

1.1 Introduction

Subjects who engage in physical activity usually do so in varying environmental conditions (e.g. temperature, humidity, wind, etc.), which are not always replicated. This variability – which is subject to other factors, such as clothing, hydration status or the athlete's metabolic rate – can induce significant increases in body temperature (Sawka, Wenger & Pandolf, 1996). These increases can cause a heat-loss response in the body through increased blood flow as well as perspiration. Since this response can be variable and, at times, very elevated, the amount of replenished water and/or electrolytes must be sufficient in order to minimize the impact to athletic performance and/or prevent clinical damage to the subject's health (Sawka & Young, 2005).

As evidenced by literature, the quality, quantity and consistency of scientific articles related to this theme is determined as one of the important factors to consider (and, therefore, to keep in mind) in order to achieve improvements when practicing sports.

The extensive documentation on this subject obliges us review, in this Module, the different recommendations regarding rehydration strategies (to be taken into account before, during and after exercising) as well as the assessment of subjects' hydration.

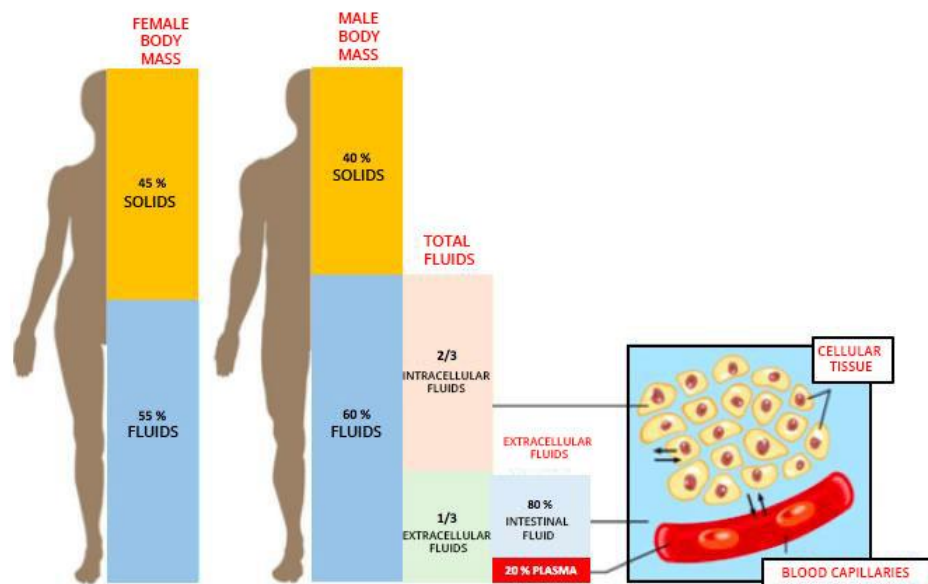
We will also expand on a few basic concepts linked to thermoregulation, as well as a practical approach to how individuals perform in the face of different environmental conditions, energy expenditure, and other factors that must be considered.

1.1.1 The Function of Water

Water is the most abundant component found in the human body, as it constitutes between 40 and 70% of total body mass (variations stem from each subject's gender, age and body composition). While the content between one subject and another is variable, content within the tissue tends to be relatively constant.

The body has two fluid compartments: the first is the intracellular compartment, which refers to the fluid within cells, and it constitutes two-thirds of the total amount of body water; the second is the extracellular compartment, which comprises the interstitial fluid (between cells) and plasma (20% of extracellular liquid). Cerebrospinal, glandular, ear and eye fluids also comprise extracellular fluids.

