the body regulate its own temperature?

• Hypothalamus control
  – Functions as a thermostat
  – Input
    • Receptors in the skin
    • Blood temperature
  – Output
    • Circulatory system compensation
    • Muscle contraction
    • Sweating
Body temperature control

• Inadequate body compensation for heat loss or gain
• Hypothermia
  – Muscular incoordination
  – Mental confusion
• Hyperthermia
  – Weakness and fatigue
  – Heat illnesses
What environmental conditions may predispose an athletic individual to hyperthermia?

• 1. Air temperature
• 2. Relative humidity
• 3. Air movement
• 4. Radiation
Exercising in the Heat

Heat Indexes

- Wet Bulb Globe Temperature
  - Air temperature
  - Relative Humidity
  - Air movement
  - Solar radiation
The WBGT Index

- Wet-Bulb Globe Temperature
  - WBGT = 0.7 Wet bulb + 0.2 Globe + 0.1 Dry bulb
    - WB = Effect of relative humidity and air movement
    - G = Radiant heat
    - DB = Air temperature
Calculation of WBGT

- $WB = 70^\circ F$
- $G = 100^\circ F$
- $DB = 80^\circ F$

$$WBGT = 0.7 \times (70) + 0.2 \times (100) + 0.1 \times (80) = 77^\circ F$$
### Heat Index

<table>
<thead>
<tr>
<th>Relative Humidity (%)</th>
<th>Air Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>70°  75°  80°  85°  90°  95°  100°  105°  110°</td>
</tr>
<tr>
<td>10</td>
<td>65°  70°  75°  80°  85°  90°  95°  100°  105°  110°</td>
</tr>
<tr>
<td>20</td>
<td>66°  72°  77°  82°  87°  93°  99°  105°  112°</td>
</tr>
<tr>
<td>30</td>
<td>67°  73°  78°  84°  90°  96°  104°  113°  123°</td>
</tr>
<tr>
<td>40</td>
<td>68°  74°  79°  86°  93°  101°  110°  123°  137°</td>
</tr>
<tr>
<td>50</td>
<td>70°  75°  81°  88°  96°  107°  120°  135°  150°</td>
</tr>
<tr>
<td>60</td>
<td>69°  76°  82°  90°  100°  114°  132°  149°  150°</td>
</tr>
<tr>
<td>70</td>
<td>71°  78°  86°  97°  113°  136°  144°  144°  149°</td>
</tr>
<tr>
<td>80</td>
<td>71°  79°  88°  102°  122°  144°  150°</td>
</tr>
<tr>
<td>90</td>
<td>72°  80°  91°  108°</td>
</tr>
</tbody>
</table>

### Heat Index Table

<table>
<thead>
<tr>
<th>Heat Index</th>
<th>Heat disorders possible with prolonged exposure and/or physical activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>80° – 89°</td>
<td>Fatigue</td>
</tr>
<tr>
<td>90° – 104°</td>
<td>Sunstroke, heat cramps, and heat exhaustion</td>
</tr>
<tr>
<td>105° – 129°</td>
<td>Sunstroke, heat cramps, or heat exhaustion likely and heatstroke possible</td>
</tr>
<tr>
<td>130° or higher</td>
<td>Heatstroke/sunstroke highly likely</td>
</tr>
</tbody>
</table>

**NOTE:** Direct sunshine increases the heat index by up to 15°F
How does exercise affect body temperature?

• Specific heat
  – Specific heat of the body is 0.83
  – 0.83 Calorie will raise 1 kg body mass 1° Celsius (C)
Body temperature at rest

• Increase in core temperature at rest with no heat loss
  – Resting for 60 minutes and expend 80 Calories
  – 80% of Calories are released as heat, or 64 Calories
  – 70 kg runner (154 pounds)
  – Storage of 58 Calories would ↑ body temperature by 1°C
    • Specific heat = 0.83 Calorie per kg body mass
    • 0.83 x 70 kg = 58 Calories
  – Body temperature would increase by 1.1°C (2°F) if body heat not dissipated
    • 64 Calories ÷ 58 Calories = 1.1 °C
  – Normal body temperature is 37°C (98.6°F)
  – If no heat is lost, body temperature ↑ to 38.1°C (100.6°F)
Body temperature with exercise

- Increase in core temperature with exercise and no heat loss
  - Run for 60 minutes and expend 900 calories
  - 80% of calories are released as heat, or 720 calories
  - Specific heat of the body is 0.83 Calorie per kg body mass
  - 70 kg runner (154 pounds)
  - 0.83 calories will raise 1 kg body mass 1°C
  - Storage of 58 calories would raise body temperature by 1°C

- Body temperature would increase by 12.4°C (22°F) if body heat not dissipated
  - 720 Calories ÷ 58 Calories = 12.4°C

- Normal body temperature is 37°C (98.6°F)
- If no heat is lost, body temperature ↑ to 49.4°C (120°F)
How is body heat dissipated during exercise?

• Exercise in a cool or cold environment
  – Radiation and convection
  – Some sweat and respiratory heat loss
  – Sweat loss may be high if excess clothing is worn
Body heat dissipation during exercise

• Exercise in a warm or hot environment
  – Evaporation of sweat is key factor
    • Total heat loss @ different ambient temperatures
      – 20% at 50°F
      – 45% at 68°F
      – 70% at 86°F
  – Sweat must evaporate to lose body heat
  – Maximal evaporation rate is about 30 ml/minute
  – Evaporation of 1 liter of sweat = 580 Calories
  – Sweat that drips off does not remove heat
  – Sweat rates vary among individuals
Exercise Performance in the Heat: Effect of Environmental Temperature and Fluid and Electrolyte Losses

• Compensated heat stress
  – Individuals are able to continue exercising because heat losses balance heat production and the core temperature does not increase excessively

• Uncompensated heat stress
  – Individuals are unable to continue exercising because heat production exceeds heat losses and exhaustion eventually occurs
How does environmental heat affect physical performance?

• Distance running performance impaired
  – Significant linear relationship between WBGT and decreased performance in 10-kilometer run

• Marathon running performance
  – Running times ↓ about 1 minute for every 1° C ↑ beyond 8-15° C (each 1.8° F beyond 46-59° F)
Environmental heat and exercise performance

• Possible mechanisms of fatigue
  – Central neural fatigue caused by ↑ brain temperature
  – Cardiovascular strain caused by changes in blood circulation
  – Muscle metabolism changes caused by increased muscle temperature
  – Dehydration caused by excessive sweat losses
Central neural fatigue

- Elevated brain temperature impairs central arousal of voluntary activation of muscle
- Brain may anticipate heat stress and reduce heat production accordingly, mainly by decreasing muscle contraction
Cardiovascular strain

• Increased blood flow to the skin may decrease blood flow to the muscles
• Increased lactic acid production at same exercise intensity
Muscle metabolism

• Shift of energy metabolism toward increased carbohydrate use and decreased fat use
• Muscle glycogen use is accelerated
  – Possible more rapid depletion
• Increased temperature may lead to dysfunction of muscle contraction
Dehydration

- Adverse effects in more prolonged endurance events
How do dehydration and hypohydration affect physical performance?

