REVIEW: Water & Fluids

• Fluid compartments
• Convection, radiation
• Mechanisms for dehydration’s adverse performance effects
• Why electrolytes are added to sports drinks
• Main purpose of fluid ingestion during exercise

The Micronutrients: Vitamins and Minerals

Chapter 9

HPER 3970
Dr. Ayers
(courtesy of Dr. Cheatham)
Water and Fat Soluble Vitamins

- Organic compounds that are needed in very small dietary quantities
- Essential for:
  - Growth and development
  - Specific metabolic reactions
- Vitamins are not produced by the body
  - Exceptions: Vitamin D (sun), K, some B (GI)
- 13 compounds are considered vitamins
  - Water soluble: C, B₁ (thiamin), B₂ (riboflavin), B₃ (niacin), B₆ (pyridoxine), pantothenic acid, biotin, folic acid, B₁₂ (cobalamin)
  - Fat soluble: A (retinol), D (calciferol), E (tocopherol), K (menadione)

Vitamin deficiencies reduce body function and impair health & exercise performance
### Water and Fat Soluble Vitamins

#### Table 9.2 The Major Functions of Water-Soluble Vitamins and the Effects of Dietary Deficiency or Excess

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Major roles in body</th>
<th>Effect of deficiency</th>
<th>Effect of excess</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1 (thiamin)</td>
<td>Forms carboxylases with flavine adenine dinucleotide and coenzyme A.</td>
<td>Loss of appetite, weight loss, depression, irritability, Wernicke-Korsakoff syndrome.</td>
<td>No toxic effects.</td>
</tr>
<tr>
<td>B2 (riboflavin)</td>
<td>Forms carboxylases with flavine adenine dinucleotide and coenzyme A.</td>
<td>Dermatitis, angular cheilitis, glossitis, conjunctivitis, and keratitis.</td>
<td>No toxic effects.</td>
</tr>
<tr>
<td>B3 (niacin)</td>
<td>Promotes growth of bacteria, promotes protein synthesis, and protects against scurvy.</td>
<td>Hepatitis, loss of appetite, skin lesions, and skeletal changes.</td>
<td>No toxic effects.</td>
</tr>
<tr>
<td>B5 (pantothenate)</td>
<td>Forms pantothenic acid, which is a component of coenzyme A and coenzyme A.</td>
<td>Headache, nausea, skin rashes, hypoglycemia, and inhibition of lipolysis.</td>
<td>No toxic effects.</td>
</tr>
<tr>
<td>B6 (pyridoxine)</td>
<td>Forms pyridoxal phosphate, which is a component of pyridoxal kinase and coenzyme A.</td>
<td>Inability to form pyridoxal phosphate, which is a component of pyridoxal kinase and coenzyme A.</td>
<td>No toxic effects.</td>
</tr>
<tr>
<td>B7 (biotin)</td>
<td>Forms biotin, which is a component of coenzyme A and coenzyme A.</td>
<td>Hair loss, dermatitis, and mucosal changes.</td>
<td>No toxic effects.</td>
</tr>
<tr>
<td>B9 (folic acid)</td>
<td>Forms folic acid, which is a component of coenzyme A and coenzyme A.</td>
<td>Anemia, dermatitis, and dermatitis of the skin.</td>
<td>No toxic effects.</td>
</tr>
<tr>
<td>B12 (cyanocobalamin)</td>
<td>Forms cyanocobalamin, which is a component of coenzyme A and coenzyme A.</td>
<td>Depression, fatigue, and neurological changes.</td>
<td>No toxic effects.</td>
</tr>
<tr>
<td>Pantothenic acid</td>
<td>Forms pantothenic acid, which is a component of coenzyme A and coenzyme A.</td>
<td>Headache, nausea, skin rashes, hypoglycemia, and inhibition of lipolysis.</td>
<td>No toxic effects.</td>
</tr>
<tr>
<td>Choline</td>
<td>Forms choline, which is a component of coenzyme A and coenzyme A.</td>
<td>Weakness, irritability, cramping, and delirium.</td>
<td>No toxic effects.</td>
</tr>
</tbody>
</table>

