Water and Hydration:
Physiological Basis in Adults
# Introduction

## I. Water in the human body: content and distribution

### I.1. Water content of the human body

#### I.1.1. Total body water

#### I.1.2. Water content of different organs

#### I.1.3. Distribution among body compartments

### I.2. Water absorption and distribution in the body

## II. Body water balance

### II.1. Body fluid losses

#### II.1.1. Insensible water losses

#### II.1.2. Fecal water losses

#### II.1.3. Sweat production

#### II.1.4. Urinary water losses

### II.2. Body water inputs

#### II.2.1. Metabolic water production

#### II.2.2. Dietary intakes

### II.3. The regulation and maintenance of body water balance

#### II.3.1. Regulation of fluid intake: physiological thirst, social and environmental factors

#### II.3.2. Regulation of water excretion by the kidneys

#### II.3.3. Body water balance impairments: dehydration and hyponatremia

## III. Recommendations for daily water intake

## Conclusion

## References
Water and Hydration: Physiological Basis in Adults

Introduction

Water, accounting on average for 60% of the body weight, is the largest component of the human body. It is essential to life and we cannot live more than a few days without water.

Water has indeed numerous functions in the body: it is the building material for cells and body fluids; it acts as a reaction medium, as a solvent and as a reactant. It is also the transporter of nutrients and helps in the elimination of body wastes through urine. It is essential for the control of body temperature through sweat evaporation.

The aim of the document is to review the current scientific evidence on hydration physiology, with a focus on adults, as being representative of the majority of the population. It details the water content, absorption and distribution in the human body, reviews the sources of fluid losses and water inputs and the regulation of body water balance. It finally gives overview of the main recommendations for daily water intake.
I. Water in the human body: content and distribution

Water is the main component of the human body; it is distributed throughout the body, in every organ, inside and between cells.

I.1. Water content of the human body

I.1.1. Total body water

Water represents on average 60% of the body weight in adult men, and 50-55% in women (EFSA 2010; IOM 2004). This means that, for a man of average weight (70 kg), body water content is about 42 liters.

This average value varies among individuals, primarily because of differences in body composition: while the water content in lean body mass is constant among in mammals, at 73%, adipose tissue (body fat) is only about 10% water (Peronnet et al. 2012; Sawka et al. 2005; Wang et al. 1999). Therefore, body fat relative mass directly influences total body water. This explains the influence of age, gender and aerobic fitness on total body water: women and older persons have lower total body water, because of lower fat-free mass. In contrast, athletes have relatively high total body water (IOM 2004; Marieb and Hoehn 2007; Watson et al. 1980).

I.1.2. Water content of different organs

Water is distributed throughout the body and organs. The water content of various organs depends on their composition, and ranges from 83% in blood to only 10% in adipose tissue (Figure 1).

![Figure 1. Water composition of tissues and organs by weight.](Adapted from Pivarnik and Palmer 1994.)
I.1.3. Distribution among body compartments

Water is distributed in the body among two main compartments: intracellular and extracellular. The intracellular compartment, representing about two thirds of body water, is the largest, representing about two thirds of body water. The extracellular compartment, representing about one third of body water, comprises plasma fluid and interstitial fluid (Armstrong 2005; Marieb and Hoehn 2007) (Figure 2). Plasma fluid and interstitial fluid have a similar electrolyte composition, the most abundant ions being sodium and chloride (IOM 2004; Marieb and Hoehn 2007; Robertson and Berl 1996).

Other compartments also contain water, such as lymph, eyeball fluid and cerebrospinal fluid for example. These compartments make up a relatively small water volume, and are usually considered to be part of the interstitial fluid (Marieb and Hoehn 2007).

![Figure 2. Distribution of total body water among compartments.](image-url)
I.2. Water absorption and distribution in the body

After ingestion, water is absorbed in the gastrointestinal tract. It then enters the vascular system, goes to interstitial spaces, and is transported to every cell (Figure 3). Intracellular water comprises 65% of all total body water.

Figure 3. Water’s journey from ingestion to cells.

After leaving the stomach, water is absorbed mostly in the early segments of the small intestine, the duodenum and the jejunum. A small portion of all water absorption occurs in the stomach and the colon (Shaffer and Thomson 1994); the small intestine absorbs 6.5L/day, whereas the colon absorbs 1.3L/day. These amounts correspond to the water ingested daily, in addition to the water produced by secretions from salivary glands, stomach, pancreas, liver and the small intestine itself (Zhang et al. 1996). The absorption process is very rapid: a recently published study showed that ingested water appears in plasma and blood cells as soon as 5 minutes after ingestion (Peronnet et al. 2012).

