UNIVERSITY OF MEDICAL SCIENCES, ONDO

DEPARTMENT OF PHYSIOLOGY

PHS 212: BLOOD AND BODY FLUID PHYSIOLOGY

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OBJECTIVES

- Introduction
- Definition of body fluids and body fluid compartments
- Physiological variation of body fluid volumes
- List the ionic composition of different body compartments
- Regulation of body fluid volumes
- Techniques for quantifying various body fluid volumes
Introduction

- Water is the major constituent of all body fluid compartments.
- In an adult human, average of 70-kilogram
- Total body water is about 60 per cent of the body weight, or about 42 liters.
Most of the variation in body fluid between individuals is as a result of variation in amount of body fat or adipose tissue (fat is only about 10% water)

- Infant: 73-80%
- Male adult: 60%
- Female adult: 40-50%
- Effects of obesity
- Old age 45%
PERCENTAGE OF H$_2$O IN TISSUES

- Newborn infant (80%)
- Adult male (60%)
- Adult female (50%)
# Normal Daily Fluid Input and Output

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ Ingestion</td>
<td>➢ Gut (Faeces 100ml)</td>
</tr>
<tr>
<td>➢ Fluid (1.25 Liters)</td>
<td>➢ Urine (1.5 Liters)</td>
</tr>
<tr>
<td>➢ Food (1 Liter)</td>
<td>➢ Breathing/Skin (900ml)</td>
</tr>
<tr>
<td>➢ Metabolism (350 ml)</td>
<td>➢ Sweating (100ml)</td>
</tr>
<tr>
<td>➢ Total (2.6 Liters)</td>
<td>➢ Total (2.6 Liters)</td>
</tr>
</tbody>
</table>
# Abnormal Fluid Input and Output

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection/Infusion</td>
<td>Gut</td>
</tr>
<tr>
<td>Hyperdipsia</td>
<td>Vomiting</td>
</tr>
<tr>
<td></td>
<td>Diarhoea</td>
</tr>
<tr>
<td></td>
<td>Skin- Burns</td>
</tr>
<tr>
<td></td>
<td>Sweating- Excessive</td>
</tr>
<tr>
<td></td>
<td>Urine- Diabetes insipidus</td>
</tr>
<tr>
<td></td>
<td>Haemorrhage</td>
</tr>
</tbody>
</table>
FLUID COMPARTMENTS

EXTRA CELLULAR FLUID

PLASMA

INTERSTITIAL FLUID

INTRA CELLULAR FLUID

TRANSCELLULAR FLUID

- CSF
- Intra ocular
- Pleural
- Peritoneal
- Synovial
- Digestive Secretions
PERCENTAGE OF WATER IN TISSUES

Average 70 kg person total body weight

- **42 litres** total H2O 60%
- **28 liters** Intracellular fluid (ICF) 40%
- **14 liters** Extracellular fluid (ECF) 20%

ECF is divided into ¾ ISF and ¼ plasma water

- **10.5 liters** Interstitial fluid (ISF) 15%
- **3.5 liters** Plasma water 5%

- All the transcellular fluids together constitute about 1 to 2 liters.
IONIC COMPOSITION OF BODY FLUIDS (mEq/l)

<table>
<thead>
<tr>
<th>Substance</th>
<th>ICF</th>
<th>ISF</th>
<th>Plasma</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na⁺</td>
<td>14</td>
<td>140</td>
<td>142</td>
</tr>
<tr>
<td>K⁺</td>
<td>150</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>2</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>30</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Anions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cl⁻</td>
<td>10</td>
<td>113</td>
<td>113</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>10</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>HPO₄²⁻/H₂PO₄⁻</td>
<td>113</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>20</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Protein</strong></td>
<td>74</td>
<td>2</td>
<td>16</td>
</tr>
</tbody>
</table>
REGULATION OF BODY Fluid VOLUME

The hypothalamus achieve this by two mechanisms:

- Thirst mechanism
- ADH mechanism
THIRST MECHANISM

➢ Thirst centre in the hypothalamus contains osmoreceptors

➢ When ECFV decreases then osmolarity increases

➢ Osmoreceptors are stimulated and this activate the thirst centre

➢ Thirst is initiated

➢ The person feels thirsty and drink water

➢ ECF volume increases and ECF osmolarity decreases
ADH MECHANISM

- When ECFV decreases, ECF osmolarity increases

- Supraoptic nucleus in the hypothalamus is stimulated

- ADH is released

- ADH causes retention of water by facultative reabsorption

- ECFV increases and osmolarity decreases

- On the contrary, when ECFV increases

- No ADH is released, decrease water reabsorption
MEASUREMENT OF BODY FLUID VOLUME

- Can be done both directly (indicator dilution method) and indirectly.

- By injecting substances that will stay in one compartment.

- Then calculate the volume of fluid in which the test substance is distributed (volume of distribution of injected material).

- Volume of distribution
  
  \[ \text{Volume of distribution} = \text{amt. of substance injected} - \text{amt. excreted/metabolized} \]

  \[ \text{concentration of the substance in the sample} \]
Example: 150mg of sucrose is injected into a 70kg man. The plasma sucrose level after mixing is 0.01mg/ml, and 10mg has been excreted or metabolized during the mixing period. Calculate the volume of distribution of sucrose.
CHARACTERISTICS OF MARKER SUBSTANCE/INDICATOR

- Must be non-toxic

- Must mix evenly throughout the compartment being measured

- Must have no effect of its own on the distribution of water or other substances in the body

- It must be unchanged by the body during mixing period, or the amount changed must be known

- It must be easy to measure
MEASUREMENT OF TOTAL BODY WATER

- Using indicator dilution method

- Indicators include:

- Radioactive water (tritium, $^3\text{H}_2\text{O}$) or heavy water (deuterium, $^2\text{H}_2\text{O}$) and antipyrine

- They mix with TBW within few hours of injection
MEASUREMENT OF ECF VOLUME

- Using indicator dilution method

- Indicators include:
  - Radioactive sodium, radioactive chloride, thiosulphate ion, inulin, mannitol and sucrrose

- The substances mix almost completely throughout ECFV within 30-60mins
MEASUREMENT OF PLASMA VOLUME

- Using indicator dilution method

- Indicators include:
  Evan’s blue (T-1824) and radioactive iodine ($^{131}$I)

- The substance binds with plasma proteins strongly

- Diffuses into ISF in small quantity or not at all
<table>
<thead>
<tr>
<th>Compartment</th>
<th>Criterion</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma</td>
<td>Substance should not cross capillaries</td>
<td>• Evans blue dye;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• radioiodinated fibrinogen;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• radioiodinated albumin</td>
</tr>
<tr>
<td>ECF volume</td>
<td>Substance should cross capillaries but not cross cell membranes</td>
<td>Isotonic solutions of sucrose, inulin, mannitol, NaCl</td>
</tr>
<tr>
<td>Total body H$_2$O (TBW)</td>
<td>Substance distributes evenly in ICF &amp; ECF</td>
<td>Heavy H$_2$O, tritiated H$_2$O, aminopyrine, antipyrine</td>
</tr>
</tbody>
</table>
Blood volume /Markers used

Obtained from plasma volume and hematocrit

- Total blood volume = \( \frac{\text{Plasma volume}}{1 - \text{Hematocrit}} \)

Example: If the plasma volume is 4 liters and the hematocrit is 0.45, total blood volume is ?
Take this problem:

100 mg of sucrose is injected into a 70 kg man. The plasma sucrose level after mixing is 0.01 mg/ml. If 5 mg has been metabolized during this period, then, what is the ECF volume?

9.5 L
14 L
17.5 L
10 L
COMPARTMENTS WITH NO COMPARTMENT-SPECIFIC SUBSTANCE

Determine by subtraction:

- How would you measure ICF volume?
  - Cannot be measured; it is calculated (estimated).
  - ICF volume = Total body H₂O – ECF volume

Interstitial volume:

- Can not be measured directly
- Interstitial Fluid Volume (ISFV):
  
  ISFV = ECFV - PV
Please emulate the biblical Bereans (Acts 17:11)