*Ref: Rees-Nabilatude*

#### Table 9.3 The Major Sources of Fat-Soluble Vitamins

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Sources</th>
<th>RDA or AI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (retinol)</td>
<td>Liver, fish, dairy products, eggs, margarine, animal liver, carrots, corn, dark green leafy vegetables, tomatoes, and oranges</td>
<td>0.9 μg (M), 0.7 μg (F)</td>
</tr>
<tr>
<td>D (vitamin D)</td>
<td>Liver, fish, eggs, fortified dairy products, oils, and margarine; formed by action of sunlight on the skin</td>
<td>5 μg* (M), 7 μg* (F)</td>
</tr>
<tr>
<td>E (tocopherol)</td>
<td>Liver, eggs, alligator, cereal products, vegetable oils, seed oils, margarine, and butter</td>
<td>1.5 mg (M), 1 mg (F)</td>
</tr>
<tr>
<td>K (menadione)</td>
<td>Liver, eggs, green leafy vegetables, cheese, and butter; formed in large intestine by bacteria</td>
<td>120 μg* (M), 90 μg* (F)</td>
</tr>
</tbody>
</table>

*RDA = recommended daily allowance, AI* = adequate intake, M = males, F = females.

*For vitamin A: 1 μg of retinol or 1 μg of β-carotene for males; 800 of these values for females.
**Water and Fat Soluble Vitamins**

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Sources</th>
<th>RDA or AI*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B&lt;sub&gt;1&lt;/sub&gt; (thiamine)</strong></td>
<td>Whole-grain cereal products, fortified bread, pulses, potatoes, legumes, nuts, pork, ham, and liver</td>
<td>1.2 mg (M) 1.1 mg (F)</td>
</tr>
<tr>
<td><strong>B&lt;sub&gt;2&lt;/sub&gt; (riboflavin)</strong></td>
<td>Dairy products*, meat, liver, eggs, green leafy vegetables, and beans</td>
<td>1.3 mg (M) 1.1 mg (F)</td>
</tr>
<tr>
<td><strong>B&lt;sub&gt;3&lt;/sub&gt; (nicotinic)</strong></td>
<td>Meat, liver, poultry, fish, whole-grain cereal products, lentils, and nuts, formed in the body from essential amino acid tryptophan</td>
<td>16 mg (M) 14 mg (F)</td>
</tr>
<tr>
<td><strong>B&lt;sub&gt;5&lt;/sub&gt; (pantothenic)</strong></td>
<td>Meat, liver, poultry, fish, whole-grain cereal products, potatoes, legumes, green leafy vegetables, dairy products*, bananas, and nuts</td>
<td>1.3 mg (M, F)</td>
</tr>
<tr>
<td><strong>B&lt;sub&gt;12&lt;/sub&gt; (cobalamin)</strong></td>
<td>Meat, fish, shellfish, poultry, liver, eggs, dairy products*, and fortified breakfast cereals</td>
<td>2.4 µg (M, F)</td>
</tr>
<tr>
<td><strong>Folic acid</strong></td>
<td>Meat, liver, green leafy vegetables, whole-grain cereal products, potatoes, legumes, nuts, and fruit</td>
<td>400 µg (M, F)</td>
</tr>
<tr>
<td><strong>Biotin</strong></td>
<td>Meat, milk, egg yolk, whole-grain cereal products, legumes, most vegetables</td>
<td>30 µg* (M, F)</td>
</tr>
<tr>
<td><strong>Pantothenic acid</strong></td>
<td>Liver, meat, dairy products*, eggs, whole-grain cereal products, legumes, and most vegetables</td>
<td>5 mg* (M, F)</td>
</tr>
<tr>
<td><strong>C (ascorbic acid)</strong></td>
<td>Citrus fruits, green leafy vegetables, broccoli, potatoes, peppers, and strawberries</td>
<td>90 mg (M) 75 mg (F)</td>
</tr>
</tbody>
</table>

RDA = recommended daily allowance; AI* = adequate intake; M = males; F = females.

