

Nutrients Involved in Fluid and Electrolyte Balance

Chapter Summary

Between 50% and 70% of a healthy adult's body weight is fluid. Electrolytes in the body fluid assist in maintaining the proper balance between intracellular and extracellular fluid compartments and in the normal functioning of cells and the nervous system. Water performs a variety of functions that are critical to support life, including protection and lubrication, and maintenance of blood volume, body temperature, and blood pressure. The primary sources of fluid intake are beverages, foods, and metabolic water. Water is lost normally through urine excretion, sweat, exhalation, and feces. Water loss can be significantly increased from fever, vomiting, diarrhea, excessive blood loss, heavy exercise, and exposure to heat, cold, and altitude. For these reasons, water intake needs are highly variable and depend upon body size, age, physical activity, and environmental conditions. The proper balance is important, as drinking too much water can lead to overhydration and hyponatremia and drinking too little water leads to dehydration. Four electrolytes that are involved in fluid balance are sodium, potassium, chloride, and phosphorus. In addition to their role in maintaining fluid balance and nerve function, these electrolytes have a variety of other functions. Excess sodium (hypernatremia) and excess potassium (hyperkalemia) most often occur when the kidneys malfunction. Hyponatremia occurs mainly when excessive fluid intake is not accompanied by adequate sodium intake.

Hypokalemia results from kidney disease, diabetic ketoacidosis, and some diuretics. Excesses and deficiencies of chloride and phosphorus are rare. Dehydration occurs when water excretion exceeds water intake. In severe cases, dehydration can lead to heat stroke. This occurs when the body's core temperature rises above 100°F, and it can lead to death. Water intoxication is caused by rapidly consuming too much water and can result in hyponatremia. Hypertension increases the risk for heart disease, stroke, and kidney disease. It is associated with excess sodium consumption in some people, but the exact cause of most cases is unknown. Reducing risk of hypertension, heart disease, and stroke can be accomplished by weight reduction, regular physical activity, limiting alcohol, and following the DASH diet plan.

Nutrition Myth or Fact addresses the question: Low sodium diets: fit for all or just a few?

Learning Objectives

After studying this chapter, the student should be able to:

1. Distinguish among extracellular fluid, intracellular fluid, interstitial fluid, and intravascular fluid (pp. 342-344).

2. Identify the critical contributions of water and electrolytes to human functioning (pp. 344–345).
3. Explain how the kidneys regulate blood pressure and blood volume (pp. 344–345).
4. Discuss the avenues of fluid intake and excretion in the body (pp. 349–352).
5. Explain how the body maintains acid-base balance (pp. 352–353).
6. Identify the DRIs for water and compare the nutritional quality of several common beverages (pp. 353–358).
7. Identify the functions, DRIs, and common dietary sources of sodium, potassium, chloride, and phosphorus (pp. 359–365).
8. Distinguish between *hypernatremia* and *hyponatremia* and identify factors that can cause these conditions (pp. 360–361).
9. Describe several disorders related to fluid and electrolyte imbalance and identify their signs and symptoms (pp. 365–371).
10. Define *hypertension* and list three lifestyle changes that can reduce it (pp. 367–368).

Key Terms

aldosterone	hypernatremia	osmotic pressure
angiotensin II	hypertension	overhydration
antidiuretic hormone	hypokalemia	phytic acid
blood volume	hyponatremia	renin
DASH diet	insensible fluid loss	salt resistant
dehydration	interstitial fluid	salt sensitivity
diuretic	intracellular fluid	seizures
electrolyte	intravascular fluid	sensible fluid loss
extracellular fluid	ion	solvent
fluid	metabolic water	thirst mechanism
heat stroke	muscle cramps	
hyperkalemia	osmosis	

Chapter Outline

I. What Is Body Fluid?

- A. A fluid is a substance characterized by its ability to move freely and changeably, adapting to the shape of the container it holds.
- B. Body fluid is the liquid portion of cells and tissues.
 1. Between 50% and 70% of a healthy adult's body weight is fluid.
 - a. Two-thirds of our body fluid is intracellular fluid.
 - b. Of the extracellular fluid, interstitial fluid flows between the cells and intravascular fluid is the water in the bloodstream and lymph.
 - c. Fluid levels vary in different tissues and for gender and age.
- C. Body fluid is composed of water and dissolved substances called electrolytes.
 1. Body fluids contain a variety of dissolved substances (solutes).