- Effects of hypohydration
  - Decrease in intracellular and extracellular fluid volume, particularly blood volume
    - ↓ stroke volume
    - ↓ cardiac output
  - Body heat storage increases
    - ↓ sweating rate
    - ↓ skin blood flow responses
  - Earlier onset of lactate threshold
  - Electrolyte imbalances
Voluntary Dehydration

• Wrestlers
  – Sauna
  – Diureticis
  – ↓ intake of fluids

• Results of studies on voluntary loss of 3-5% body mass on exercise performance are equivocal
  – Little to no effect on strength or power
  – Anaerobic muscular endurance tasks longer than 20-30 seconds may be impaired
    • May be decreased central drive
Involuntary Dehydration

• Prolonged aerobic endurance events
  – In cold environments
    • Dehydration of 3% has marginal influence on aerobic endurance performance
  – In heat-stress environments
    • Adverse effects of dehydration
Involuntary Dehydration
ACSM Position Stand

• Dehydration, especially in warm-hot weather, increases physiologic strain and perceived effort

• Dehydration can degrades aerobic exercise performance

• The greater the dehydration level, the greater the physiologic strain and impairment in performance

• The critical water deficit and adverse effects are related to the heat stress, exercise task, and the individuals unique biological characteristics
Figure 9.8

- Plasma volume
- Plasma osmolality
- Blood viscosity
- Central blood volume
- Filling of the heart
- Stroke volume
- Heart rate
- Cardiac output
- Skin blood flow
- Sweat rate
- Core temperature
Involuntary Dehydration

• Effects on mental/cognitive performance
  – May impair vigilance in dynamic sports environments, such as basketball
  – Progressive deterioration in basketball skills with increasing levels of dehydration from 2-4 %

• Effects on gastrointestinal distress
  – Nausea, GI cramps
How fast may an individual dehydrate while exercising?

- Sweat rates may be as high as 3-4 liters per hour, or about 6.5-9.0 pounds of water
- Most athletes lose less, about 2-3 liters per hour when exercising in the heat
- Some athletes may lose up to 10 kg (22 pounds) in multiple daily workouts
- Males sweat almost twice as much as females
- Children may sweat somewhat less than adults
- Sweat losses may be highly individualistic
Fluid Losses during Exercise

• **Factors that influence sweat rate**
  
  – **Environment**
    • Air temperature
    • Relative humidity
    • Radiant heat (solar and ground)
    • Wind
    • Clothing worn
  
  – **Individual characteristics**
    • Body weight
    • Genetic predisposition
    • Metabolic efficiency
    • Heat acclimatization state
    • Wide individual variability
How can I determine my sweat rate?

• Body weight may be a simple and effective measure of hydration status
  – Weigh yourself nude in the morning after urinating
  – Obtain 3-4 consecutive morning nude weights to establish a baseline
  – Women may need more measurements due to fluctuations of body weight associated with the menstrual cycle
  – Body weight should be stable and not vary by more than 1%
### How can I determine my sweat rate?

<table>
<thead>
<tr>
<th></th>
<th>Athlete A (metric)</th>
<th>Athlete B (English)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Body weight before exercise</td>
<td>70.5 kg</td>
<td>180 lbs</td>
</tr>
<tr>
<td>b. Body weight after exercise</td>
<td>68.9 kg</td>
<td>174 lbs</td>
</tr>
<tr>
<td>c. Change in body weight</td>
<td>-1.6 kg (1600 g)</td>
<td>- 6 lbs (96 oz)</td>
</tr>
<tr>
<td>d. Drink volume</td>
<td>300 ml</td>
<td>16 oz</td>
</tr>
<tr>
<td>e. Urine volume</td>
<td>-100 ml</td>
<td>0 oz</td>
</tr>
<tr>
<td>f. Sweat loss (c + d – e)</td>
<td>1800 ml</td>
<td>112 oz</td>
</tr>
<tr>
<td>g. Exercise time</td>
<td>60 min</td>
<td>90 min</td>
</tr>
<tr>
<td>h. Sweat rate (f ÷ g)</td>
<td>30 ml/min</td>
<td>1.25 oz/min</td>
</tr>
</tbody>
</table>
What is the composition of sweat?

• Sweat from the eccrine sweat glands
  – Mostly water (99%)
  – Major electrolytes
    • Sodium, chloride, potassium
    • Sodium chloride (average about 2.6 g/L (45 mEq)
      – 58 mg = 1 mEq
  – Hypotonic to body fluids
  – Other nutrients
    • Calcium, iron, copper, zinc
    • Small quantities of amino acids, water-soluble vitamins
  – Sweat composition may vary after acclimatization
Is excessive sweating likely to create an electrolyte deficiency?

• During exercise
  – Serum electrolyte concentration normally increases during exercise as sweat is hypotonic to the blood
  – Serum electrolyte imbalances may occur with improper fluid replacement

• During recovery
  – Electrolyte losses should be replaced on a daily basis or a deficiency will occur over time
Exercise in the Heat: Fluid, Carbohydrate, and Electrolyte Replacement

- Evolution of Fluid Replacement Guidelines
- American College of Sports Medicine
Which is more important to replace during exercise in the heat—water, carbohydrate, or electrolytes?

• Water
  – Prevent or delay dehydration

• Carbohydrate
  – Provide energy

• Electrolytes
  – Prevent heat illness
Sports Drinks

• Contents
  – Fluid
  – Carbohydrate
  – Electrolytes
  – Other substances
  – Vitamins; minerals; caffeine; herbals

