LLL- Live - Module 3

Body Composition

Nutritional Screening and Assessment

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Learning objectives

- To know the different compartment of the body and their composition.
- To understand the importance of the different body chemical components.
- To know the assessment methods for body composition for practical and research use.
The importance of evaluating body composition

- Nutritional assessment
- Evaluating medical and nutritional treatments

CHF, Obesity, Nutrition Support, Liver and kidney diseases
Body composition – 70 kg man

12 kg storage fat (triglycerides)
- Subcutaneous
- Intramuscular
- Intra-abdominal
- 3 kg essential fat
- Bone marrow lipids
- CNS lipids

45% structural protein
- Collagen
- Dermis
- Walls of blood vessels
- 55% cells and circulating protein

Glycogen stores
- 500 g in muscle
- 200 g in liver

- Total body water (TBW) = 60% of body weight
- Intracellular fluid = 66% TBW
- Extracellular fluid (ECF) = 33% TBW
- ECF = interstitial fluid (80% ECF)
- Plasma (20% ECF)
# Body composition on the molecular level for the 70-kg Reference Man

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount [kg]</th>
<th>% of Body wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>extracellular</td>
<td>18</td>
<td>26</td>
</tr>
<tr>
<td>intracellular</td>
<td>24</td>
<td>34</td>
</tr>
<tr>
<td>Lipid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-essential</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>essential</td>
<td>1.5</td>
<td>2.1</td>
</tr>
<tr>
<td>Pr</td>
<td>10.6</td>
<td>15.0</td>
</tr>
<tr>
<td>Mineral</td>
<td>3.7</td>
<td>5.3</td>
</tr>
<tr>
<td>Total</td>
<td>69.8</td>
<td>99.4</td>
</tr>
</tbody>
</table>
# Body composition on tissue-system level of the Reference Man

<table>
<thead>
<tr>
<th>Tissue/Organ</th>
<th>Amount (kg)</th>
<th>% body wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skeletal muscle</td>
<td>28</td>
<td>40</td>
</tr>
<tr>
<td>Adipose tissue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>subcutaneous</td>
<td>7.5</td>
<td>11</td>
</tr>
<tr>
<td>visceral</td>
<td>5</td>
<td>7.1</td>
</tr>
<tr>
<td>interstitial</td>
<td>1</td>
<td>1.4</td>
</tr>
<tr>
<td>yellow marrow</td>
<td>1.5</td>
<td>2.1</td>
</tr>
<tr>
<td>Bone</td>
<td>5</td>
<td>7.1</td>
</tr>
</tbody>
</table>
Changes in Body Composition with Age
### Body Composition Changes in Normal Adult Males

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Muscle (kg)</th>
<th>Body fat (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-29</td>
<td>24</td>
<td>15</td>
</tr>
<tr>
<td>40-49</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>60-69</td>
<td>17</td>
<td>23</td>
</tr>
<tr>
<td>70-79</td>
<td>13</td>
<td>25</td>
</tr>
</tbody>
</table>
Body Water - with Aging

Bar chart showing the percentage of body water for males and females at 20 years and 80 years of age.
Bone Mass- with Aging

![Bar chart showing bone mass with aging for male and female from 40 to 80 years.](chart.png)
Sarcopenia of Aging

Figure 1. Absolute fat and lean changes per decade as a function of age in men. Studies are ordered by age at baseline. All changes are standardized to 10-year follow-up. HD = hydrodensiometry; SF = skinfold; BI = bioimpedance.
Figure 2. Absolute fat and lean changes per decade as a function of age in women. Studies are ordered by age at baseline. All changes are standardized to 10-year follow-up. HD = hydrodensiometry; SF = skinfold; BI = bioimpedance.
Body composition in different ages
Role of Components

![Diagram showing the role of components in the body.](chart.png)
Vitamins

- Composed of various chemical elements
- Vital to life
- Needed in tiny amounts
- Fat soluble
- Water soluble
- Yields no energy
Minerals

- Inorganic substances
- Needed in tiny amounts
- Trace minerals
- Major minerals
- Yields no energy
Water

- Composed of H, O (H2O)
- Vital to life
- Is a solvent, lubricant, medium for transport, and temperature regulator
- Makes up majority of our body
- Yields no energy
Contribution of Organs to Body Composition

<table>
<thead>
<tr>
<th>Organ or tissue</th>
<th>Fetus (% body wt)*</th>
<th>Full-term newborn (% body wt)</th>
<th>Adult (% body wt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skeletal muscle</td>
<td>25.0</td>
<td>25.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Skeleton</td>
<td>22.0</td>
<td>18.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Heart</td>
<td>0.6</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Lungs</td>
<td>3.3</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Liver</td>
<td>4.0</td>
<td>5.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Kidneys</td>
<td>0.7</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Brain</td>
<td>13.0</td>
<td>12.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

* 20 to 24 weeks old.