- a. The six major minerals found in body fluid are sodium, potassium, chloride, phosphorus, calcium, and magnesium and are consumed as salts.
 - b. Mineral salts are called electrolytes because they form ions when they dissolve in water.
2. Potassium (K⁺) and phosphorus are the major intracellular electrolytes, and sodium (Na⁺) and chloride (Cl⁻) are the major extracellular electrolytes.

Key Terms: fluid, intracellular fluid, extracellular fluid, interstitial fluid, intravascular fluid, electrolyte, ion

Nutrition Animations: Intracellular and Extracellular Fluid; Role of Electrolytes in Water Balance (located in IR-DVD folder).

Figure:

Figure 9.1: The components of body fluid.

II. What Are the Functions of Water and Electrolytes?

A. Water performs functions critical to life.

- 1. Fluids dissolve and transport substances, including most nutrients.
- 2. Fluids account for blood volume regulated by the kidneys.
 - a. When fluid is lost, blood volume decreases and blood pressure drops.
 - b. Antidiuretic hormone stimulates the kidneys to reabsorb water.
 - c. Kidneys secrete renin, activating angiotensin II, which constricts blood vessels, raising blood pressure.
 - d. The hormone aldosterone stimulates the kidneys to retain sodium and chloride, which also raises blood pressure.
- 3. Fluids help maintain body temperature.
- 4. Fluids protect and lubricate the tissues.

B. Electrolytes support many body functions.

- 1. Electrolytes help regulate fluid balance.
 - a. Water follows the movement of electrolytes through osmosis.
 - b. By using transport proteins to pump electrolytes through cell membranes, cells regulate osmotic pressure to maintain fluid balance.
 - c. High concentrations of electrolytes within cells cause them to swell with water and burst, just as high concentrations extracellularly cause the cell to dry up.
 - d. Life-threatening fluid and electrolyte imbalances caused by excessive diarrhea or vomiting can change the flow of electrical impulses to the heart.
- 2. Electrolytes enable nerves to respond to stimuli by changing the electrical charge across the cell membrane.
- 3. Electrolytes signal muscles to contract through a series of complex physiological changes.

Key Term: solvent, blood volume, antidiuretic hormone (ADH), diuretic, renin, angiotensin II, aldosterone, osmosis, osmotic pressure

Figures:

Figure 9.2: Regulation of blood volume and blood pressure by the kidneys.

Figure 9.3: Evaporative cooling occurs when heat is transported from the body core through the bloodstream to the surface of the skin.

Figure 9.4: Osmosis.

Figure 9.5: Fluid and Electrolyte Balance

Figure 9.6: The role of electrolytes in conduction of a nerve impulse.

III. How Does the Body Maintain Fluid Balance?

- A. We gain fluids through consumption and metabolism.
 - 1. The thirst mechanism in the hypothalamus prompts thirst.
 - a. Increased salt concentration and other dissolved substances causes thirst.
 - b. Reduction in blood volume or blood pressure causes thirst.
 - c. Dryness in the tissues of the mouth and throat causes thirst.
 - 2. Kidneys return more water to the bloodstream and secrete renin, resulting in constriction of blood vessels, further drying the mouth.
 - 3. The thirst mechanism is limited in its ability to restore adequate fluid volume.
- B. The body gains fluids through consuming beverages and foods and through metabolism.
 - 1. Beverages are the primary source of water, but a substantial amount can be obtained from foods.
 - 2. Metabolic water, produced from metabolism of the macronutrients, provides 10–14% of the body's need for water.
- C. Fluids are lost through urine, sweat, evaporation, exhalation, and feces.
 - 1. Sensible water loss occurs in the form of urine (the major loss) and sweat.
 - 2. Insensible water loss includes water lost from the skin and from the lungs during breathing.
 - 3. We excrete a small amount of water through our feces, but the intestines reabsorb most of the water used for digestion.
 - 4. Certain situations can cause significant water loss.
 - a. Illnesses can increase water loss.
 - b. Traumatic injury, or any type of blood loss, increases fluid loss.
 - c. Exercise increases fluid loss.
 - d. Environmental conditions such as high altitudes, flying in an airplane, cold and hot temperatures, and low humidity can increase fluid loss.
 - e. Pregnancy increases the mother's fluid loss.
 - f. Breastfeeding results in fluid loss.
 - g. Consumption of diuretics results in fluid loss.

Key Terms: thirst mechanism, metabolic water, sensible fluid loss, insensible fluid loss

Nutrition Animation: Water Balance (located in IR-DVD folder).

Figure:

Figure 9.7: Water content of different foods.

IV. How Does the Body Maintain Acid–Base Balance?

(Refer also to details in chapter 6 (pp. 224), and chapter 11 (p. 431) for information on acid–base balance.)