• Carbohydrate-Electrolyte solutions
  – Gatorade; PowerAde; All-Sport; Accelerade
<table>
<thead>
<tr>
<th>Beverage</th>
<th>Carbohydrate ingredient</th>
<th>Carbohydrate (% concentration)</th>
<th>(grams)</th>
<th>Sodium (mg)</th>
<th>Potassium (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatorade Thirst Quencher (Gatorade Company)</td>
<td>Sucrose, Glucose, Fructose</td>
<td>6</td>
<td>14</td>
<td>110</td>
<td>30</td>
</tr>
<tr>
<td>Gatorade Endurance Formula</td>
<td>Sucrose, Glucose, Fructose</td>
<td>6</td>
<td>14</td>
<td>200</td>
<td>90</td>
</tr>
<tr>
<td>Accelerade (Pacific Health Laboratories)</td>
<td>Sucrose, Trehalose (disaccharide)</td>
<td>6</td>
<td>15</td>
<td>120</td>
<td>15</td>
</tr>
<tr>
<td>PowerAde (The Coca-Cola Company)</td>
<td>High-fructose corn syrup</td>
<td>8</td>
<td>19</td>
<td>55</td>
<td>30</td>
</tr>
<tr>
<td>Lucozade Sport (GlaxoSmithKline)</td>
<td>Glucose; Maltodextrin</td>
<td>6</td>
<td>15</td>
<td>Trace</td>
<td>Trace</td>
</tr>
<tr>
<td>All Sport (Monarch Beverages)</td>
<td>High-fructose corn syrup</td>
<td>8</td>
<td>20</td>
<td>80</td>
<td>50</td>
</tr>
<tr>
<td>Ultima (Ultima Replenisher)</td>
<td>Maltodextrin</td>
<td>1.5</td>
<td>3</td>
<td>37</td>
<td>100</td>
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<tr>
<td>(Cytosport) Cytomax Performance Drink</td>
<td>alpha-L-polylactate</td>
<td>9</td>
<td>22</td>
<td>120</td>
<td>60</td>
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<tr>
<td>Coca-Cola</td>
<td>High-fructose corn syrup, Sucrose</td>
<td>11</td>
<td>26</td>
<td>9.2</td>
<td>Trace</td>
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<tr>
<td>Diet Soft Drinks</td>
<td>None</td>
<td>0</td>
<td>0</td>
<td>0–25</td>
<td>Low</td>
</tr>
<tr>
<td>Orange Juice</td>
<td>Fructose, Sucrose</td>
<td>11</td>
<td>26</td>
<td>2.7</td>
<td>510</td>
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<tr>
<td>Water</td>
<td>None</td>
<td>0</td>
<td>0</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Gatorade Energy Drink (Gatorade Company)</td>
<td>Maltodextrin, Glucose, Fructose</td>
<td>23</td>
<td>53</td>
<td>133</td>
<td>70</td>
</tr>
</tbody>
</table>
What are some sound guidelines for maintaining water balance during exercise?

• **Benefits of proper hydration**
  – Decrease fluid loss
  – Reduce cardiovascular strain
  – Enhance performance
  – Prevent some heat illnesses

• **Techniques**
  – Skin wetting
  – Hyperhydration
  – Rehydration
Skin wetting

• Effects are equivocal
  – Possible beneficial effects
    • May decrease sweat loss
    • Psychological relief
  – No effects
    • Core temperature
    • Cardiovascular responses
    • May encourage faster pace, more heat production
Hyperhydration

• Possible beneficial effects
  – Help maintain temperature regulation and cardiovascular functions when fluids may not be ingested during exercise

• No effects
  – Little evidence of beneficial effects in comparison to euhydration

• ACSM recommends hyperhydration

• Glycerol hyperhydration covered later
Rehydration

• The most effective technique
• May have small benefits to performance in weight-control sports, such as wrestling
  – Local muscular endurance
• Benefits to endurance athletes
  – Minimize ↑ in core temperature
  – Minimize ↓ in blood volume
  – Maintain optimal race pace for longer time
• ACSM position stand focuses on rehydration
What factors influence gastric emptying and intestinal absorption?

- Ingested fluids may appear in plasma and sweat within 10-20 minutes

- Influenced by
  - Gastric emptying
  - Intestinal absorption
Factors influencing gastric emptying

• **Volume of fluid**
  – Larger volumes (up to 700 ml) empty more rapidly

• **Solute or caloric density**
  – A 6% to 8% solution appears optimal

• **Osmolality**
  – Lower osmolality may empty faster

• **Drink temperature**
  – Cold beverages empty rapidly
Factors influencing gastric emptying

• **Exercise intensity**
  – Moderate-intensity facilitates emptying, whereas high intensity (> 75%) may decrease emptying

• **Mode of exercise**
  – Little difference between running and cycling

• **Dehydration**
  – Excessive dehydration (> 3%) may decrease emptying
Factors influencing intestinal absorption

• Water absorbed rapidly by passive diffusion
• Glucose-sodium co-transport
  – Glucose helps pull water in
  – Adequate sodium in the intestines
• Problem of reverse transport of fluids
  – The Dumping Syndrome
    • Abdominal cramping and diarrhea
• Multiple carbohydrate receptors
  – Use variety of monosaccharides and disaccharides
• Individual differences
Figure 9.10

Hypotonic GES in lumen of small intestine

Circulation (dehydrated blood)

Normal osmotic flow of water

H₂O

H₂O

Glucose–sodium co-transport facilitates osmotic flow of water to circulation

(a)

Hypertonic concentrated sugar solution in lumen of small intestine

Circulation

Reverse osmotic flow

H₂O

H₂O

Glucose–sodium transport

(b)
How should carbohydrate be replaced during exercise in the heat?

• Goal is to consume carbohydrate without impairing water absorption

• Both water and carbohydrate intake during exercise may enhance performance, but the combination is more effective than either alone

• Recommendations for sports drinks
  – 6-10% solutions
    • Some athletes may experiment with higher concentrations
  – Multiple sources of carbohydrate
  – Amount provided may range from 1.0-1.7 grams/minute
<table>
<thead>
<tr>
<th>Percent concentration</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
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<tr>
<td>2%</td>
<td>1,500</td>
<td>2,000</td>
<td>2,500</td>
<td>3,000</td>
<td>3,500</td>
<td>4,000</td>
<td>4,500</td>
<td>5,000</td>
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<tr>
<td>4%</td>
<td>750</td>
<td>1,000</td>
<td>1,250</td>
<td>1,500</td>
<td>1,750</td>
<td>2,000</td>
<td>2,250</td>
<td>2,500</td>
</tr>
<tr>
<td>6%</td>
<td>500</td>
<td>666</td>
<td>833</td>
<td>1,000</td>
<td>1,166</td>
<td>1,333</td>
<td>1,500</td>
<td>1,666</td>
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<tr>
<td>8%</td>
<td>375</td>
<td>500</td>
<td>625</td>
<td>750</td>
<td>875</td>
<td>1,000</td>
<td>1,125</td>
<td>1,250</td>
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<td>10%</td>
<td>300</td>
<td>400</td>
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<td>600</td>
<td>700</td>
<td>800</td>
<td>900</td>
<td>1,000</td>
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<tr>
<td>12%</td>
<td>250</td>
<td>333</td>
<td>417</td>
<td>500</td>
<td>583</td>
<td>667</td>
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<td>15%</td>
<td>225</td>
<td>300</td>
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<td>20%</td>
<td>150</td>
<td>200</td>
<td>250</td>
<td>300</td>
<td>350</td>
<td>400</td>
<td>450</td>
<td>500</td>
</tr>
</tbody>
</table>
How should electrolytes be replaced during or following exercise?

• During exercise
  – Not needed during moderately prolonged exercise
  – May be helpful in ultraendurance events

• Daily replacement
  – Normal diet will help maintain electrolyte levels
  – Adding salt to meals may help when sweat losses are high
What is hyponatremia and what causes it during exercise?