The two compartments model
Body composition
Multi-compartment Model

Carbon
Ca, P, K, Na, etc.
Hydrogen
Oxygen
Nitrogen

Lipid
Mineral
Water
Glycogen
Protein

Fat
ECS
ECW
Body Cell Mass

Adipose tissue
Skeleton
Skeletal muscle
Visceral organs and residual

Elemental
Molecular
Cellular
Functional

What should we measure?

- **Fat body mass**
  - body fat percentage
  - Fat distribution (visceral fat)

- **Lean body mass**
  - water-extra and intracellular
  - Body cell mass
  - Muscle mass
  - Bone
# Definition of Obesity Using Body Mass Index

<table>
<thead>
<tr>
<th>Classification</th>
<th>BMI (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt; 18.5</td>
</tr>
<tr>
<td>Normal Weight</td>
<td>19 - 24.9</td>
</tr>
<tr>
<td>Overweight</td>
<td>25 - 29.9</td>
</tr>
<tr>
<td>Class I Obesity</td>
<td>30 - 34.9</td>
</tr>
<tr>
<td>Class II Obesity</td>
<td>35 - 39.9</td>
</tr>
<tr>
<td>Class III Obesity</td>
<td>≥ 40</td>
</tr>
</tbody>
</table>

Mortality with BMI

BMI = weight/height$^2$ [kg/m$^2$]

Mortality Rate Per 1000

BMI Category

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Body Fat Distribution

- People store body fat in two general ways; either above or below the waist.
- In both men and women, excess intra-abdominal adipose tissue correlates strongly with cardiovascular disease, dyslipidemia, hypertension, stroke and type 2 diabetes.
- Documenting body fat distribution, in conjunction with BMI, is important to assess risk.
Body Fat Distribution

Waist Circumference

- Measured at the mid-point between the ileac crest and the lower rib.
- Correlates strongly with intra-abdominal adipose tissue as assessed by CT and MRI.
- Upper body obesity defined as a waist circumference:
  - ≥ 40 inches for men
  - ≥ 35 inches for women
Densitometry

• Density \( (g/cm^3) = \text{weight/volume} \)
• Density of fat \( \neq \) Density of FFM
• Density of fat and fat free mass differ substantially: 0.900 and 1.100 respectively
• \( 1/Db = f\text{Fat}/Df + f\text{FFM}/Dffm \)
Anthropometry

Muscle mass

Fat mass
Subcutaneous Skinfold

- Based on the two-compartment model from body density.
- Based on measuring subcutaneous skinfold thickness at various sites by calipers.
- Highly affected by examiner.
- Use prediction equations to convert sum of skinfold thicknesses to body fat %
- Standard error of estimate 3-11%.

\[ R = \frac{c}{2 \pi} = \text{muscle} + \text{fat} + \text{bone} \]

\[ C = 2 \pi R \]

Figure 3-6. This cross-sectional diagram shows the technique for measuring a skinfold, a double layer of subcutaneous fat and skin. In this case, the triceps skinfold is being measured with the Lange skinfold calipers. (From Grant, A.: Nutritional Assessment Guidelines. Berkeley, California, Cutter Biological, Miles Inc., 1979, with permission.)
Dilutional Techniques

- **Assumptions:**
  - The isotope has the same distribution volume as water and exchanged by the body like water. Nontoxic.
  - The calculation is based upon the relationship: \( C_1V_1 = C_2V_2 \)
    (\( c \) = concentration, \( v \) = volume of distribution).
  - The length of time required for tracer equilibration depends upon the compartment and the physiologic volume of distribution.
  - Measurements involve: water, albumin, potassium, chloride, sodium, bromide.
Whole Body Potassium (TBK)

- Potassium is essentially intracellular cation not present in adipose tissue.
- Potassium-40, a radioactive isotope, exists in the body at fixed abundance (0.012%).
- 2.5 and 2.31 gram K/kg fat free mass for men and women.
Bioelectrical Impedance

- Based upon the nature of conduction of an applied electrical current in an organism.
- Application of a constant, low-level alternating current produces an impedance to the spread of the current that is frequency dependent.
- At low frequencies the current mainly passes through the ECW with higher frequencies penetrates the cells also.
- The impedance ($Z$) of a geometrical system is related to conductor length ($L$) and configuration, cross-sectional area ($A$) and volume resistivity ($\delta$)
- $Z = \delta L/A = \delta L^2 /LA = \delta L^2 /V$
  
  $V = \delta L^2 /Z$

Absorptiometry

• The compartment (mainly bone mineral content) is assumed to be directly proportional to the amount of photon energy absorbed by it.