---

**Water and Fat Soluble Vitamins**

- Effect of exercise on vitamin requirements:
  - Inadequate vitamin status is associated with impaired exercise performance
  - Theoretically, exercise can induce a marginal vitamin status (deficiency):
    - Decreased absorption from digestive tract
    - Increased excretion in sweat, urine, and feces
    - Increased turnover (degradation)
    - Increased requirements because of biochemical adaptations to training
Water and Fat Soluble Vitamins

- Assessing vitamin status:
  - Biopsy samples
  - Blood cells or plasma
  - Dietary analysis
    - Very little evidence that athletes’ vitamin intakes are inadequate based on the RDA
- Recommended intake of vitamins:
  - EAR, RDI/RDA, AI
  - Data to determine these values often times did not include athletes
  - With balanced diet and proper caloric intake, most athletes should get adequate vitamin intake from food (see next slide)
  - Individuals at risk:
    - Low-energy or unbalanced diet
    - Vegetarians

As shown for thiamin and vitamin C, athletes’ vitamin intakes are correlated with energy intake up to 4,800 kcal/day.

Balanced diet = adequate vitamins
Water and Fat Soluble Vitamins

• Dietary surveys of vitamin intakes in elite athletes:
  – Athletes do not always consume a well-balanced diet
    • Risk due to fatiguing and time-consuming demands of training
    • Most at risk:
      – Female adolescent athletes
      – Athletes attempting to maintain low body weights (wrestlers, gymnasts, ballet dancers)

As shown for vitamin C and B₂, endurance athletes’ intakes are adequate and were correlated with higher total energy intakes.
Macro- and Microminerals

- A mineral is an inorganic compound found in nature and are essential to life processes

7 major macrominerals (each = @ least 0.01% total body mass):
  - Potassium, sodium, chloride, calcium, mangesium, phosphorus, sulfur

10 major microminerals (trace elements):
  - Chromium, cobalt, copper, fluorine, iodine, iron, manganese, molybdenum, selenium, zinc

Inadequate mineral nutrition has been associated with:
  - Anemia, cancer, diabetes, hypertension, osteoporosis and tooth decay

## Table 9.6 The Major Functions of Macrominerals and the Effects of Dietary Deficiency or Excess

<table>
<thead>
<tr>
<th>Macrominerals</th>
<th>Major roles in the body</th>
<th>Effect of deficiency</th>
<th>Effect of excess</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>Promotes bone and teeth formation, muscle contraction, membrane potentials, and nerve impulse transmission; regulates enzyme activity</td>
<td>Osteoporosis, brittle bones, impaired muscle contraction, muscle cramps</td>
<td>Improved bone mineralization, cardiac arrhythmia, constipation, kidney stones, and calcification of soft tissue</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Promotes nerve impulse conduction and hydration acid formation in the stomach</td>
<td>Convulsions</td>
<td>Hypertension</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Promotes protein synthesis and cell function, ATPase, and 2,3 DPG formation; bone component</td>
<td>Muscle weakness, fatigue, apathy, muscle tremor, and cramps</td>
<td>Nausea, vomiting, and diarrhea</td>
</tr>
<tr>
<td>Potassium</td>
<td>Promotes membrane potential, nerve impulse formation, muscle contraction, and acid-base balance</td>
<td>Hyperkalemia, muscle cramps, apathy, loss of appetite, and irregular heart beat</td>
<td>Hypertension, cardiac arrhythmia, and cardiac failure</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Promotes bone formation; buffer in muscle contraction; component of ATP, PC, NADP, DHA, RNA, and cell membranes;</td>
<td>Cholesterol, brittle bones, muscle weakness, and muscle cramps</td>
<td>Impaired function, mental, and copper absorption; impaired calcium metabolism</td>
</tr>
<tr>
<td>Sodium</td>
<td>Promotes blood volume homeostasis, nerve impulse generation, muscle contraction, acid-base balance</td>
<td>Hyponatremia, diarrhea, coma, muscle cramps, nausea, vomiting, loss of appetite, and seizures</td>
<td>Hypertension and nausea</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Acid-base balance; liver function</td>
<td>Unknown and very unlikely to occur</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

In some instances, deficiency can be caused by excess vomiting. In connection with excess sodium.
## Macro- and Microminerals