• Fall in plasma sodium

• ↓ Serum Na (<135 mmol/L)
  – Mild (130-134 mmol/L)
  – Moderate (< 130 mmol/L)
  – Severe (<120 mmol/L)

• Hyponatremia associated with prolonged endurance exercise tasks is known as Exercise-Associated Hyponatremia (EAH)
Hyponatremia

• Signs and symptoms
  – Mild to moderate
    • Bloating
    • Puffiness of hands and feet
    • Nausea
    • Vomiting
    • Headache
  – Severe
    • Brain swelling and seizures
    • Coma
    • Respiratory arrest
    • Permanent brain damage or death
Exercise-Associated Hyponatremia (EAH)

- Hyponatremia could be fatal
  - Cerebral edema with seizure and possible coma and death

- Hyponatremia has been associated with the deaths of several female runners in major marathons, such as Boston and Houston
Exercise-Associated Hyponatremia

• Individuals at risk
  – Excessive drinking of fluids before, during and after the race
  – Considerable weight gain over the course of the event
  – Slower runners, endurance athletes > 4 hours
  – Females
  – Low body weight
  – Individuals with high sweat sodium losses
  – Heat-unacclimatized individuals
  – Individuals with inadequate sodium intake
  – Individuals who use NSAIDS
Exercise-associated hyponatremia

• Prevention
  – Do not consume fluids in excess before, during, or after exercise
  – Consume extra salt in days before prolonged exercise
  – Body weight should not increase during exercise
  – Consume sports drinks with increased sodium content
    • Gatorade Endurance Formula (35 mEq Na)
    • Typical sports drink = 20 mEq Na

• Treatment
  – Prompt medical attention is essential
Are salt tablets or potassium supplements necessary?

• In general, no. However, increased salt intake may be recommended during acclimatization to exercise in the heat
  – Some recommend about 4-10 grams of sodium, or 10-25 grams of salt (2-5 teaspoons)
  – One recommendation: Take salt tablets if water intake exceeds 4 quarts daily associated with sweat losses
    • Average salt tablet contains 0.5 gram of sodium
    • Take two tablets with each quart of water

• Potassium supplements are not recommended
  – Sweat losses are small
  – Excess may be dangerous
What are some prudent guidelines relative to fluid replacement while exercising under warm or hot environmental conditions?

- Before competition and practice
- During competition and practice
- After competition and practice
- In training

American College of Sports Medicine Position Stand
Exercise and Fluid Replacement
www.mhhe.com/williams
Fluids and Electrolytes in Training and Competition

- Exercising in warm or hot environmental conditions imposes additional stress on temperature regulation.
- Proper hydration is probably the most important nutritional strategy an athlete can use in training and competition.

Main reference source:
### TABLE 9.7 Fluid intake guidelines before, during, and after exercise in warm or hot environmental conditions

**Before competition and practice**
The goal of the ACSM guidelines is to start in a state of euhydration with normal plasma electrolyte levels.

- Drink slowly about 5–7 milliliters/kilogram (0.08–0.11 ounce/pound) body weight at least 4 hours prior to exercise. For an athlete weighing 70 kg (154 pounds), this would approximate 350–490 milliliters, or 12–17 ounces of fluids. Athletes weighing more or less will drink accordingly.
- Drink another 3–5 ml/kg body weight about 2 hours prior to exercise if no urine is produced or the urine is dark or highly concentrated. Your urine should be a clear pale yellow before competition or practice.
- Drink water. However, carbohydrate-electrolyte solutions (CES) also may be used if preferred.
- Drink beverages with carbohydrate (6–8 percent) to help increase body stores of glucose and glycogen for use in prolonged exercise bouts.
- Drink beverages with sodium (20–50 mEq/L) and/or salty foods or snacks to help increase body stores of sodium and water for prolonged exercise.
- Do not drink excessively, which may increase the risk of dilutional hyponatremia if fluids are aggressively replaced during and after exercise.
During competition and practice
The goal of the ACSM guidelines is to prevent excessive dehydration (> 2% body weight loss from water deficit).

- Determine your sweat loss for a given intensity and duration of exercise in the heat. This will provide you with an estimate for fluid intake during exercise. A procedure is presented on page 369.
- Drink about 0.4 to 0.8 liters of fluids per hour, which is about 14 to 28 ounces. Smaller athletes may consume 14 ounces or about 3–4 ounces every 15 minutes. Larger athletes my consume 28 ounces, or about 7 ounces every 15 minutes. However, the fluids may be consumed at your pleasure, or ad libitum, on other time schedules as conditions permit. Athletes can adjust the amounts according to personal needs.
- Drink cold water when carbohydrate intake is of little or no concern, such as in endurance events less than 50–60 minutes. CES may be consumed during such events if preferred, but provide no advantages over water alone.
- Drink fluids with carbohydrates for longer duration events.
  - Select a CES with a 6–8 percent concentration.
  - Use a CES containing multiple sources of carbohydrate, including glucose, sucrose, fructose, and maltodextrins.
  - Consume enough fluid to provide about 30–80 grams of carbohydrate per hour. One ounce of a CES provides about 2 grams of carbohydrate.
  - Use sports gels or sports beans to provide additional carbohydrate if the necessary fluid intake would be unreasonable. Sports gels and beans may provide about 25–30 grams of carbohydrate per serving.
  - Drink fluids with small amounts of electrolytes, particularly sodium and potassium. Many CES contain about 20–30 mEq of sodium and 2–5 mEq of potassium, which amounts to about 110–160 grams of sodium and 19–45 grams of potassium in an 8-ounce serving.
After competition and practice
The goal of the ACSM guidelines is to fully replace any fluid and electrolyte deficit.

- Rapid replacement
- Drink 1.5 liter of fluid for every kilogram of body weight loss, or about 1.5 pints for each pound loss.
- Consume about 1.0 to 1.5 grams of carbohydrate per kilogram body weight (about 0.5 to 0.7 grams per pound body weight) each hour for 3–4 hours. For a 60-kg athlete, this would represent about 60–90 grams of carbohydrate per hour.
- Consume adequate sodium. Salty carbohydrate snacks, such as pretzels, may provide both sodium and carbohydrate.
- Leisurely replacement (24-hour recovery).
- Eat a diet rich in wholesome, natural foods adhering to healthy eating practices to help replenish needed electrolytes.
- Extra salt may be added to meals when sodium losses are high.
- Drink fluids with added sodium or with salty foods or snacks.
ACSM Fluid Replacement Guidelines Relative to Hyperhydration before Exercise

- Goal is to start being euhydrated with normal plasma electrolyte levels
- Drink slowly about 5-7 ml/kg body weight at least 4 hours prior to exercise (70 kg, 154 lbs: 350-500 ml or 10-17 oz)
- If no urine is produced, or urine is dark or highly concentrated, drink another 3-5 ml/kg body weight about 2 hours prior to exercise
- Beverages with sodium (20-50 mEq/L and/or salty foods or snacks will help stimulate thirst and retain fluids. Fluid palatability (temperature, sodium, flavoring) will enhance fluid intake
- Do not excessively overhydrate, which may increase the risk of dilutional hyponatremia if fluids are aggressively replaced during exercise
ACSM Fluid Replacement Guidelines Relative to Fluid Replacement during Exercise or Competition

- Cold water is effective when carbohydrate intake is of little or no concern, for example, in endurance events less than 50-60 minutes.

