

BODY FLUID COMPARTMENTS

In a 70-kg adult man, the total body water is about 60% of the body weight, or about 42 liters. The total body fluid is distributed mainly between two compartments:

- Intracellular fluid.
- Extracellular fluid.
 - i) Interstitial fluid.
 - ii) Blood plasma.

INTRACELLULAR FLUID COMPARTMENT:

- Intracellular fluid is the body fluids inside the cells.
- It constitutes about 40% of the total body weight (28 liters) in an “average” person.
- The intracellular fluid contains only small quantities of sodium and chloride ions and almost no calcium ions. Instead, it contains large amounts of potassium and phosphate ions plus moderate quantities of magnesium and sulfate ions.
- Cells contain large amounts of protein—almost four times as much as in the plasma.

EXTRACELLULAR FLUID COMPARTMENT (INTERNAL ENVIRONMENT)

- It includes all the fluids outside the cells.
- In the extracellular fluid are the ions and nutrients needed by the cells to maintain life. Thus, all cells live in essentially the same environment—the extracellular fluid. For this reason, the extracellular fluid is also called the internal environment of the body.
- It accounts for about 20% of the body weight, or about 14 liters in a 70-kg man.
- The two largest compartments of the extracellular fluid are:
 - i) Interstitial fluid, which makes up more than three-fourths (11 liters) of the extracellular fluid.
 - ii) The plasma, which makes up almost one-fourth of the extracellular fluid, or about 3 liters.
- The plasma is the noncellular part of the blood; it exchanges substances continuously with the interstitial fluid through the pores of the capillary membranes. These pores are highly permeable to almost all solutes in the extracellular fluid, except the proteins. Therefore, the extracellular fluids are

constantly mixing so the plasma and interstitial fluids have about the same composition, except for proteins, which have a higher concentration in the plasma. The concentrations of ions in interstitial fluid and plasma are considered to be about equal.

- Extracellular fluid contains large amounts of sodium and chloride ions and reasonably large amounts of bicarbonate ions but only small quantities of potassium, calcium, magnesium, phosphate, and organic acid ions.

Homeostasis:

- It is a term used to describe maintenance of nearly constant conditions in the internal environment. Essentially, all organs and tissues of the body perform functions that help maintain these relatively constant conditions.
- For example, the lungs provide oxygen to the extracellular fluid to replenish the oxygen used by the cells, the kidneys maintain constant ion concentrations, and the gastrointestinal system provides nutrients while eliminating waste from the body.

Regulation of Body Fluid Compartments

Water Balance :

- Cells are largely made of water and are surrounded by a “sea” of water.
- Water is constantly being exchanged between the cells and surrounding environment.
- Keeping a constant volume of water is essential for homeostasis.
- To maintain fluid balance: Total intake (2300 ml) = Total loss (2300 ml)

DAILY INTAKE OF WATER

Water is added to the body by two major sources:

(1) it is ingested in the form of liquids or water in food, which together normally add about 2100 ml/day to the body fluids.

(2) it is synthesized in the body by oxidation of carbohydrates, adding about 200 ml/day.

These mechanisms provide a total water intake of about 2300 ml/day

However, intake of water is highly variable among different people and even within the same person on different days, depending on climate, habits, and level of physical activity.

DAILY LOSS OF BODY WATER

Insensible Water Loss:

- It occurs continually in all living people.
- Insensible water loss through the skin occurs independently of sweating .
- It account for about 700 ml/day of water loss under normal conditions.
- This type of water loss is by evaporation from the respiratory tract and diffusion through the skin.

Fluid Loss in Sweat:

- The amount of water lost by sweating is highly variable, depending on physical activity and environmental temperature.
- The volume of sweat normally is about 100 ml/day, but in very hot weather or during heavy exercise, fluid loss in sweat occasionally increases to 1 to 2 L/hour.

Water Loss in Feces:

- Only a small amount of water (100 ml/day) normally is lost in the feces.
- This loss can increase to several liters a day in people with severe diarrhea.

Water Loss by the Kidneys:

- The remaining water loss from the body occurs in the urine excreted by the kidneys (1400 ml/day).
- Multiple mechanisms control the rate of urine excretion.

BLOOD VOLUME: Blood is considered to be a separate fluid compartment because it is contained in a chamber of its own, the circulatory system. The blood volume is especially important in the control of cardiovascular dynamics. The average blood volume of adults is about 7% of body weight, or about 5 liters. About 55% of the blood is plasma and 45% is blood cells, but these percentages can vary considerably in different people, depending on sex, weight, and other factors.