**Table 9.7** The Major Functions of Microminerals (Trace Elements) and the Effects of Dietary Deficiency or Excess

<table>
<thead>
<tr>
<th>Micromineral</th>
<th>Major roles in body</th>
<th>Effect of deficiency</th>
<th>Effect of excess</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium</td>
<td>Augments insulin action</td>
<td>Glucose intolerance, and impaired lipid metabolism</td>
<td>Rare toxic effects</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Forms component of vitamin B&lt;sub&gt;12&lt;/sub&gt; needed for red blood cell development</td>
<td>Pernicious anemia</td>
<td>Nausea, vomiting, and death</td>
</tr>
<tr>
<td>Copper</td>
<td>Promotes normal iron absorption, oxidative metabolism, connective tissue formation, and hemoglobin synthesis; forms cofactor with superoxide dismutase</td>
<td>Anemia, impaired immune function, and bone demineralization</td>
<td>Nausea and vomiting</td>
</tr>
<tr>
<td>Fluorine</td>
<td>Promotes bone and tooth formation</td>
<td>Dental caries</td>
<td>Discolored teeth, inhibited glycolysis in high doses</td>
</tr>
<tr>
<td>Iodine</td>
<td>Forms component of thyroid hormones T&lt;sub&gt;3&lt;/sub&gt; and T&lt;sub&gt;4&lt;/sub&gt;</td>
<td>Gouty and reduced metabolic rate</td>
<td>Depressed thyroid gland activity</td>
</tr>
<tr>
<td>Iron</td>
<td>Transports oxygen, as hemoglobin and myoglobin; forms cytochromes and metalloenzymes; promotes immune function</td>
<td>Anemia, fatigue, and increased infections</td>
<td>Hemochromatosis, liver cirrhosis, heart disease, and increased infections</td>
</tr>
</tbody>
</table>

(continued)

### (continued)

<table>
<thead>
<tr>
<th>Micromineral</th>
<th>Major roles in body</th>
<th>Effect of deficiency</th>
<th>Effect of excess</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manganese</td>
<td>Forms cofactor with energy metabolism enzymes; promotes bone formation and fat synthesis</td>
<td>Poor growth</td>
<td>Weakness and confusion</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Forms cofactor with riboflavin in carbohydrate and fat metabolism enzymes</td>
<td>No deficiency effects</td>
<td>Rare toxic effects</td>
</tr>
<tr>
<td>Selenium</td>
<td>Forms cofactor with glutathione peroxidase</td>
<td>Cardiomyopathy, cancer, heart disease, impaired immune function, and erythrocyte fragility</td>
<td>Nausea, vomiting, fatigue, and hair loss</td>
</tr>
<tr>
<td>Zinc</td>
<td>Forms metalloenzymes, promotes protein synthesis, immune function, tissue repair, energy metabolism, and antioxidant activity</td>
<td>Impaired growth, impaired healing, increased infections, and anorexia</td>
<td>Impaired absorption of Fe and Cu, increased HDL cholesterol/LDL cholesterol ratio; anemia, nausea, vomiting, and impaired immunity</td>
</tr>
</tbody>
</table>
**Macro- and Microminerals**

- Recommended intake of minerals:
  - RDA for 7 minerals and AI for 5

### Table 9.8 Sources and Recommended Daily Allowances or Adequate Intakes of Microminerals for Adults 19 to 50 Years of Age

<table>
<thead>
<tr>
<th>Micromineral</th>
<th>Sources</th>
<th>RDA or AI*</th>
<th>Percent absorbed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>Dairy products, egg yolk, beans and peas, dark-green vegetables, and cauliflower</td>
<td>1,000 mg* (M, F)</td>
<td>30-40</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Meat, fish, bread, canned foods, table salt, beans, and milk</td>
<td>750 mg** (M, F)</td>
<td>90-99</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Seafood, nuts, green leafy vegetables, fruits, whole-grain products, milk, and yogurt</td>
<td>420 mg (M), 320 mg (F)</td>
<td>23-60</td>
</tr>
<tr>
<td>Potassium</td>
<td>Meat, fish, milk, yogurt, fruit, vegetables, and bread</td>
<td>2,000 mg** (M, F)</td>
<td>90-99</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Meat, eggs, fish, milk, cheese, beans, peas, whole-grain products, soft drinks</td>
<td>700 mg (M, F)</td>
<td>80-90</td>
</tr>
<tr>
<td>Sodium</td>
<td>Meat, fish, bread, canned foods, table salt, sauces, and pickles</td>
<td>500 mg** (M, F), 320 mg** (F)</td>
<td>90-99</td>
</tr>
</tbody>
</table>

RDA = Recommended Daily Allowance; AI* = Adequate Intake; AI** = Estimated requirement. M = males; F = females. Also shown is the proportion of the ingested amount that is absorbed; the remainder is excreted in the feces.