- Sports drinks with 6-8% carbohydrates and normal electrolyte content may also be consumed, but provide no advantages over water alone.
ACSM Fluid Replacement Guidelines Relative to Fluid Replacement during Exercise or Competition

• Composition of the fluid is considered important for prolonged endurance events
  – Contain about 20-30 mEq sodium
  – Contain about 2-5 mEq potassium
  – Contain about 6-10 % carbohydrate

• These components may be in the drink or nonfluid sources such as gels or energy bars

• Sodium and potassium help replace lost electrolytes

• Carbohydrate provides energy
ACSM Fluid Replacement Guidelines Relative to Fluid Replacement during Exercise or Competition

- Goal is to prevent excessive dehydration (> 2% body weight loss from water deficit)
- Amount and rate of fluid replacement depends on individual sweating rate, exercise duration, and opportunities to rehydrate
- Individuals should monitor body weight changes during training/competition sessions to estimate fluid losses during a particular exercise task
- Possible starting point for marathon runners is to drink *ad libitum* 0.4-0.8 liter of fluids per hour. Smaller runners at 0.4 liter and bigger runners at 0.8 liter.
ACSM Fluid Replacement Guidelines Relative to Fluid Replacement after Exercise or Competition

• Goal is to fully replace any fluid and electrolyte deficit
  – If time is short to next exercise session, aggressive rehydration is important
    • Drink 1.5 liter of fluid for every kilogram of body weight loss
    • Additional fluid is needed to compensate for increased urine output
    • Consume adequate electrolytes as well
    • Pretzels/other salty snacks may provide sodium and carbohydrate
  – If recovery time permits (24 hours), normal meal and water intake will restore euhydration provided sodium intake is adequate

• Sodium replacement is important
  – Drink fluids with added sodium or with salty foods or snacks
  – Many foods can supply the needed electrolytes
  – Extra salt may be added to meals when sodium losses are high
    • Check for dried salt on skin and clothing
Sports Drinks

• Contents
  – Water
    • To help prevent dehydration
  – Electrolytes
    • To help maintain fluid balance
  – Carbohydrate
    • To provide energy
  – Other substances (vitamins, minerals, caffeine)
    • Provide essential nutrients;
    • Substances theorized to enhance performance

• Most sports drinks are hypotonic compared to sweat
  – Excessive intake of sports drinks may dilute serum sodium concentrations, predisposing to hyponatremia
## Sports Drinks and Other Fluids

<table>
<thead>
<tr>
<th>Beverage</th>
<th>Carbohydrate (% and grams)</th>
<th>Sodium (milligrams)</th>
<th>Potassium (milligrams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatorade</td>
<td>6%; 14 g</td>
<td>110 (20 mEq)</td>
<td>25 (~3 mEq)</td>
</tr>
<tr>
<td>Gatorade Endurance Formula</td>
<td>6%; 14 g</td>
<td>200</td>
<td>90</td>
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<tr>
<td>Accelerade</td>
<td>7%; 17 g</td>
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<tr>
<td>Powerade</td>
<td>8%; 19 g</td>
<td>55</td>
<td>30</td>
</tr>
<tr>
<td>Ultima</td>
<td>1.7%; 4 g</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Coca-Cola</td>
<td>11%; 26 g</td>
<td>9</td>
<td>Trace</td>
</tr>
<tr>
<td>Orange juice</td>
<td>11%; 26 g</td>
<td>3</td>
<td>510</td>
</tr>
<tr>
<td>Gatorade Energy Drink</td>
<td>23%; 53 g</td>
<td>133</td>
<td>70</td>
</tr>
</tbody>
</table>
Electrolytes in Sports Drinks

• Drinking solutions with 30 mEq (690 mg/liter; 165 mg/8 oz) of sodium before and during marathons > 4 hours duration may help minimize hyponatremia in females

• Sodium
  – 1 milliequivalent mEq = 23 mg/liter
  – 20 mEq = 460 mg/liter
  – 240 ml (8 oz) of 20 mEq drink contains 110 mg

• Potassium
  – 1 milliequivalent mEq = 39 mg/liter
  – 20 mEq = 780 mg/liter
  – 240 ml (8 oz) of 20 mEq drink contains 187 mg
Sports Drinks
Carbohydrate/Electrolyte Solutions (CES)

• A qualitative review of studies evaluating commercially available sports drinks containing low carbohydrate concentrations (<10%) came to the following conclusion

  – In studies where a practical protocol has been used along with a currently available sports beverage, there is evidence to suggest that consuming a sports drink will improve performance compared with consuming a placebo beverage.
<table>
<thead>
<tr>
<th>Beverage</th>
<th>Carbohydrate ingredient</th>
<th>Carbohydrate (% concentration)</th>
<th>(grams)</th>
<th>Sodium (mg)</th>
<th>Potassium (mg)</th>
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</thead>
<tbody>
<tr>
<td>Gatorade Thirst Quencher (Gatorade Company)</td>
<td>Sucrose, Glucose, Fructose</td>
<td>6</td>
<td>14</td>
<td>110</td>
<td>30</td>
</tr>
<tr>
<td>Gatorade Endurance Formula</td>
<td>Sucrose, Glucose, Fructose</td>
<td>6</td>
<td>14</td>
<td>200</td>
<td>90</td>
</tr>
<tr>
<td>Accelerade (Pacific Health Laboratories)</td>
<td>Sucrose, Trehalose (disaccharide)</td>
<td>6</td>
<td>15</td>
<td>120</td>
<td>15</td>
</tr>
<tr>
<td>PowerAde (The Coca-Cola Company)</td>
<td>High-fructose corn syrup</td>
<td>8</td>
<td>19</td>
<td>55</td>
<td>30</td>
</tr>
<tr>
<td>Lucozade Sport (GlaxoSmithKline)</td>
<td>Glucose; Maltodextrin</td>
<td>6</td>
<td>15</td>
<td>Trace</td>
<td>Trace</td>
</tr>
<tr>
<td>All Sport (Monarch Beverages)</td>
<td>High-fructose corn syrup</td>
<td>8</td>
<td>20</td>
<td>80</td>
<td>50</td>
</tr>
<tr>
<td>Ultima (Ultima Replenisher)</td>
<td>Maltodextrin</td>
<td>1.5</td>
<td>3</td>
<td>37</td>
<td>100</td>
</tr>
<tr>
<td>(Cytosport) Cytomax Performance Drink</td>
<td>alpha-L-poly lactate</td>
<td>9</td>
<td>22</td>
<td>120</td>
<td>60</td>
</tr>
<tr>
<td>Coca-Cola</td>
<td>High-fructose corn syrup, Sucrose</td>
<td>11</td>
<td>26</td>
<td>9.2</td>
<td>Trace</td>
</tr>
<tr>
<td>Diet Soft Drinks</td>
<td>None</td>
<td>0</td>
<td>0</td>
<td>0–25</td>
<td>Low</td>
</tr>
<tr>
<td>Orange Juice</td>
<td>Fructose, Sucrose</td>
<td>11</td>
<td>26</td>
<td>2.7</td>
<td>510</td>
</tr>
<tr>
<td>Water</td>
<td>None</td>
<td>0</td>
<td>0</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Gatorade Energy Drink (Gatorade Company)</td>
<td>Maltodextrin, Glucose, Fructose</td>
<td>23</td>
<td>53</td>
<td>133</td>
<td>70</td>
</tr>
</tbody>
</table>
Practice Fluid Intake during Training