Water passes from the intestinal lumen into plasma mainly by passive transport, regulated by osmotic gradients. Water molecules are then transported via blood circulation to be distributed all over the body, to the interstitial fluids and to cells.

Water moves freely in the interstitial compartment and moves across cell membranes via water specific channels, the aquaporins. Fluid exchanges between compartments are regulated by osmotic and hydrostatic pressure, and water flows in accord with changes in the extracellular fluid osmolality (Marieb and Hoehn 2007).

The body water pool is renewed at a rate depending on the quantity of ingested water: the more a person drinks, the faster body water is renewed. For a man drinking 2L of water per day, a molecule of water stays in the body on average 10 days, and 99% of the body water pool is renewed within 50 days (Peronnet et al. 2012).

The renewal of body water is driven by ingested water, replacing the constant losses the body is facing. This allows for the maintenance of body water balance.
Water represents on average 60% of body weight in adult men. However, this percentage decreases along with lean body mass.

- Most of the organs and tissues contain more than 70% water: blood and kidneys consist of 83% water, and muscles 76% water. However, adipose tissue contains only 10% of water.

- Two third of the body water is intracellular. The extracellular fluid consists of plasma and interstitial fluids.

- Ingested water is absorbed mainly in the small intestine. It appears in the blood as soon as 5 minutes after ingestion.

- The body water pool is renewed at a rate depending on the quantity of ingested water. For a man drinking 2L of water per day, a molecule of water stays in the body on average 10 days, and 99% of the body water pool is renewed within 50 days.
II. Body water balance

Under moderate ambient temperatures and with a moderate activity level, body water remains relatively constant. Body water balance, defined as the net difference between the sum of water intake plus endogenous water production, and minus the sum of losses (EFSA 2010), is indeed tightly controlled to respond to changes in consumption and losses and maintain homeostasis (Grandjean and Campbell 2004).

Water losses occur mainly through urine, sweat, insensible losses (skin and lungs) and stools. Metabolic water production compensates only a small part of these losses, which therefore have to be compensated by dietary intakes from food and fluids to reach water balance (EFSA 2010).

II.1. Body fluid losses

The main sources of water losses for the body are urine and sweat. These losses vary widely depending on fluid consumption, diet, physical activity and temperature. The body also loses water insensibly, through skin, lungs (breathing), and through stools (EFSA 2010).

II.1.1. Insensible water losses

Insensible water losses, called as such because usually not perceived by the subject, include water lost from skin evaporation and through breathing (Sherwood 2010).

Water diffusion to the epidermis is essential for the normal functioning of the skin, as this physiological process enables hydration of the superficial layers of the skin. It eventually leads to some water evaporation at the skin surface (Verdier-Sevrain and Bonte 2007). In adults, insensible diffusion through skin represents about 450 mL/d. This figure varies with ambient temperature, humidity, air currents or clothing (EFSA 2010).

Water is also lost via evaporation from the lungs, when breathing. In sedentary people, this loss represents about 250 – 300 mL/day. It increases with physical activity level, along with the increase of ventilatory volume: active persons at sea level have respiratory losses of about 500 – 600 mL/day. This water loss also increases with altitude, especially when temperature and humidity are low (EFSA 2010; Grandjean et al. 2003). Respiratory losses are approximately equal to metabolic water production regardless of physical activity level (Hoyt 1996) (see also part II.2.1).

II.1.2. Fecal water losses

Fecal water losses are relatively small in healthy adults, about 200 mL/d in normal conditions (EFSA 2010). This quantity can increase dramatically in case of diarrhea, from 5 to 8 times above normal in infants (Fomon 1993).
II.1.3. Sweat production

Sweat production is highly variable: low for sedentary people exposed to moderate temperature, it can reach several liters per day during intense physical activity, high ambient temperature, and/or high humidity (EFSA 2010). The body adapts sweat production to maintain body core temperature (Powers and Howley 1997).

Sweat is produced in the dermis by sweat glands. It comes from interstitial water and is filtered deep in the sweat gland tubule before being reabsorbed distally (Figure 4). Sweat is usually 99% water, with a pH between 5 and 7. It contains approximately 0.5% of minerals (potassium and sodium chloride) and 0.5% of organic substances (urea, lactic acid) (Montain et al. 2007).