Figure 1: Distribution by Fluid Compartment



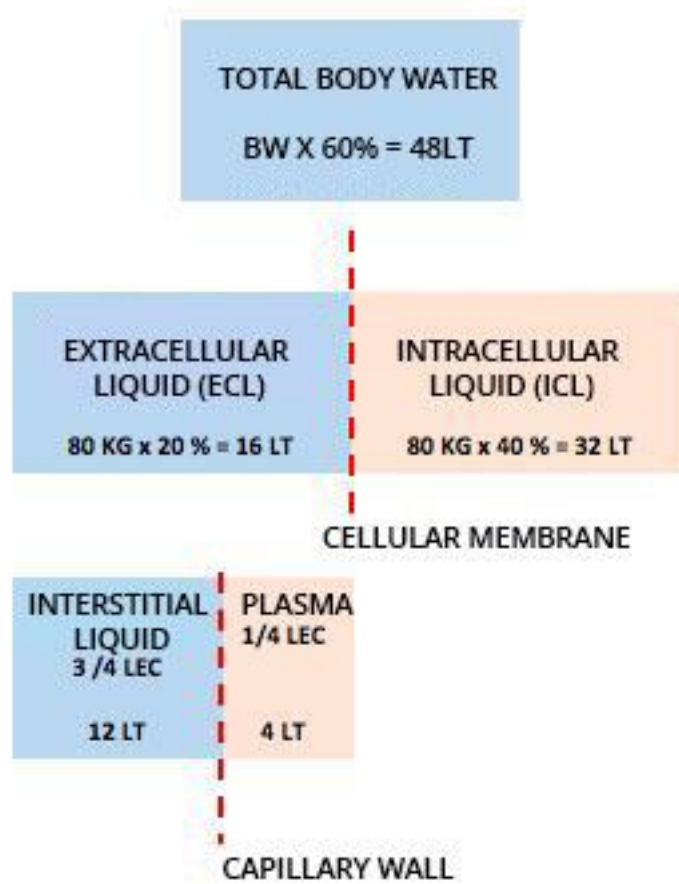
Source: Retrieved from goo.gl/duc7dJ

As we can see in the graph, approximately 60% of total body water is represented in the intracellular compartment, while the remaining 40% corresponds to extracellular sources. Water comprises between 65 and 75% of muscle weight and 10% of fat weight. Taking this into account, people with more fat tend to have a lower percentage of water in their bodies than those who are proportionately leaner.

These volumes reflect averages of a dynamic exchange of liquid between the two different compartments, particularly in physically active men and women. Intense physical training predisposes the body to increase the amount of water distributed within the intracellular compartment, because muscle mass usually increases.

In this game of percentages, we must understand that the largest loss of fluids through sweat comes from the extracellular compartment, through blood plasma.

Figure 2: Distribution of Body Water in a 80 kg Man



Source: Prepared by the author.

1.1.2 Distribution of Body Water and its Composition

Sodium is the principal electrolyte found in extracellular fluid, while potassium is significantly less concentrated. On the other hand, the principal electrolyte found in intracellular fluid is potassium, with small concentrations of sodium. It is essential for the body that this distribution of electrolytes is maintained properly, so that chemical and electrical gradients ensure the integrity of cellular function, allowing electric communication throughout the body.

There's a constant exchange between the two different body water compartments, which depends, to a certain extent, on the osmolality of the bodily fluids. Osmolality refers to the amount of solutes dissolved in 1 kg of solvent. One mole of a non-splittable substance, such as glucose, dissolved in 1 kg of solvent, is equivalent to 1 osmole. One millimole (mmol), on the other hand, is equivalent to one milliosmole (mosm). If the substance is split into two ions, as in the case of sodium chloride, one mole is equivalent to two osmoles. There are many substances in the body that affect osmolality. For example, sodium and its associated anions – chloride and bicarbonate – are the largest source of plasma's

osmotically active components, together with plasma proteins, the latter of which contribute in a small but important way.

Another term related to osmolality is tonicity, which means tension or pressure. When two solutions with different solute concentrations are separated by a permeable membrane, the pressure difference between solutions allows water to move. This pressure is called osmotic pressure. When two solutions have the same osmotic pressure or the same solute content, they are called isotonic.

When we compare two solutions with different solute concentrations, whichever has the highest osmotic pressure is called hypertonic (high solute concentration and low water content) and the other is called hypotonic (low solute concentration and high water content). Water moves between the membrane of a hypotonic solution towards a hypertonic one in order to balance the different concentrations on both sides of the membrane.

This is why the following details are so important, as we will explain the importance of isotonic drinks in rehydration, because, when they have osmolality similar to that of the plasma, it is easier for them to be absorbed by the intestine.

1.1.3 Fluid Balance

Fluid balance is obtained from the net difference between water loss and gain. This balance may vary depending on the factors which impact the relation of the two.

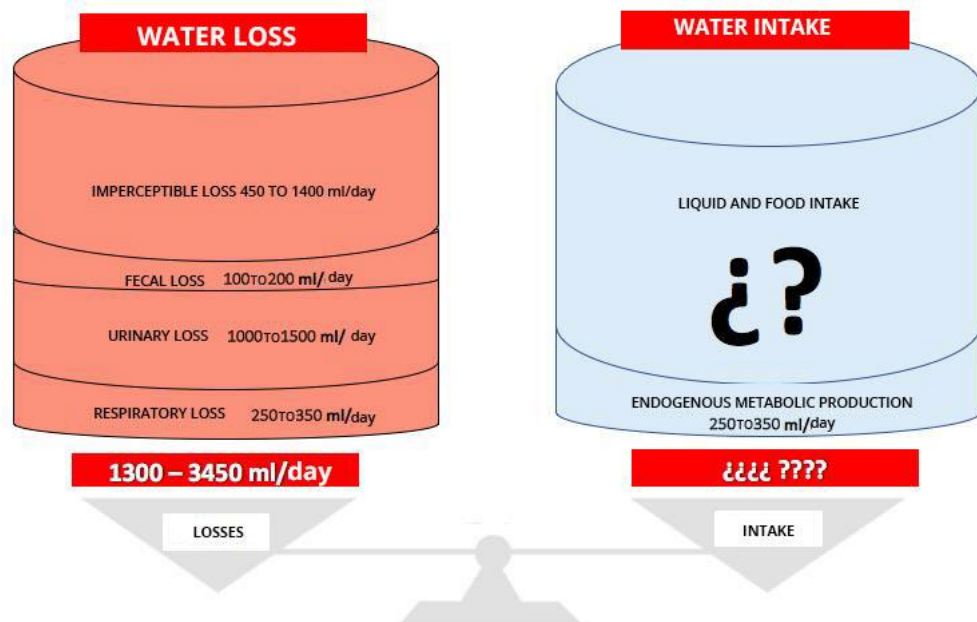
Water intake

In a regular thermal environment (approximately 20°C), a sedentary adult requires nearly 2.5 liters of water per day (beyond the differences we'll review later regarding fluid intake recommendations at the global level).