• Practice consuming fluids while you train
• Determine your rate of sweat loss to individualize your fluid replacement plan
• Use a trial and error approach to see what works with you
  – Timing and amounts before exercise
  – Amounts consumed during exercise
  – Concentration of carbohydrates
  – Concentration of sodium
  – Carrying your own fluids
  – Experiment with brand to be used in race
Ergogenic Aspects

- Hypohydration
- Oxygen water
- Pre-cooling techniques
- Sodium loading
- Glycerol supplementation
- Sodium bicarbonate
Hypohydration

- Decrease body mass
- Force = Mass $\times$ Acceleration
- Acceleration = Force $\div$ Mass
- Decreasing body mass without loss in force will ↑ acceleration
Oxygen water

- **Theory**
  - Increase oxygen delivery to muscles

- **Marketed as** *performance water*

- **Research reports**
  - Oxygen in bottled water would last 2 seconds
  - Questionable whether $O_2$ is absorbed into bloodstream
  - No effect on oxygen consumption during exercise
  - No effect on exercise performance in hypoxic conditions
Pre-cooling techniques

• Theory
  – Decrease skin blood flow and increase central blood flow
  – Decrease core body temperature as a buffer to delay increase in body temperature
  – Athlete can generate more work before critical body temperature is reached

• Research findings from several studies
  – Lower core temperature during exercise in the heat
  – Improved running performance in the heat

• American and Australian athletes used cooling vests in the 2004 Olympic games in Athens
Sodium loading

• Theory
  – Consume high sodium beverage before exercise
  – Sodium is one of the main determinants of blood volume
  – ↑ blood volume could ↑ oxygen delivery

• Research findings from several studies
  – ↑ plasma volume
  – ↓ ratings of perceived exertion
  – ↓ thermoregulatory strain
  – ↑ exercise time to exhaustion in warm conditions

• Additional research recommended
Glycerol supplementation

- **Theory**
  - Glycerol ingestion may increase osmotic pressure, helping retain more body fluids and increasing blood volume
  - General procedure is to consume
    - 1 gram of glycerol
    - along with 20-25 milliliter of water
    - for each kilogram body weight
  - Glycerol hyperhydration is theorized to improve temperature regulation and performance while exercising in warm or hot environmental conditions
Glycerol and hyperhydration

• Hyperhydration before exercise
  – Consuming fluids
  – Glycerol

• The ACSM indicates that hyperhydration does not provide any thermoregulatory advantages, but can delay the onset of dehydration, which may account for small performance benefits occasionally reported.
Glycerol supplementation

- Glycerol-containing products have been marketed to both endurance and strength athletes
Glycerol Hyperhydration

• Research studies and reviews are equivocal
  – Body-water levels,
  – Temperature regulation
  – Endurance exercise performance

• Supportive studies have shown beneficial effects during exercise
  – Body water content
  – Reducing thermal stress
  – Increased plasma volume
  – Decreased heart rate
  – Enhanced cycling endurance

• Nonsupportive studies reported no beneficial effects compared to water hyperhydration alone
Glycerol supplementation

• Caveats
  – Excess glycerol may cause
    • Excess fluid in intracellular spaces and tissue damage
    • Predisposition to hyponatremia
    • Nausea, vomiting, headaches
  – Glycerol may be ergolytic
    • Extra body weight in running
Glycerol Hyperhydration

  - Several elite U.S. marathon runners used glycerol in some of their best marathons run in the heat
Health Aspects: Heat Illness

American College of Sports Medicine
Position Stand on Exertional Heat Illness during training and competition.

www.acsm.msse.org

Click on Position Stands and then on this position stand.
Should I exercise in the heat?

- A high heat index poses one of the most significant health risks to the exercising individual
- Check your local weather for the heat index

www.weather.com
# ACSM Guidelines to help prevent heat illnesses

## Table 9.8: American College of Sports Medicine guidelines for modifying or canceling competition or training to help prevent heat illness

<table>
<thead>
<tr>
<th>WBGT [°F (°C)]</th>
<th>Continuous activity and competition</th>
<th>Training and noncontinuous activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;50–65 (10–18.3)</td>
<td><strong>Generally safe</strong></td>
<td><strong>Normal activity</strong></td>
</tr>
</tbody>
</table>
| 65.1–72.0 (18.4–22.2) | Risk of heat illness begins to rise; *High-risk*: Should be monitored or not compete | *Low-risk*: Normal activity  
 *High-risk*: Increase rest:exercise ratio and monitor fluid intake |
| 72.1–78.0 (22.3–25.6) | Risk for all competitors is increased | *Low-risk*: Normal activity and monitor fluid intake  
 *High-risk*: Increase the rest:exercise ratio and decrease total duration of activity |
| 78.1–82.0 (25.7–27.8) | *High-risk*: Risk is high            | *Low-risk*: Normal activity and monitor fluid intake  
 *High-risk*: Increase the rest:exercise ratio and decrease intensity and total duration of activity |
| 82.1–86.0 (27.9–30.0) | Cancel for those at risk of exertional heat stroke | *Low-risk*: Plan intense or prolonged exercise with discretion*  
 *High-risk*: Increase the rest:exercise ratio to 1:1 and decrease intensity and total duration of activity* |
| 86.1–90.0 (30.1–32.2) |                                        | *Low-risk*: Limit intense exercise and total daily exposure to heat and humidity  
 *High-risk*: Cancel or stop practice and competition |
| >90 (>32.3)          | Cancel exercise when uncompensable heat stress exists for all athletes* |
What are some of the potential health hazards of excessive heat stress imposed on the body?
Heat syncope

• Fainting
  – Also known as *exercise-associated collapse*

• Caused by excessive vasodilation and decreased relative blood volume
  – Venous return ↓ and cardiac output then ↓
  – Blood flow to brain is decreased

• Prevention
  – Cool down after exercise; maintain venous return from legs

• Recovery is usually rapid
Heat cramps

• Exercise-associated muscle cramps
  – May occur at any temperature, but more common in hot, humid conditions

• Theories:
  – Cause still remains a mystery
  – Fatigue and abnormal spinal control of motor neurons
  – Salt losses
    • Oral or intravenous saline can stop cramping

• Prevention
  – Consume salt solutions at first sign of muscle twitches
  – EnduroLyte; GatorLYTES
Heat exhaustion

• Causes
  – Dehydration
  – Inadequate salt replacement

• Symptoms
  – Fatigue and weakness
  – Rapid pulse
  – Headache, nausea, vomiting, chills
  – Rectal temperature < 104° F

• Generally resolves with rest and fluids
Heat stroke

• Exertional heat stroke
• Cause by interaction of various factors
  – Hot environment
  – Strenuous exercise
  – Clothing that limits evaporation of sweat
  – Inadequate heat acclimitization
  – Too much body fat
  – Lack of fitness
Heat stroke

• Most dangerous of heat illnesses
• Symptoms
  – Confusion
  – Disorientation
  – Aggressiveness
  – Convulsions
  – Rectal temperature > 104°F
• May be fatal
What are the symptoms and treatment of heat injuries?