Figure 4. Sweat production by sweat glands.
Sweat is the major mechanism for thermoregulation for active people. During physical activity, for example, metabolic efficiency of the muscles is about 20%, liberating 80% of energy as heat (Powers and Howley 1997). Sweat evaporation is, in this process, particularly efficient: the evaporation of 1 liter of sweat at 30°C results in 580 kcal lost as heat (Wenger 1972).

However, sweat evaporation is influenced by several factors including temperature, humidity, air currents, intensity of sunshine, and clothing (EFSA 2010). The higher the humidity, the less sweat will evaporate and therefore cool the body (Powers and Howley 1997). Wearing impermeable clothing, i.e. which does not allow sweat evaporation, both increases sweat losses and hampers body cooling (Havenith et al. 2008). On the contrary, convective currents around the body help in sweat evaporation (Powers and Howley 1997).

Sweat production during physical activity can be very different depending on factors such as the considered sport and intensity (training or competition), and on personal and environmental factors. Sweat rate varies within a range of about 0.3 to 2.6 L/h (Sawka et al. 2007). Examples of sweat rate for male practicing different sports are given in Table 1.

<table>
<thead>
<tr>
<th>Sport</th>
<th>Intensity</th>
<th>Ambient temperature (°C)</th>
<th>Approximate sweat rate (L/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running</td>
<td>Moderate</td>
<td>22</td>
<td>1.41</td>
</tr>
<tr>
<td>Cycling</td>
<td>Moderate</td>
<td>20</td>
<td>1.1</td>
</tr>
<tr>
<td>Soccer</td>
<td>Training</td>
<td>25</td>
<td>1.0</td>
</tr>
<tr>
<td>Basketball</td>
<td>Training</td>
<td>24</td>
<td>1.0</td>
</tr>
<tr>
<td>Waterpolo</td>
<td>Training</td>
<td>27</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Table 1. Approximate sweat rate for males practicing different sports. 
*Adapted from Rehrer and Burke 1996.*

Sweat losses can therefore have an important impact on the water balance, and water intake should be adapted depending on the activities and subsequent sweat losses (Armstrong 2007).
II.1.4. Urinary water losses
Quantitatively, urinary water losses usually represent the largest loss of water in healthy, adults who do not exercise. Urine volume can however vary over a wide range, from about 500 mL to about several liters per day (EFSA 2010). Most of the other water losses are unregulated and occur irrespectively of the body fluid status; intakes are also partially regulated. On the opposite, urine volume is tightly controlled and serves as a way to tightly regulate the body fluid balance (see part II.3), along with its other role of solute waste excretion.

Urine is in fact the result of the two major functions of the kidneys; the excretion of solute wastes and the regulation of body fluid volumes. In most cases, these functions can be achieved independently: for example if there is a high amount of water to eliminate, there will be no substantial changes in the amount of total solute load to be excreted. This relies on the ability of kidneys to produce a wide range of urine concentration, from 50 mOsm/L to 1200 mOsm/L (Brenner and Rector 2008). This maximal urine osmolarity constitutes a limit above which the two functions of kidneys cannot coexist anymore: it defines a minimal obligatory volume strictly necessary to excrete the solute load, whatever the body water balance status. Most of the solute load eliminated by kidneys come from the ingested foods, either as such (e.g. minerals) or as a result of metabolism (e.g. urea). For example, in a diet containing 650 mOsm, the minimal obligatory urine volume will be 500 mL, if kidneys are at their maximal concentration capacity (EFSA 2010). The water eliminated on top of this minimal obligatory volume is the excess water eliminated during water balance regulation. The table below (Table 2) indicates the urine volume to be excreted depending on the solute load and on urine osmolality.