![Macro- and Microminerals](image)

### Table 9.9 (continued)

<table>
<thead>
<tr>
<th>Micromineral</th>
<th>Sources</th>
<th>RDA or AI*</th>
<th>Percent absorbed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>Liver, kidney, shellfish, meat, fish, poultry, eggs, bean crepes, wheat, legumes, broccoli, bananas, avocados</td>
<td>0.9 mg (M, F)</td>
<td>20-80</td>
</tr>
<tr>
<td>Iron</td>
<td>Red and dark leafy vegetables, liver, and whole-grain products</td>
<td>15 mg (M, F)</td>
<td>20-80</td>
</tr>
<tr>
<td>Iodine</td>
<td>Seafood, avocado, and broccoli</td>
<td>250 μg (M), 200 μg (F)</td>
<td>50-70</td>
</tr>
<tr>
<td>Manganese</td>
<td>White grains, peas and beans, leafy vegetables, and banana</td>
<td>1.0 mg (M), 0.5 mg (F)</td>
<td>10-50</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Liver, kidney, white-grain products, beans, and peas</td>
<td>35 μg (M, F)</td>
<td>50-80</td>
</tr>
<tr>
<td>Selenium</td>
<td>Meat, fish, kidney, poultry, and dairy products, seafood, whole grains, and tubers from selenium-rich soil</td>
<td>10 μg (M, F)</td>
<td>10-50</td>
</tr>
<tr>
<td>Zinc</td>
<td>Oysters, shellfish, beef, liver, poultry, dairy products, white grains, vegetables, asparagus, and spinach</td>
<td>10 μg (M, F)</td>
<td>10-50</td>
</tr>
</tbody>
</table>

RDA = Recommended daily allowance; AI* = adequate intake. M = males; F = females. Also shown is the proportion of the ingested amount that is absorbed; the remainder is excreted in the feces.
Macro- and Microminerals

• Effect of exercise on mineral requirements:

[Diagram showing mineral absorption and retention]

Figure 9.4 Factors affecting absorption and tissue distribution of minerals. Exercise may increase losses of minerals in urine and sweat, and several other components of the diet may interfere with mineral absorption.

Macro- and Microminerals

• Dietary surveys of mineral intakes by elite athletes:
  • More difficult than vitamins
  • Dietary records, plasma levels
    – Iron, zinc, calcium, and magnesium may be of some concern especially for young athletes and women athletes of all ages
    – Functions by categories, not list of micronutrients
**Micronutrients Form the Building Blocks of Tissues**

- Calcium, phosphorus, flourine important in bones and teeth
- Vitamin D is required for normal absorption of dietary calcium
- Vitamin C is required for the production of collagen (connective tissue and cartilage)
- Calcium:
  - Role of menstruation and estrogen
    - Chronically low plasma estrogen levels
  - If amenorrhea is present:
    - 120% of RDA is recommended

**Micronutrients as Antioxidants**

- Prevent or limit the actions of free-radicals, usually by removing their unpaired electrons and converting them to something less reactive
- Free-radicals damage membranes, proteins, and DNA
- Vitamins C, E, beta-carotene
  - Athletes may require increased intake due to exercise-induced increases in free-radical formation
- Role in exercise-induced muscle damage
  - Reactive oxygen species (ROS)
  - Inconclusive data
**Micronutrients as Antioxidants**

- Possible risks of high-dose antioxidant supplementation:
  - In heavy smokers, Vitamin E and beta-carotene may increase risk for lung cancer
  - Other side effects:
    - Urinary stone formation (Vitamin C)
    - Birth defects (Vitamin A)
    - Inhibit absorption of other vitamins
  - Conclusion:
    - Athletes should consume a natural diet that is rich in antioxidants

**Essential Functions of the Micronutrients**

- Oxygen Transport
  - Iron: Heme and myoglobin, cytochromes
  - Anemia: Can negatively impact performance