<table>
<thead>
<tr>
<th>Heat injury</th>
<th>Causes</th>
<th>Clinical findings</th>
<th>Treatment*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat syncope (Exercise-associated collapse)</td>
<td>Excessive vasodilation: pooling of blood in the skin</td>
<td>Fainting, Weakness, Fatigue</td>
<td>Place on back in cool environment; give cool fluids</td>
</tr>
<tr>
<td>Heat cramps</td>
<td>Excessive loss of electrolytes in sweat; inadequate salt intake</td>
<td>Muscle cramps</td>
<td>Rest in cool environment; oral ingestion of salt drinks; salt foods daily; medical treatment in severe cases</td>
</tr>
<tr>
<td>Heat exhaustion</td>
<td>Excessive loss of water and salt; inadequate fluid and salt intake</td>
<td>Fatigue, Nausea, Cool, pale, moist skin, Weakness, Dizziness, Chills, Rectal temperature lower than 104°F (40.5°C)</td>
<td>Rest in cool environment; replace fluids and salt by mouth; medical treatment if serious</td>
</tr>
<tr>
<td>Heat stroke (Exercise-associated heat stroke)</td>
<td>Excessive body temperature</td>
<td>Headache, Confusion, Blank stare, Disorientation, Unconsciousness, Rectal temperature greater than 104°F (40.5°C)</td>
<td>Cool body immediately to 102°F (38.9°C), preferably with cold-water immersion; if not, cool body areas with ice packs, ice, or cold water; give cool drinks with glucose if conscious; administer intravenous fluids if available; get medical help immediately</td>
</tr>
<tr>
<td>Hyponatremia (Exercise-associated hyponatremia)</td>
<td>Excessive fluid intake</td>
<td>Confusion, Lethargy, Agitation, Coma</td>
<td>**Need to determine by serum sodium level lower than 135 mmol/L</td>
</tr>
</tbody>
</table>
Do some individuals have problems tolerating exercise in the heat?

• Predisposing factors associated with heat injury
  – Poor physical fitness
  – Obesity
  – Previous heat illness
  – Not heat acclimated
Exercise in the heat

• Gender
  – Women sweat less
    • May be advantageous in hot, humid conditions
    • May be disadvantageous in hot, dry conditions
  – Menstrual cycle has little effect on exercise tolerance in the heat
  – Do not appear to be any differences if matched for fitness level and degree of acclimatization
Exercise in the heat

• Age: Compared to adults children
  – May produce more metabolic heat in comparison to their body size
  – Do not have as great a sweating capacity
  – Have a reduced capacity to transfer heat to the skin
  – Acclimate at a much slower rate

• Some guidelines are presented by the American Academy of Pediatrics Committee on Sports Medicine and Fitness to modify practice sessions for exercising children
<table>
<thead>
<tr>
<th>WBGT (°F)</th>
<th>WBGT (°C)</th>
<th>Restraints on activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 75.0</td>
<td>&lt; 24.0</td>
<td>All activities allowed, but watch for symptoms of heat illnesses in prolonged events</td>
</tr>
<tr>
<td>75.0–78.6</td>
<td>24.0–25.9</td>
<td>Have longer rest periods in the shade; enforce fluid intake every 15 minutes</td>
</tr>
<tr>
<td>79.0–84.0</td>
<td>26.0–29.0</td>
<td>Stop activity for unacclimatized and high-risk children; limit activities of others; cancel long-distance races and cut the duration of other activities</td>
</tr>
<tr>
<td>&gt;85.0</td>
<td>&gt;29.0</td>
<td>Cancel all athletic activities</td>
</tr>
</tbody>
</table>
How can I reduce the hazards associated with exercise in a hot environment?

1. Check temperature and humidity; slow pace
2. Exercise in the cool of the day
3. Exercise in the shade if possible
4. Wear sports clothing designed for the heat
5. Run with wind first, against wind later
6. Drink cold fluids periodically
7. Replenish your water daily; weigh yourself
8. Hyperhydrate before prolonged exercise
9. Replenish lost electrolytes (sodium, potassium)
10. Avoid excess dietary protein intake
11. Avoid ephedrine
12. Check your responses to caffeine
13. Avoid alcohol
14. Use caution if overweight, sedentary, aged
15. Know signs and symptoms of heat illnesses
16. Do not exercise if ill or with fever
17. Check your medications; some may impair skin blood flow
18. Acclimatize yourself to exercise in the heat
How can I become acclimatized to exercise in the heat?

- Living in a hot environment confers a small degree of acclimitization
- Physical activity itself confers a significant amount of acclimitization
- To obtain full acclimitization one must exercise in the heat
Acclimitization to exercise in the heat

• Cut back on the intensity and/or duration of your normal exercise routine when ambient temperatures increase

• Gradually increase the intensity and duration of exercise

• Full acclimitization takes about 10-14 days, but longer in children
Heat acclimitization

• Favorable adaptations
  – ↑ total body water and blood volume
    • ↑ sodium and protein
  – ↑ cardiac output to muscles and skin
  – ↑ size of sweat glands and ↑ sweat rate
  – ↑ sweating at a lower core temperature
  – ↓ muscle glycogen usage
  – ↓ loss of body salt and sodium
  – ↓ in rate of core temperature increase
  – ↓ psychological feeling of stress
What is high blood pressure, or hypertension?
High blood pressure

- Systolic: Blood pressure during heart contraction
- Diastolic: Blood pressure at rest

<table>
<thead>
<tr>
<th>Category</th>
<th>Systolic (mmHg)</th>
<th>Diastolic (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt;120</td>
<td>&lt;80</td>
</tr>
<tr>
<td>Pre-hypertension</td>
<td>120–139</td>
<td>80–89</td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 1</td>
<td>140–159</td>
<td>90–99</td>
</tr>
<tr>
<td>Stage 2</td>
<td>&gt;160</td>
<td>&gt;100</td>
</tr>
</tbody>
</table>

Source: National Heart, Lung, and Blood Institute.
High blood pressure

• Major determinants
  – Blood volume
  – Resistance to blood flow

• The silent disease
  – About 1 in 5 Americans have hypertension
  – 2 million youth
  – One-third do not know they are hypertensive
  – A disease by itself
  – Major risk factor for CHD and stroke

• Cause unknown in 90% of cases
  – Essential hypertension
How is high blood pressure treated?

• Essential hypertension is incurable
• Drugs to control hypertension
  – Diuretics (may impair exercise performance)
  – Beta-blockers (may impair exercise performance)
  – ACE inhibitors
• Use nonpharmacologic approach first
  – Lifestyle modifications
What dietary modifications may help reduce or prevent hypertension?