<table>
<thead>
<tr>
<th>Solute load (mOsmol)</th>
<th>Urine osmolality (mOsmol/L)</th>
<th>300</th>
<th>500</th>
<th>800</th>
<th>1200</th>
<th>1400</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td></td>
<td>1.3</td>
<td>0.8</td>
<td>0.5</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>600</td>
<td></td>
<td>2.0</td>
<td>1.2</td>
<td>0.8</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>800</td>
<td></td>
<td>2.7</td>
<td>1.6</td>
<td>1.0</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td>3.3</td>
<td>2.0</td>
<td>1.3</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>1200</td>
<td></td>
<td>4.0</td>
<td>2.4</td>
<td>1.5</td>
<td>1.0</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Table 2. Urine volume (Uvol, L) as a function of solute load to be excreted and urine osmolality.

\[ Uvol = \frac{SL}{Uosm}. \]

The determination of a desirable urine osmolality is therefore a key element for determining desirable urine volume, and consequently adequate intake. The European Food Safety Authority (EFSA) was the first agency to integrate this parameter for the setting of water adequate intake, considering a desirable urine osmolality to be 500 mOsmol/L. Considering a typical diet of 1600 mOsmol/day for men and 1000 mOsmol/day for women, the EFSA suggests that men would need a urine volume of 2.0 L/day and women of 1.6 L/day (EFSA 2010). These values are far above the minimum urine volume (and therefore the minimum fluid intake volume) required for the excretion of metabolic wastes. The hypothesis that desirable urine osmolality could be lower than the concentrating capacity of kidneys is also supported by observational results suggesting that high urine volumes and high fluid intakes could slow the decline of kidney function associated with aging and protect against chronic kidney disease (Clark et al. 2011; Sontrop et al. 2013; Strippoli et al. 2011).
URINE PRODUCTION AND CONCENTRATION/DILUTION PROCESS

The urinary tract system includes the kidneys, which produce urine. The urine then flows through the ureters to the bladder, where it is stored until its elimination via the urethra. Within the kidneys, urine is produced by the functioning units of the kidneys: nephrons. Each human kidney contains around one million nephrons (Figure 5) (Brenner and Rector 2008; Valtin and Schafer 1995).

![Figure 5. Urinary Tract and renal anatomy.](image)

Urine is elaborated from blood filtration in three steps (Figure 6):

1. **Filtration**: Blood is filtered in the glomerulus, along a pressure gradient in Bowman's capsule. The glomerulus, composed of fenestrated blood vessels, results in the retention of big molecules such as proteins and of blood cells; only smaller molecules enter the nephron at this stage. The filtrate is called primary urine. The glomerular filtration rate (GFR), or the rate of filtrate formation in kidneys is about 125 mL/min or 180L/day. The entire blood volume is thus filtered 50 times per day (Valtin and Schafer 1995).

2. **Reabsorption**: Most filtered substances are reabsorbed to preserve body homeostasis. For example, more than 99% of water and sodium are reabsorbed. Glucose is a small molecule and is thus found in primary urine. It is normally fully reabsorbed. The maximum reabsorption capacity for glucose is approximately 200 mg of glucose for 100 ml of plasma. When blood glucose level exceeds this limit, as in case of diabetes, the excess remains in urine (glycosuria).
3. **Secretion:** In the renal tubules, some additional substances are secreted from the blood into the tubular fluid and then eliminated in urine. The selective tubular secretion of hydrogenated ammonium ions helps to regulate plasma pH and the acid-balance of the body fluids. Metabolic end products such as creatine, and detoxification products are also secreted into renal tubules at this stage *(Guyton and Hall 2006).*

![Figure 6. Urine formation in the nephron.](image-url)
II.2. Body water inputs

To compensate for daily water loss, water inputs are necessary. The body produces a small quantity of water from its metabolic activity, but most of the water inputs come from the diet (food and fluids).

II.2.1. Metabolic water production

Metabolic water is produced by the oxidation of hydrogen-containing substrate or energy-yielding nutrients (IOM 2004). Lipid oxidation produces the most water per gram (Table 3).

![Table 3. Metabolic water produced by oxidation of lipids, carbohydrates and proteins.](From EFSA 2010, IOM 2004.)

Metabolic water production is therefore proportional to the energy intake. Metabolic water production is estimated to represent on average approximately 250 to 350mL/day for sedentary persons (EFSA 2010) but can increase up to 600 mL/day with strenuous physical activity (Pivarnik and Palmer 1994). However, as seen in part II.1.1, respiratory losses also increase with physical activity, and these two processes approximately offset each other (Hoyt 1996).

II.2.2. Dietary intakes

Dietary total water intakes are, by far, the most important source of water for the body. Because production of water by the body is limited, dietary intakes should compensate for most of the losses.

Water is consumed as drinking water, beverages, and food moisture. But drinking water and beverages represent the majority of the total fluid intake, on average 70-80%, while water in food represents only 20-30% (EFSA 2010).