• A highly collimated beam pass across and the integral of the changes in its intensity is proportional to the content.

• Mainly used for bone mineral content.
Dual energy X-ray absorptiometry (DEXA)

- Three-compartment model.
- Adipose tissue, bone and non-adipose lean tissue attenuate energy from X-ray differently.
- State of hydration may affect results.
In vivo neutron activation analysis (IVNAA) (1)

- A technique for in-vivo measurement of the multi-elemental composition of the body.
- A moderated beam of fast neutrons is delivered to the subject, these are captured by the target elements and unstable isotopes are created.
In vivo neutron activation analysis (IVNAA) (2)

- The isotopes revert to stable condition by emission of one or more gamma rays of characteristic energy.
- Can be used to measure: carbon, nitrogen, potassium, calcium, hydrogen, phosphorous, sodium, chloride, magnesium, cadmium.
- Accuracies ranging from 2-10%.

2. Typical gamma ray spectrum of a patient. The photopeaks of hydrogen, iron, and lead are at 2.2, 6.87, and 7.65 MeV, respectively. The first escape peak of nitrogen at 10.3 MeV is identified.
Infrared interactance

- Based upon light absorption and reflection using near-infrared spectroscopy.
- The probe emits electromagnetic radiation wave length 700-1100 nm.
- The signal penetrates the underlying tissue to a depth of 1 cm and the composition is assessed only at the examined site.
Nitrogen Index

- Nitrogen can be used as a measure of protein in the body, assuming a numerical relationship of 6.25 gram of protein per gram of nitrogen.
- Nitrogen is incorporated in different body proteins as part of amino acids, DNA, RNA.
- Nitrogen is daily excreted by the urine and less so, but still significantly in the stool.
Creatinine

- 98% of creatine is located in skeletal muscle mostly in the form of creatine phosphate.
- Creatinine is formed in a nonenzymatic hydrolysis of free creatine liberated by dephosphorylation of creatine phosphate.
- 1 gram of creatinine excreted in 24-h urine collection is derived from 17.9/20 kg muscle.
Creatine Phosphate (Pcr)

- A high-energy compound that is formed and stored in the muscle cells
- \( \text{PCr} + \text{ADP} \rightarrow \text{Cr} + \text{ATP} \)
  - Activated instantly and replenish ATP
  - Not enough is stored or made in the muscle
  - ATP plus Pcr ~10 to 15 seconds of maximum work by muscles
Creatinine excretion in urine

• Creatinine excretion correlates with lean body mass and body weight
• 18-20 kg of muscle produce 1 g of creatinine
• Dietary protein sources contribute up to 20% of excreted creatinine
• Urinary creatinine excretion is proportional to the skeletal muscle mass (normal renal function)
Creatinine height index (CHI)

\[ \text{CHI} \equiv \text{lean body mass} \]
Urinary 3-Methylhistidine

- Suggested as a marker of muscle protein breakdown.
- Principally located in skeletal muscle.
- After catabolism neither reutilize nor metabolized, but excreted in the urine.
- FFM by densitometry well correlated with 24-h $r=0.90$ but was significantly related to skeletal muscle mass but not to non-muscle mass.
Limitations of methods of determining body composition

<table>
<thead>
<tr>
<th>Method</th>
<th>Cost</th>
<th>Technical difficulty</th>
<th>Precision FFM</th>
<th>Precision %FAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water deuterium</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Oxygen18</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Potassium</td>
<td>4</td>
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<tr>
<td>Creatinine</td>
<td>2</td>
<td>3</td>
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<td>1</td>
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<tr>
<td>Densitometry</td>
<td>3</td>
<td>4</td>
<td>5</td>
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Limitations of methods of determining body composition

<table>
<thead>
<tr>
<th>Method</th>
<th>Cost</th>
<th>Technical Precision</th>
<th>Technical Difficulty</th>
<th>FFM</th>
<th>FAT%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skinfolds</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Arm Circ.</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Neutron Act</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Photon Abs</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
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<tr>
<td>BEI</td>
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<tr>
<td>CT</td>
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<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Infrared</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
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<tr>
<td>MRI</td>
<td>5</td>
<td>5</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

Lukaski HC, AJCN 1987:46:537-56
Summary
Practical methods for measuring FBM

• Subcutaneous skin folds measurements
• DEXA
• BEI
Summary

Practical methods for measuring FFBM

- Mid-arm circumference
- DEXA
- Whole body potassium
- BEI
- Height-creatinine index
- 3-Methyl Histidine
Summary
Practical methods for measuring water

• Dilution
• BEI
Summary

Practical methods for measuring bone

- DEXA
- Bone turnover metabolites
- TBCa
THANK YOU!

- Knowing the **body composition** we know what happens to our patient and how we influence him with our **medical** and **nutritional interventions**.