• Five key points
  1. Achieve and maintain a healthy body weight
  2. Reduce or moderate sodium intake
  3. Consume a diet rich in fruits, vegetables, and low-fat, protein-rich foods with reduced saturated and total fat
  4. Moderate alcohol consumption
  5. Be cautious with dietary supplements
Healthy body weight

• **Achieve and maintain a healthy body weight**
  – Loss of 10 pounds will reduce blood pressure in overweight, hypertensive individuals
  – Maintaining a healthy body weight may be one of the most effective preventive measures
  – Healthful weight control is discussed in chapter 11
Sodium intake

• **Reduce or moderate sodium intake**
  – Recommendation is controversial, especially with normotensive individuals
  – Health professionals recommend intakes of 1,500 to 2,300 mg per day
  – Prudent recommendation for Americans and Canadians
    • 30% to 50% of adults may be salt sensitive
    • Blood pressure increases with salt intake
  – Dietary practices
    • Eat natural, wholesome foods
    • Minimize intake of highly processed foods
    • Do not add salt to foods
Diets rich in fruits, vegetables, protein and low in saturated fat

• Consume a diet rich in fruits, vegetables, and low-fat, protein-rich foods and with reduced saturated and total fat
  – The DASH (Dietary Approaches to Stop Hypertension) diet
    www.nhlbi.nih.gov
    Click on Heart/Vascular; scroll to High Blood Pressure, and Information on DASH diet

  – The OMNI (Optimal MacroNutrient Intake) diet
    www.omniheart.org
<table>
<thead>
<tr>
<th>Food group</th>
<th>Servings</th>
<th>Serving sizes</th>
<th>Examples and notes</th>
<th>Significance to the DASH eating plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grains and grain products</td>
<td>7–8 per day</td>
<td>1 slice bread, 1 oz dry cereal, ½ cup cooked rice, pasta, or cereal</td>
<td>Whole wheat bread, English muffin, pita bread, bagel, cereals, oatmeal, unsalted pretzels, popcorn</td>
<td>Major sources of energy and fiber</td>
</tr>
<tr>
<td>Vegetables</td>
<td>4–5 per day</td>
<td>1 cup raw leafy vegetable, ½ cup cooked vegetable, 6 oz vegetable juice</td>
<td>Tomatoes, potatoes, carrots, green peas, broccoli, kale, spinach, lima beans, sweet potatoes</td>
<td>Rich sources of potassium, magnesium, and fiber</td>
</tr>
<tr>
<td>Fruits</td>
<td>4–5 per day</td>
<td>6 oz fruit juice, 1 medium fruit, ¼ cup dried fruit</td>
<td>Apricots, bananas, dates, grapes, oranges, orange juice, melons, peaches pineapples, raisins, strawberries</td>
<td>Important sources of potassium, magnesium, and fiber</td>
</tr>
<tr>
<td>Lowfat or fat free dairy foods</td>
<td>2–3 per day</td>
<td>8 oz milk, 1 cup yogurt, 1½ oz cheese</td>
<td>Fat-free (skim) milk, fat-free or low-fat regular or frozen yogurt, low-fat and fat-free cheese</td>
<td>Major sources of calcium and protein</td>
</tr>
<tr>
<td>Meats, poultry, and fish</td>
<td>2 or less per day</td>
<td>3 oz cooked meats, poultry, or fish</td>
<td>Select only lean; trim away visible fats; broil, roast, or boil, instead of frying; remove skin from poultry</td>
<td>Rich sources of protein and magnesium</td>
</tr>
<tr>
<td>Nuts, seeds, and dry beans</td>
<td>4–5 per week</td>
<td>⅓ cup or 1½ oz nuts, 2 Tbsp or ⅓ oz seeds, ½ cup cooked dry beans or peas</td>
<td>Almonds, mixed nuts, peanuts, walnuts, sunflower seeds, kidney beans</td>
<td>Rich sources of energy, magnesium, potassium, protein, and fiber</td>
</tr>
<tr>
<td>Fats and oils</td>
<td>2–3 per day</td>
<td>1 tsp soft margarine, 1 Tbsp low-fat mayonnaise, 2 Tbsp light salad dressing, 1 tsp vegetable oil</td>
<td>Soft margarine, low-fat mayonnaise, light salad dressing, vegetable oil (olive, corn, canola)</td>
<td>DASH has 27 percent of Calories as fat, including fat in or added to foods. 1 Tbsp fat-free dressing equals 0 servings</td>
</tr>
<tr>
<td>Sweets</td>
<td>5 per week</td>
<td>1 Tbsp sugar, 1 Tbsp jelly or jam, ½ oz jelly beans</td>
<td>Sugar, jelly, jam, jelly beans, hard candy, sorbet, ices</td>
<td></td>
</tr>
</tbody>
</table>

Alcohol intake

• Moderate alcohol consumption
  – Excess alcohol intake is linked to high blood pressure
Dietary supplements

• Potassium, calcium, magnesium
  – Potassium may lower blood pressure
    • Obtain potassium from the diet
    • Consult with physician about use of supplements
  – Calcium and magnesium supplements not shown to reduce blood pressure
Can exercise help prevent or treat hypertension?

- Regular, mild- to moderate-intensity aerobic exercise is recommended to reduce high blood pressure
  - May induce sympathetic relaxation of blood vessels
  - May contribute to weight loss
  - May decrease blood pressure in normotensives, and more so in hypertensives
  - Even small reductions reduce risk of CHD and stroke

- Exercise snacks may be effective
  - 3 x 10-minute brisk walks daily
ACSM Position Stand
Exercise and Hypertension

• Key Points
  – Exercise programs including aerobic endurance and resistance exercise help reduce blood pressure
  – Exercise should be done daily for 30 minutes or more
  – A higher level of physical activity is recommended; fitter people with hypertension have lower blood pressure than those who are less fit
  – Even a single session exercise bout provides an immediate reduction in blood pressure, which can last all day
ACSM Position Stand
Exercise and Hypertension

• Special considerations
  – Individuals with controlled hypertension and on CHD or kidney disease may exercise
  – Overweight adults should use exercise to lose weight
  – People on medications should be cautious of developing heat illness during exercise
  – Adults with hypertension should extend the cool-down period of the workout; some medications may cause blood pressure to go too low after ending exercise
  – Hypertensive individuals should consult with their physicians about exercise, especially resistance exercise
Lifestyle and High Blood Pressure

- The more healthful lifestyle behaviors one develops, the greater will be the reduction in blood pressure

<table>
<thead>
<tr>
<th>Lifestyle Change</th>
<th>↓ in Blood Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight reduction (10 kg)</td>
<td>5-20 mmHg</td>
</tr>
<tr>
<td>DASH eating plan</td>
<td>8-14 mmHg</td>
</tr>
<tr>
<td>Dietary sodium reduction</td>
<td>2-8 mmHg</td>
</tr>
<tr>
<td>Increased physical activity</td>
<td>4-9 mmHg</td>
</tr>
<tr>
<td>Moderation in alcohol intake</td>
<td>2-4 mmHg</td>
</tr>
</tbody>
</table>

- JNCDET