This distribution varies depending on the diet: the higher the consumption of water-rich foods (e.g., fruits, vegetables or soup), the higher the intake of water from food. Fruits and vegetables are indeed the food group which contains the most water: from 96% in a cucumber to 72% in an avocado, most contain more than 85% water. It is noticeable that most fruits have approximately the same water content (in terms of %) as most beverages. Soups are the category that contains the second highest level of water, with values ranging between 82 and 95% water, depending on recipes. Dry products such as breakfast cereals, nuts, biscuits and chocolates often have a water content below 5% (Food Standard Agency 2002).

Water intake through drinking water and beverages varies widely between individuals, as shown in dietary surveys. In the 2005-2006 NHANES survey, the total water intake was more than three-fold higher in the 80th percentile (5.4L/day) compared to the intake in the 20th percentile (1.6L/day) (Sontrop et al. 2013). A recent survey in China reported individual daily total fluid intake ranging from less than 100mL to over 7L (Ma et al. 2012). Drinking habits also seem different depending on countries: national surveys in Europe report median daily fluid intakes ranging from 635 to 2490 mL/day (EFSA 2008). However, these surveys are difficult to
compare, and these wide variations are difficult to interpret, as it is not known whether they are due to actual consumption differences, or to differences in survey methodologies (i.e., 2-day dietary record, 7-day dietary record, 2-times 24h recall) and in liquid categorization (EFSA 2010). These limitations of fluid intake surveys have an important impact, as dietary recommendations are often based on consumption observed in these surveys (see also part III).

Water inputs and losses are dependent upon numerous factors, and some of them can be highly variable. Typical figures are summarized in Figure 7.

![Figure 7. Typical daily water inputs and losses.](image)

As illustrated above, urine is critical for the body to adjust losses, whereas dietary intakes, and in particular fluid intakes, are the main sources of water inputs.

II.3. The regulation and maintenance of body water balance

Despite continuous water losses and wide variations in water and salt intakes, the human body generally has the ability to maintain a tight constancy in water content: total body water is estimated to vary by less than 1% over 24 hours (Cheuvront et al. 2004). This is of primary importance for the maintenance of a constant composition of extracellular fluid, needed for the cells to function properly. Body water is controlled, on one hand, by fluid intake, stimulated by thirst, and on the other hand by renal excretion of water (Brenner and Rector 2008).

II.3.1. Regulation of fluid intake: physiological thirst, social and environmental factors

Physiologically, fluid intake is regulated by thirst, defined as the conscious desire to drink (Guyton and Hall 2006). But fluid intake can also occur, for example, because of habits, social influence, dry mouth, or accompanying food during meals (McKinley et al. 2004; McKinley and Johnson 2004). Thus, purposeful fluid intake has a substantial behavioral component that interacts with physiological mechanisms.

The main stimulus for thirst is an increase in plasma osmolality. This increase is detected by osmoreceptors that initiate neural mechanisms resulting in the sensation of thirst (McKinley and Johnson 2004). However, the secretion of the anti-diuretic hormone (ADH) in response to increased plasma osmolality occurs at a lower
threshold than the threshold for thirst, around 280 mOsm/kg versus 290-295 mOsm/kg respectively (Bouby and Fernandes 2003; Peters et al. 2007; Verbalis 2003). It is worth noting that the sensitivity and threshold of the osmoregulatory system, and of thirst in particular, vary widely between individuals (Bouby and Fernandes 2003).

Other factors can also induce thirst: a decrease in blood volume (>10%) or pressure, an increase in circulating angiotensin, or mouth dryness. On the contrary, gastric distension decreases thirst (Guyton and Hall 2006; Tanner 2009).

Fluid intake also often occurs without thirst sensation and without increased plasma osmolality (McKiernan et al. 2009; Phillips et al. 1984). Drinking is indeed often associated with eating: some studies have found that approximately 70% of fluid intake occurs peri-prandially (de Castro 1988; Engell 1988; Phillips et al. 1984). The intake of fluids is also influenced by their direct availability (Engell et al. 1996), and can be socially facilitated or inhibited by the presence of other individuals (de Castro and de Castro 1989; Engell et al. 1996; Peneau et al. 2009).

Fluid intake is therefore not driven only by physiological mechanisms, and the final regulation of body water balance relies on the regulation of water excretion by the kidneys.