- A. The body's cellular processes, including energy metabolism, result in the constant production of both acids and bases.

1. The pH (or acid–base balance) of the blood, which is normally slightly alkaline, is enabled by homeostatic mechanisms to stay within a narrow range.
2. Acidosis is a state in which blood pH drops below 7.35; alkalosis is a condition in which blood pH rises above 7.45.
3. Three major systems account for the body’s ability to regulate acid–base balance: blood buffers, the lungs (respiratory compensation), and the kidneys (renal compensation).

V. How Much Water Should We Drink, and What are the Best Sources?

A. Water is essential for life.

B. Our requirements for water are individualized.

1. Fluid requirements vary with age, body size, health status, physical activity, and environmental conditions.
2. The DRI for water is 9 cups for women and 13 cups for men.
3. Although athletes and active individuals working in hot environments may need more, most adults can maintain fluid balance with 8 cups of beverages per day.

C. Public tap water is safe to drink.

1. Many sources of drinking water are available including tap, carbonated, and mineral water.
2. Knowing the difference between the types of water and the controversies over their benefits and harm is important.

D. All beverages are not created equal.

1. Milk and milk substitutes, especially low-fat and skim varieties, can be healthful beverage choices.
2. Hot beverages, such as teas, coffee, and cocoa drinks can be healthful if consumed in moderation.
3. Soft drinks and sweet beverages are often loaded with sugar, and attention should be paid to their Caloric content.
4. Energy drinks are increasingly popular but caution should be exercised and their added sugar content should also be factored in to the decision to consume them.
5. Drinks with added sugars, like cane sugar or fruit juice concentrate, are high in empty calories.
6. Specialty waters make varying claims, which should be evaluated critically.
7. Sports beverages and coconut water are a good source of electrolytes, but are only necessary for those who exercise or do manual labor vigorously for 60 minutes or more.

Figure:

Figure 9.8: Amounts and categories of water sources and losses for a woman expending 2,500 kcal per day.

VI. How Do Four Major Mineral Contribute to Fluid Balance?

A. Sodium is the body’s major extracellular cation.

1. Sodium is an essential nutrient that our body needs to function optimally.
2. Sodium has a variety of functions.
 - a. Sodium is the major positive ion in extracellular fluid.

- b. It allows cells to maintain proper fluid balance and blood pressure.
 - c. Sodium assists with transmission of nerve signals and aids in muscle contraction and relaxation.
 - d. Sodium assists in the absorption of nutrients such as glucose.
2. How much sodium should we consume?
 - a. The AI for sodium is 1.5 g/day (1,500 mg) for adults, but the average U.S. daily consumption is between 3.5 g and 6 g. The AI drops to 1.3 g/day for people aged 51 to 70, and goes down to 1.2 g/day for people over 70 years of age.
 - b. Most health organizations recommend a daily sodium intake of no more than 2.3 g or 2.4 g per day.
 - c. Processed foods generally contain higher sodium levels than unprocessed foods.
 3. What happens if we consume too much sodium?
 - a. The role of high dietary sodium in causing high blood pressure and bone loss is controversial.
 - b. Eating excess sodium may cause an increased excretion of calcium in some people.
 - c. Hyponatremia refers to an abnormally high blood sodium concentration caused by rapid high intake of sodium or inability to excrete excess sodium.
 - d. Hyponatremia increases blood volume, resulting in edema and an unhealthy rise in blood pressure.
 4. What happens if we don't consume enough sodium?
 - a. Sodium deficiencies are rare.
 - b. Hyponatremia, abnormally low blood sodium concentration, can occur in active people who drink large volumes of water and fail to replace sodium.
 - c. Hyponatremia symptoms include headache, fatigue, nausea, and vomiting and can lead to seizures, coma, and death.
- B. Potassium is the body's major intracellular cation.**
1. Potassium has many functions in the body.
 - a. Potassium and sodium work together to maintain proper fluid balance.
 - b. Potassium has a major role in muscle contraction and transmission of nerve impulses.
 - c. Potassium assists in maintaining blood pressure.
 2. How much potassium should we consume?
 - a. The minimum recommended intake for potassium is 4.7 g (4,700 mg) per day.
 - b. The best sources of potassium include fresh fruits and vegetables.
 3. What happens if we consume too much potassium?
 - a. People with healthy kidneys excrete excess potassium.
 - b. Hyperkalemia occurs when potassium is not excreted efficiently from the body and can result in heart attack and death.
 - c. Salt substitutes should be avoided by people at risk for hyperkalemia.
 4. What happens if we don't consume enough potassium?
 - a. Deficiency occurs in people who suffer kidney disease, diabetic ketoacidosis, and other illnesses.
 - b. Individuals on certain diuretic medication are at risk for potassium deficiency and hypokalemia, or low blood potassium concentration.