---

**Table 9.12 Stages of Iron Drain From Normal Iron Status Through to Iron Deficiency Anemia**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Characteristics</th>
<th>Blood hemoglobin (g/L)</th>
<th>Serum ferritin (µg/dL)</th>
<th>Serum transferrin saturation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal iron status</td>
<td>Normal iron status measurements and normal oxygen carrying capacity of RBCs</td>
<td>&gt;120 [L]</td>
<td>&gt;20 [F]</td>
<td>20-40 [M, F]</td>
</tr>
<tr>
<td>Iron deficiency anaemia</td>
<td>Low hemoglobin and high transferrin saturation, small and pale RBCs</td>
<td>&lt;12 [M, F]</td>
<td>10-20 [M, F]</td>
<td></td>
</tr>
</tbody>
</table>
### Essential Functions of the Micronutrients

- Cofactors in enzyme catalyzed reactions:
  - Niacin, pyridoxine, thiamin are involved in carbohydrate metabolism
  - Riboflavin, thiamin, pantothenic acid, and biotin are involved in fat metabolism
  - Vitamin B<sub>6</sub> and K are involved in protein metabolism
  - Niacin is a precursor of NAD and NADP
  - Riboflavin is a precursor of FAD and FMN
  - Zinc and magnesium are important for 200 and 300 enzymes, respectively

---

**Essential Functions of the Micronutrients**

**micronuts are WIDELY involved in metabolism**

---

![Image of a biochemical pathway](image_url)

*Figure 9.9* B vitamins as precursors of coenzymes in energy metabolism. CoA = coenzyme A; FAD = flavin adenine dinucleotide; NAD = nicotinamide adenine dinucleotide; TPP = pyrophosphate; TTP = thiamin phosphate.
**Essential Functions of the Micronutrients**

- Micronutrients in immune function and resistance to infection:
  - $B_{12}$ and folic acid are needed for the normal production of white blood cells
  - A, C, and E are needed for normal immune function
  - Zinc, iron, copper, and selenium are essential for optimal immune function

**Electrolytes in body fluids**

- Conduct an electrical current when dissolved in water
- Major electrolytes:
  - Sodium, potassium, chloride, bicarbonate, phosphate, sulfate, magnesium, calcium
- Major functions:
  - Na and K = nerve signal transduction
  - Fluid balance (where Na goes, so follows water)

- Other tissue functions
  - Calcium = muscle contraction and energy metabolism
  - Calcium and Vitamin K = blood clotting
  - Zinc = appetite
  - Vitamin A = vision
  - B complex = synthesis of neurotransmitters
**Effects of Vitamins on Exercise Performance**

- Older research reported an ergogenic effect of vitamins on performance:
  - Many of these studies were poorly controlled
- More recent research has shown no ergogenic effect on performance if dietary intake was adequate

**Ergogenic Effect of Mineral Supplementation**

- Phosphates:
  - Purported effects:
    - Increase ATP synthesis
    - Improve oxygen extraction by muscle (2,3-DGP)
  - Experimental evidence is lacking
- Bicarbonate
  - Improve buffering of lactic acid
  - Amount needed for effect often leads to severe GI distress
  - Can lead to inadequate absorption of carbohydrates and other essential micronutrients
**Recommendations for Micronutrient Intake in Athletes**

- In general, supplementation of vitamins and antioxidants is not recommended and may do more harm than good
- Dietary intake should be adequate for most athletes with a proper diet
- However, some athletes at risk (esp. w/ energy-restricted diet)
  - Recommendations for calcium:
    - 3 servings/day of low-fat dairy foods
    - Include these dairy foods in high-CHO meals
    - Eat fish with bones (i.e. sardines)
    - Include calcium-enriched soy products
    - Eat leafy green vegetables
  - Iron intake:
    - Eat foods rich in iron at least 4x/week
    - Eat iron fortified foods
    - Include non-heme iron food sources
    - Combine non-heme sources with Vitamin C rich foods
    - Avoid caffeine (tea, coffee) with meals

- **Recommendations for Micronutrient Intake in Athletes**

- Amenorrheic female athletes:
  - Calcium supplements
- Athletes who train and compete in hot environments:
  - Increase iron, zinc, magnesium
  - Should not exceed 1 to 2x the RDA
  - Increased needs are due to sweat losses
- Overall, a healthy, balanced, calorically proper diet should provide the appropriate vitamins and minerals for most all athletes