**II.3.2. Regulation of water excretion by the kidneys**

As seen previously (part II.1.4), the kidneys have the ability to widely adapt the quantity of excreted water, while maintaining stable solute excretion. Depending on body hydration state and fluid intake, metabolic waste is therefore excreted in a more or less concentrated urine.

The excretion of water by the kidney is indeed regulated to maintain a constant composition and concentration of extracellular fluids and in particular a constant plasma osmolarity. This is made possible thanks to a feedback system based on the anti-diuretic hormone (ADH) or vasopressin.

In the case of water deficit, osmolality of the extracellular fluids, in particular of plasma, increases above its normal value (about 280 mOsmol/kg H2O). This increase, which in practice means an increase in plasma sodium concentration, is detected by osmoreceptors that stimulate the release of ADH. ADH is synthesized in the hypothalamus and stored in the posterior pituitary gland. Once ADH released, it is transported via the blood to the kidneys, where it increases the permeability of the distal tubules and collecting ducts to water. The increased water permeability causes increased water reabsorption and excretion of a small volume of concentrated urine. Water is therefore conserved in the body, while sodium and other solutes continue to be excreted. This causes the dilution of the extracellular fluids and therefore corrects the plasma osmolality (Figure 8) (Guyton and Hall 2006).
On the contrary, in case of excess water in the body, ADH secretion is decreased, water permeability in the nephrons is increased, which leads to less water reabsorption and larger amount of dilute urine excretion (Guyton and Hall 2006).

It is worth noting that ADH release is also stimulated by decreased blood pressure and blood volume, which occur in cases such as hemorrhage. However, ADH is considerably more sensitive to small changes in osmolality than changes in blood volume: a 1% decrease of plasma osmolality stimulates ADH secretion, whereas a 10% decrease in blood volume is necessary to clearly increase ADH levels (Guyton and Hall 2006).

The maintenance of body water balance therefore depends on different physiological processes: the renal regulation, thirst and drinking behavior, but also sweating. The relative importance of those physiological processes and their interactions depend upon the prevailing activities, as illustrated in Table 4 below (Armstrong 2007).
Table 4. Relative roles of physiological processes in body water balance, for different life scenarios.
Adapted from Armstrong 2007.

II.3.3. Body water balance impairments: dehydration and hyponatremia
Although tightly regulated, body water balance can encounter challenges leading to a temporary state of hypohydration or hyperhydration.

Dehydration is the process of losing body water, while hypohydration refers to an equilibrated state of body water deficit, and is therefore the result of dehydration (EFSA 2010). Depending on the relative loss of water and solutes from extracellular fluids, dehydration can be hypertonic (water loss concentrates extracellular water), hypotonic (sodium loss dilutes extracellular water) or isotonic (water and sodium losses with no change in concentration). The potential causes of these different types of dehydration are summarized in Table 5.

Table 5. Potential causes of three types of dehydration.
Adapted from EFSA 2010; Grandjean et al. 2003; IOM 2004.
On the contrary, excessive consumption of water over a short period of time may lead to hyperhydration and hyponatremia, defined as serum sodium levels less than 135 mmol/L. This condition has been observed in psychiatric patients with polydipsia, but also in athletes during or after intense and prolonged exercise (e.g., ultra-marathon, military training). While potentially serious, symptomatic hyponatremia is rare, and is associated with fluid consumption that far exceeds water losses, as well as slow running pace and extended exercise duration (Hew et al. 2003). However, in healthy people with normal dietary habits, it is well-recognized that hyponatremia is very difficult to achieve (EFSA 2010; IOM 2004). Indeed, it would mean, in healthy individuals, exceeding the kidney’s maximal excretion rate, i.e. 0.7 – 1.0 L/hour (EFSA 2010).

The diagnosis and proper treatment of hyponatremia is complicated by the fact that symptoms are closely related to those of dehydration, including headache, fatigue, confusion, nausea, vomiting, and cramps. (EFSA 2010; Grandjean et al. 2003; IOM 2004).

**KEY MESSAGES**

Body water balance is tightly regulated, to ensure body homeostasis and to respond to changes in consumption and losses.

- The main sources of water losses from the body are urine and sweat, but water is also lost through stools and insensibly through skin and breathing.

- The adjustment of urine volume is critical for the body to regulate the body water balance.