- c. Severe hypokalemia causes confusion, loss of appetite, and muscle weakness and can result in fatal changes in heart rate.

C. Chloride is the body's major extracellular anion.

1. Chloride works with sodium to assist with the maintenance of fluid balance.
2. Chloride is part of hydrochloric acid (HCl) in the stomach.
3. Chloride works with the white blood cells during an immune response to help kill bacteria and assist in nerve impulse transmission.
4. The AI for chloride is 2.3 g (2,300 mg) per day for adults.
5. Table salt is about 60% chloride, making it readily available.
6. As virtually all chloride is consumed as sodium chloride, excess consumption may lead to hypertension in salt-sensitive individuals.
7. Chloride deficiency may occur during conditions of severe dehydration and frequent vomiting.

D. Phosphorus is the body's major intracellular anion.

1. Phosphorus is an essential constituent of all cells.
 - a. Phosphorus works with potassium to maintain proper fluid balance.
 - b. Phosphorus is part of the mineral complex of bone, a primary component of ATP and a part of DNA and RNA.
 - c. Phosphorus helps regulate many biochemical reactions and is a component of cell membranes as phospholipids and lipoproteins.
 - d. The RDA for phosphorus is 700 mg per day.
 - e. Phosphorus in animal foods is readily absorbed.
 - f. Phosphorus in plant foods is in the form phytic acid, and although humans do not produce enzymes to break it down, about 50% of it is absorbed.
 - g. Kidney disease, excessive vitamin D supplementation, or phosphorus-based antacids can cause high phosphorus levels, muscle spasms, and convulsions.
 - h. Phosphorus deficiencies occur in premature infants, alcohol abusers, and some other populations. Deficiency is rare.

Key Terms: hypernatremia, hyponatremia, hyperkalemia, hypokalemia, phytic acid

Figures and Tables:

Figure 9.9: Common food sources of potassium.

Figure 9.10: Common food sources of phosphorus.

Table 9.1: Overview of Nutrients Involved in Hydration and Neuromuscular Function

Table 9.2: High-Sodium Foods and Lower-Sodium Alternatives

VII. What Disorders Are Related to Fluid and Electrolyte Imbalances?

A. Dehydration develops when fluid loss exceeds fluid intake.

1. Dehydration commonly occurs as a result of heavy exercise or exposure to high environmental temperatures.
2. Infants and elderly people are at higher risk for dehydration.
3. Minimal loss of weight in water is enough to cause mild discomfort.
4. Greater water loss is serious and life-threatening.

5. Two methods to determine adequate hydration are weighing before and after exercise and observing urine color.
- B.** Heat stroke is a potentially fatal response to high temperature characterized by failure of the body's heat-regulating mechanisms.
- C.** Water intoxication or overhydration is rare but can be fatal.
 1. It occurs when the kidneys retain too much water.
- D.** A majority of Americans have hypertension (high blood pressure) or pre-hypertension.
 1. Hypertension (HTN) affects about one-third of the population.
 - a. It is usually without symptoms but can lead to many other serious conditions.
 2. Prehypertension, in which blood pressure is above normal but not high enough for a HTN diagnosis, affects 1 in 3 Americans.
 3. Diagnosis of HTN
 - a. It is measured using two phases: systolic and diastolic. Optimal blood pressure is less than or equal to 120 systolic "over" 80 diastolic blood pressure.
 - b. Prehypertension is systolic blood pressure between 120 and 139 and diastolic blood pressure between 80 and 89.
 - c. Hypertension is blood pressure that is greater or equal to 140 systolic or 90 diastolic.
 3. What are the causes and risk factors for hypertension?
 - a. Ninety to 95% is primary hypertension with the cause unknown.
 - b. Five to 10% of hypertension may be due to kidney disease, sleep apnea, or chronic alcohol abuse.
 - c. Salt sensitivity most likely contributes to hypertension in about half of the cases.
 - d. Risk factors include overweight and obesity, a sedentary lifestyle, tobacco use, excessive alcohol intake, and a diet high in sodium and low in potassium.
 4. Certain lifestyle changes can reduce hypertension.
 - a. Lose weight; even small losses of weight have shown significant decrease in blood pressures.
 - b. Increased daily physical activity helps lower blood pressure.
 - c. Limiting alcohol intake improves hypertension.
 - d. Reduced sodium intake, particularly in salt-sensitive individuals, lowers blood pressure.
 - e. Increasing consumption of whole grains, fruits, vegetables, and low-fat dairy foods reduces risk of hypertension and lowers blood pressure.
 - f. Stop smoking, or don't start.
 5. The Dietary Approaches to Stop Hypertension (DASH) diet plan has shown much promise in lowering blood pressure.
 - a. The DASH diet plan is low in fat and rich in potassium, calcium, magnesium, and fiber, with a sodium content of 3g.
 - b. Years of research confirm significant reductions in blood pressure and could reduce heart disease and stroke in healthy populations.
 - c. Further reduction in blood pressure can be achieved by following the plan with lower sodium intake.