EDEMA: EXCESS FLUID IN THE TISSUES

Edema refers to the presence of excess fluid in the body tissues. In many cases, edema occurs mainly in the extracellular fluid compartment, but it can also involve intracellular fluid accumulation.

INTRACELLULAR EDEMA

Conditions that cause intracellular swelling:

- (1) Hyponatremia.
- (2) Depression of the metabolic systems of the tissues.
- (3) Lack of adequate nutrition to the cells.
- (4) Intracellular edema can also occur in inflamed tissues. Inflammation usually increases cell membrane permeability, allowing sodium and other ions to diffuse into the interior of the cell, with subsequent osmosis of water into the cells.

EXTRACELLULAR EDEMA

Extracellular edema occurs when excess fluid accumulates in the extracellular spaces.

There are two general causes of extracellular edema:

- (1) abnormal leakage of fluid from the plasma to the interstitial spaces across the capillaries.
- (2) failure of the lymphatics to return fluid from the interstitium back into the blood, often called *lymphedema*.

The most common clinical cause of interstitial fluid accumulation is excessive capillary fluid filtration.

Conditions that can cause extracellular edema:

I. Increased capillary pressure

A. Excessive kidney retention of salt and water

1. Acute or chronic kidney failure
2. Mineralocorticoid excess

B. High venous pressure and venous constriction

1. Heart failure
2. Venous obstruction
3. Failure of venous pumps
 - a) Paralysis of muscles
 - b) Immobilization of parts of the body
 - c) Failure of venous valves

C. Decreased arteriolar resistance

1. Excessive body heat
2. Insufficiency of sympathetic nervous system
3. Vasodilator drugs

II. Decreased plasma proteins

A. Loss of proteins in urine (nephrotic syndrome)

B. Loss of protein from denuded skin areas

1. Burns
2. Wounds

C. Failure to produce proteins

1. Liver disease (e.g., cirrhosis)
2. Serious protein or caloric malnutrition

III. Increased capillary permeability

A. Immune reactions that cause release of histamine and other immune products

B. Toxins

C. Bacterial infections

D. Vitamin deficiency, especially vitamin C

E. Prolonged ischemia

F. Burns

IV. Blockage of lymph return

A. Cancer

B. Infections (e.g., filarial nematodes)

C. Surgery

D. Congenital absence or abnormality of lymphatic vessels

DEHYDRATION: Loss of fluid from all fluid compartments of the body with an accompanying disruption of metabolic processes is called *dehydration*. It occurs when free water loss exceeds free water intake, usually due to exercise, disease, or high environmental temperature. Dehydration can be fatal when fluid loss exceeds more than 15% of the total body water.

Dehydration can be classified according to serum sodium concentration into hypernatremic, hyponatremic, or isonatremic dehydration.

1. If water loss is greater in comparison to sodium loss, then the serum sodium concentration increases, resulting in hypernatremic (or hypertonic) dehydration.

Causes:

- i) Fever.
- ii) Polyuria:

- iii) Decreased water intake
- iv) Excessive sweating
- v) End-stage renal disease

2. If water loss is accompanied by excessive sodium loss, then the serum sodium concentration decreases, resulting in hyponatremic (or hypotonic) dehydration.

Causes:

- a) Addison's disease
- b) Renal tubular acidosis
- c) Iatrogenic causes: hypotonic fluids or regular saline used for IV hydration in patients with heat stroke or diarrhea.
- d) Diuretics: loop, thiazide, and osmotic diuretics, especially with prolonged use.
- e) Cystic fibrosis.

3. If water and sodium are lost at the same rate, then the serum sodium concentration remains the same. This is called isonatremic (or isotonic) dehydration.

Causes:

- i. Vomiting and diarrhea:
- ii. Excessive sweating

Signs and Symptoms of Dehydration

- Most patients with dehydration present with: thirst, headaches & fatigue.
- Symptoms of mild dehydration include: constipation, dry mouth, dizziness, low urine volume (unless the cause of dehydration is polyuria)
- Symptoms of more severe dehydration include: dry skin, sunken eyes, dry mucous membranes, confusion, dizziness, hypotension, tachycardia, fever, poor skin elasticity, lethargy, oliguria, seizures, shock, coma & death.
- Signs of hypovolemia may also be present, including: tachycardia, orthostatic hypotension, flat neck veins.
- Dehydration is more clinically evident in the elderly, especially in hot weather, due to impaired thirst sensation. Elderly or hospitalized patients will show signs of irritability and, occasionally, delirium.