- The kidneys are able to concentrate or dilute urine within a wide range, from 50 mOsmol/L to 1200 mOsmol/L. Urine concentration within those ranges depends on the metabolic wastes to be excreted and on the quantity of water to be excreted for body water regulation.

- Observational studies suggest that high urine volumes, and therefore high fluid intakes, could slow the decline of kidney function which occurs with aging, and protect against chronic kidney disease.

- Dietary fluid intake should compensate for most of the body water losses. Drinking water and beverages represent 70 to 80% of total fluid intake, while water coming from food represents about 20-30% of the total intake.

- Body water is controlled on one hand by fluid intake that is stimulated by thirst, and on the other hand by renal excretion of water.
III. Recommendations for daily water intake

As seen in section II above, the human body is able to adapt to a wide range of fluid intake and losses, thanks to a precise homeostatic regulation and to the wide ranges of urine osmolality kidneys are able to achieve. But, in contrast to other nutrients, there is today insufficient research regarding the amount of water required to prevent disease or improve health. As a result, neither upper nor lower consumption thresholds have been clearly linked to a specific benefit or risk.

This can explain why most of the guidelines for total water intake are based today on median population intake. This is true in the USA and Canada, for example, where adequate intake is based on the median water intake from NHANES III data (Third National Health and Nutrition Examination Survey) (IOM 2004). Australia and New-Zealand follow this same methodology (NHMRC 2006).

Recent official guidelines for total water intakes (water + beverages + food moisture) were published by the European Food Safety Authority (EFSA) in 2010. These guidelines are the first ones to use both observed intakes and physiological parameters to set adequate intake. A desirable urine osmolarity of 500 mOsmol/L is proposed, and based on this value and on the osmotic load of a standard European diet, a urinary volume and associated total fluid intake is determined (EFSA 2010). This recommendation does not take into account extra fluid loss due to physical activity, which induces large variation in the adequate water intake.

Table 6 summarizes the water intake recommendations of four international authorities.

<table>
<thead>
<tr>
<th></th>
<th>European Food Safety Authority, 2010</th>
<th>National Health and Medical Research Council, 2006</th>
<th>Institute of Medicine, 2004</th>
<th>World Health Organization, 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td>2.5</td>
<td>3.4</td>
<td>3.7</td>
<td>Sedentary 2.9 Active 4.5</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td>2.0</td>
<td>2.8</td>
<td>2.7</td>
<td>Sedentary 2.2 Active 4.5</td>
</tr>
</tbody>
</table>

Table 6. Reference values for total water intake (food + fluid), L/day.

These recommendations for total water intake include water from food and water from beverages of all kind, including water. For adults, the contribution of food to total water intake is usually considered to represent 20% to 30% (EFSA 2010).

It is interesting to notice that no upper safety limit has been set, due to the ability of the kidneys of healthy individuals to excrete excess water, up to 0.7 - 1.0 liter of urine per hour for adults (EFSA 2010).
Today, neither upper nor lower water consumption limits have been clearly linked to a specific benefit or risk, and most of the guidelines for total water intake are based on median population intake.

The European Food Safety Authority has been the first one to introduce a physiological parameter to determine adequate intake and to propose a desirable urine osmolarity of 500 mOsmol/L.

International recommendations for total water intake (food + fluid) of men vary considerably, from 2.5/day in Europe to 3.7L/day in the United States and Canada.
Conclusion

Water is the largest component of the human body, and is distributed throughout all tissues. The regulation of body water balance is therefore critical for maintaining homeostasis. Despite constant losses, the human body regulates efficiently its water balance, thanks to a fine control of urine volume and concentration.

This explains the broad range of fluid intakes observed in healthy individuals. However, the long-term health consequences of low or high fluid intake have been poorly investigated. Preliminary evidence seems to indicate that chronic low fluid intake may impact kidney health, as it may be associated with a more rapid decline of kidney function and higher risk of chronic kidney disease.

Additional research is therefore needed to evaluate the optimal daily fluid intake to prevent diseases or improve health, and to issue precise water intake guidelines for adults, but also for other demographic groups, such as children, pregnant and breastfeeding women, senior adults, and residents of hot climates.
References


Shaffer EA and Thomson ABR. (1994). *First principles of gastroenterology: the basis of disease and an approach to management*. Canadian Association of Gastroenterology; Astra Pharma Inc.


WWW.H4HINITIATIVE.COM THE HYDRATION AND HEALTH WEBSITE
For healthcare professionals, scientists and academic researchers