There are three main sources of water intake:

- **Water in food:** generally speaking, water in food constitutes, approximately, around 20 or 30% of the recommended total fluid intake. Fruits and vegetables contain a considerable amount of water, while, on the other hand, baked goods, cereals, chocolates or high-fat foods contain a small amount of water (Food Standard Agency, 2002).
- **Water from fluids:** in normal conditions, the average individual drinks between 1,200 and 1,500 milliliters of water every day, on account of the amount of fluids he or she drinks during the four main meals. Thus, both intense physical activity and thermal stress increase daily fluid needs by about 4 to 5 times. Food intake is critical in order to ensure complete rehydration on a day-to-day basis. The loss of electrolytes via sweat (e.g., sodium and potassium) must be recovered in order to restore the total body water; this can be achieved mostly through food (ACSM, 2007).
- **Endogenous metabolic production:** the degradation of nutrients' molecules via metabolism forms carbon dioxide and water. This metabolic water provides nearly 14% of the daily water needs of a sedentary person. The metabolism of glucose releases 55 grams of metabolic water. A larger amount of water also stems from protein catabolism (100 grams) and fat (107 grams). Production of metabolic water is usually equivalent to the water lost due to breathing.

Figure 3: Daily Fluid Balance



Source: Prepared by the author.

Water Output

The outflow of water from the body can occur in the following ways:

- **Loss of water through urine:** In normal conditions, the kidneys absorb nearly 99% of the 140 to 160 liters of renal filtration that builds up every day. Because of this, the volume of urine excreted by the kidneys varies between 1,000 and 1,500 milliliters per day.
- **Loss of water through the skin:** each day, nearly 350 milliliters of water are filtered from the deepest tissues through the skin all the way to the body's surface, through imperceptible transpiration. Water loss via the skin also occurs through perspiration produced by sweat glands. Sweat evaporation takes place as a refrigeration mechanism for the body. This produces between 500 and 700 milliliters of sweat each day, under regular thermal conditions and normal physical activity. Clearly, the amounts lost to this type of fluid loss are completely different depending on the variability of environmental conditions as well as energy expenditure.
- **Loss of water through vapor:** imperceptible water loss through small exhaled drops of water in the air are between 250 and 350 milliliters per day, due to the complete humidification of the inhaled air as it goes through the pulmonary tract. Physical activity affects this source of water loss. In physically active people, the respiratory tract releases between 2 and 5 milliliters of water for each minute of intense training, depending on climatic conditions. Loss of water through the respiratory tract is lesser in warm and humid climate, and greater in cold temperatures (this inhaled air contains less humidity) and high altitudes (because the volumes of inhaled air, requiring humidity, are much greater than at sea level).
- **Loss of water through feces:** intestinal disposal produces between 100 and 200 milliliters of water loss, because fecal matter is nearly 70% water. In the case of diarrhea or vomit, water loss increases to the point that it becomes a dangerous situation, often causing a rupture in the balance of fluids and electrolytes.

1.1.4 Recommendations for Water Intake

The human body has the ability to adapt to the variability between fluid intake and loss due to, on one hand, precise homeostatic regulation, and, on the other, the broad ranges of urine osmolarity that kidneys can achieve.

To this date, and beyond the studies conducted regarding the subject in question, no minimum or maximum values have been precisely identified for informing the general population.

In Table 1, we can see that several world-renowned authorities propose varying reference values regarding total water intake (IOM, 2004).

Table 1: Intake Recommendations, According to World-Renowned Authorities, in Liters per Day

	European Food Safety Authority 2010	National Health and Medical Research Council, 2006	Institute of medicine, 2004	World Health Organization, 2003
MALES	2,5	3,4	3,7	Sedentary 2,9
				Active 4,5
FEMALES	2,0	2,8	2,7	Sedentary 2,2
				Active 4,5

Source: Retrieved from www.h4hinitiative.com

Clearly, and in relation to what we have previously seen in this module, we can interpret that, in the face of different environmental conditions as well as the intensity/volume in energy expenditure, recommendations for athletes are completely individual in nature. The American College of Sports Medicine suggests, in its 2007 position, that fluid intake illustrates the need to make recommendations regarding consumption in relation to individual sweat rate (later in the module, we'll see how to obtain it).

Physical activity, ambient temperature and relative humidity are the three factors that determine the broad variability in the amount of water the subject needs to compensate for liquid loss through sweat.