Regulation of body fluids and Salt water balance I

Prof. K.A. Kirsch
**Solids and water distribution**  
**Usual daily sources of water intake**

![Diagram of body water distribution](image)

**TABLE 5-1**  
Usual Daily Sources of Water Intake and Loss for the Average Adult

<table>
<thead>
<tr>
<th>Intake</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid intake</td>
<td>Urine</td>
</tr>
<tr>
<td>Water content of ingested food</td>
<td>Insensible loss</td>
</tr>
<tr>
<td>Water of oxidation</td>
<td>Skin</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>Lungs</td>
</tr>
<tr>
<td>1200–1800 ml</td>
<td>1500–2000 ml</td>
</tr>
<tr>
<td>700–1000 ml</td>
<td>300–600 ml</td>
</tr>
<tr>
<td>250–300 ml</td>
<td>200–400 ml</td>
</tr>
<tr>
<td>2000–3000 ml</td>
<td><strong>Total</strong></td>
</tr>
<tr>
<td></td>
<td>2000–3000 ml</td>
</tr>
</tbody>
</table>

**FIGURE 5-1.** Distribution of body water.
Body Composition and Body Fluid Compartments

ECFV = Extracellular Fluid Volume
ICFV = Intracellular Fluid Volume
Fluid Balance

• **External Balance** =
  
  Fluid Input versus Fluid Output

• **Internal Balance** =
  
  Shifts between the Body Fluid Compartments
Distribution and Exchange of water and changes in external water balance
Fluid Balance
Factors to be considered

- Water intake (thirst)
- Water output
  - Kidneys
  - Perspiration
    - Respiratory water loss
    - Transdermal water loss
- Food intake
- Salt intake Salt output
Fig. 4. A diagrammatic summary of the proposed regulatory pathways (I-IV) of the central nervous system in total blood volume control: (I) thirst control, (II) urine output, (III) extracellular volume (interstitial and plasma volume), (IV) red cell volume.
Regulation of body fluids and Salt water balance I

Regulation of water and NaCl output

- Hypervolemia
  - H₂O
  - Osmolarity ↓
  - Renin
  - A II ↓
  - Quabain
  - ANF
  - ADH ↓
  - R H₂O ↓
  - Aldosterone
  - Diuresis

- NaCl
  - Osmolarity ↑
  - Renin
  - A II
  - Quabain
  - ANF
  - ADH ↑
  - R H₂O ↑
  - Natriuresis
  - Antidiuresis
### Historical Information Sought in Assessing Water Balance

<table>
<thead>
<tr>
<th>Intake</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average daily intake of water and other fluids</td>
<td>Skin losses sweating* (duration and severity)</td>
</tr>
<tr>
<td>Recent alterations in intake pattern and cause (nausea or vomiting, inability to swallow, etc.)</td>
<td>abnormalities of environment leading to excessive losses</td>
</tr>
<tr>
<td>Recent weight changes (acute changes in weight over period of several days are always caused by changes in body water)</td>
<td>Lungs abnormal rate of breathing excessively dry ambient air</td>
</tr>
<tr>
<td></td>
<td>Gastrointestinal diarrhoea or vomiting* (estimate frequency and amount)</td>
</tr>
<tr>
<td></td>
<td>fistulas, enteric or biliary* (attempt quantitative estimate)</td>
</tr>
<tr>
<td></td>
<td>gastrointestinal intubation* (quantify drainage)</td>
</tr>
<tr>
<td></td>
<td>Renal frequency and volume of urination</td>
</tr>
<tr>
<td></td>
<td>history of renal disease (including conditions impairing concentrating ability)</td>
</tr>
</tbody>
</table>

*Represent sources of loss of both water and electrolytes.
Ascent to high altitude is associated with a

- Decrease in Body weight
- Decrease in Water intake
- Increase in urine output

(Change in the external balance)
Factors contributing to the negative water balance in high altitude

- Sensation of thirst is blunted
- Increased water loss via the lungs
  - cold $\rightarrow$ low humidity
- Solar radiation
- Low food intake
Regulation of body fluids and Salt water balance I

K.A. Kirsch April 2005

Cumulative water balance under a exposure at 4.300 m

Figure 9.1. Cumulative water balances calculated from metabolic balances in fifteen normal subjects exposed to 14,110 feet (4,300 m). Water changes are assumed to be the differences between observed and calculated weight changes. Group I consisted of five men receiving a normal diet of 48 percent of calories as carbohydrate and 40 percent as fat; Groups II, III, and IV each consisted of ten men on a high carbohydrate (68 percent) and a low fat (20 percent) diet. The decrease in weight during the control period was due to a change from a standard Army ad libitum diet to an all-liquid diet. From Joluson et al., 1969; 28: 1195 - 98
The change in levels of **serum proteins**, **hematocrit**, and **hemoglobin** three hours after the arrival at the altitude of 2,390 m