- d. DASH has been effective in reducing blood pressure and other cardiovascular risk factors.
- 6. Medication may be the only effective way to bring blood pressure down, but lifestyle changes should be continued with medication.
- E. Neuromuscular disorders can result from electrolyte imbalances.
 - 1. Seizures are uncontrollable muscle spasms.
 - 2. Muscle cramps are involuntary, spasmodic, and painful muscle contractions that last for many seconds or even minutes.
- F. Kidney disorders commonly affect body fluids because the kidneys play a major role in the regulation of fluid, electrolyte, and acid-base balance.
- G. Congestive heart failure may be managed with fluid restriction.
- H. Intake of sugary drinks can promote obesity.

Key Terms: dehydration, heat stroke, overhydration, hypertension (HTN), salt sensitivity, salt resistant, DASH diet, seizure, muscle cramps

Figures and Table:

Figure 9.11: Urine color chart.

Figure 9.12: The DASH diet.

Table 9.3: Percentages of Body Fluid Loss Correlated with Weight Loss and Symptoms

Activities

1. To demonstrate the movement of water into cells, place a piece of limp celery into a container of water with red food coloring added. Examine the celery every 30 minutes during class to check for firmness and to observe the location of the dye.
2. Ask for volunteers to prepare at home one of their favorite vegetables without adding salt or another sodium additive and to bring it to class. Ask other students to volunteer to bring in several different salt substitutes, including seasoning mixtures. Divide the prepared vegetables into portions. Leave some vegetables unflavored. Add the salt substitutes to others. Allow students to sample the various flavored and unflavored vegetables.
3. Have students make a list of the beverages that are available on campus in the vending machines and the dining establishments. Develop a chart or pamphlet with the typical serving, calories, macronutrients, and electrolytes. Sugar content should be included. Students can determine what additional information could be added to the pamphlet to educate other students and help improve their beverage consumption.
4. Have students create a list of the ill effects of caffeine, both those they believe and those they have heard. Then ask them to research those claims for validity and list the benefits of caffeine, coffee, and tea. Note: All three have specific benefits. Discuss their findings.
5. Provide students with more information on the DASH diet. You can retrieve information from: www.nhlbi.nih.gov/health/health-topics/topics/dash. Have students compare the DASH eating plan to a low-sodium diet in terms of prevention and treatment of hypertension, other benefits, and the overall acceptability and ease-of-use of each diet.

Diet Analysis Activity

6. Using the nutritional assessment previously completed, students should note the following:
 - a. How many milligrams of sodium do you consume daily?
 - b. How does your sodium intake compare to recommendations?
 - c. What three foods that you consumed contained the highest amount of sodium? How many milligrams of sodium were in each food?
 - d. How many milligrams of potassium do you consume daily?
 - e. How does your potassium intake compare to recommendations?
 - f. How much water do you consume daily? (MyDietAnalysis only)
 - g. How does your water intake compare to recommendations? (MyDietAnalysis only)

Nutrition Debate Activity

7. Most health organizations recommend that healthy adults consume no more than 2,400 mg of sodium daily. Have students search for research that would have led to this recommendation. A prescribed low-sodium diet limits daily sodium to 1,500. Debate the value of setting the sodium recommendation for healthy adults so low. Now that researchers realize the importance of other nutrients in maintaining blood pressure, should less emphasis be placed on sodium while more emphasis is placed on other nutrients? Discuss the implications of the three recommendations above.

Web Resources

US Environmental Protection Agency

water.epa.gov

International Bottled Water Association

www.bottledwater.org

MEDLINE Plus Health Information

www.nlm.nih.gov/medlineplus

National Heart, Lung, and Blood Institute

www.nhlbi.nih.gov

American Heart Association

www.americanheart.org

National Institutes of Health

www.nih.gov