**Effect of altitude exposure on the plasma volume**

Hutardo et al. J. Appl. Physiol. 1932; 100: 487-505

Regulation of body fluids and Salt water balance II

Prof. K.A. Kirsch
Mean changes in **hematoglobin, red cell volume, plasma volume, total blood volume** during a Himalayan Expedition

![Graph showing percentage changes in hematoglobin, red cell volume, blood volume, and plasma volume.](image)

*Figure 5.2.* Mean changes in hemoglobin, red cell volumes, plasma volume and total blood volume in four subjects during an eight month Himalayan expedition. (1) After 18 weeks between 13,000 feet (4,000 m) and 19,000 feet (5,800 m). (2) After 3 to 6 weeks at 19,000 feet. (3) After 9 to 14 weeks at 19,000 feet or above 19,000 feet. Red cell volume progressively increases. Plasma volume is decreased. From Pugh, ref. 9.

Calculated changes in body fluid volumes during several days of hill walking at sea level

Figure 7.2. Calculated changes in body fluid volumes during several days of hill walking at sea level. Sodium and water retention occurred, along with a modest increase in plasma volume. These changes are frequently accompanied by systemic edema both at sea level and at high altitude. From Williams, ref. 36.

Williams E. Proc. Royal Soc. 1966; 165: 266 - 80
Fig. 4. A diagrammatic summary of the proposed regulatory pathways (I-IV) of the central nervous system in total blood volume control: (I) thirst control, (II) urine output, (III) extracellular volume (interstitial and plasma volume), (IV) red cell volume.
ANP in acute mountain sickness

**Fig. 1.** Acute mountain sickness (AMS) score and arterial O$_2$ saturation (means ± SE) in 14 subjects without AMS (AMS −) and 11 subjects with AMS (AMS +) at 550 m (LA) and 6 h (HA 1), 18 h (HA 2), and 42 h (HA 3) after arrival at 4,559 m. Significant differences between groups (** P < 0.01 and *** P < 0.001) refer to single investigations. O$_2$ saturation was not measured at LA and was assumed to be >95%.

**Fig. 2.** Urine volume and sodium excretion (means ± SE) in 13 subjects without AMS (AMS −) and 11 subjects with AMS (AMS +) at 550 m (LA) and 6 h (HA 1), 18 h (HA 2), and 42 h (HA 3) after arrival at 4,559 m. Significant differences within a group compared with corresponding baseline values: * P < 0.05. Significant differences between groups (** P < 0.01 and *** P < 0.001) refer to single investigations.

Hematocrit and circulation

Regulation of body fluids and Salt water balance II

Regulation of water and NaCl output

- Hypervolemia
  - Osmolarity ↓
  - Renin
  - ADH ↓
  - Atrium
  - A II ↓
  - Quabain
  - ANF
  - R H₂O ↓
  - Aldosterone
  - Diuresis

- NaCl
  - Osmolarity ↑
  - ADH ↑
  - R H₂O ↑
  - Antidiuresis
  - Natriuresis
The influence of AMS on the Renin - Angiotensin - System

Changes in potassium at high altitude

![Graph showing changes in potassium levels at different altitudes.](Graph.png)

**Figure 9.2.** Urinary potassium excretion and serum potassium in ten normal subjects on a constant electrolyte intake and a controlled diet at sea level and during nine days on Pikes Peak, 14,110 feet (4,300 m). Urinary potassium excretion decreases as serum potassium rises. Potassium excretion expressed as milliequivalents per day and serum potassium as milliequivalents per liter. From Janoski et al., ref. 1.

Influence of volume depletion on acute response of plasma ADH to osmotic stimulation

FIGURE 6-6. Influence of volume depletion on acute response of plasma ADH to osmotic stimulation. The effect of progressive volume depletion is a much more rapid rise in circulating ADH for a given increment in osmolality. The slope relating rise in ADH to increase in osmolality increases threefold following large volume depletion. Thus the combination of an osmotic increment and volume deficit produce a much more vigorous ADH response.
## Disorders Associated with Chronic Sodium Depletion

| Renal | Chronic diuretic use associated with decreased sodium intake  
| Salt-losing nephritis  
| Medullary cystic disease  
| Renal tubular acidosis |
|---|---|
| Endocrine | Hypopituitarism  
| Hypoadrenalism  
| Inappropriate secretion of antidiuretic hormone |
| GI Tract | Chronic nasogastric suction or vomiting  
| Ileostomy or small bowel fistulae with decreased sodium intake  
| Biliary fistulae  
| Chronic diarrhea  
| Villous adenoma |
| Skin | Chronic heat exposure and sweating with decreased sodium intake  
| Burns with slow healing |