Energy Homeostasis in Humans

Benjamin Caballero, MD, PhD
Johns Hopkins University
Section A

General Concepts of Energy Metabolism
Types of Energy

- Solar
- Chemical
- Mechanical
- Thermal
- Electrical
Units of Energy

- **Calorie**
  - Defined as the amount of heat required to rise the temperature of one kg of water from 14.5 to 15.5° C
  - Also defined based on the heat of combustion of benzoic acid (thermochemical calorie)
  - Standardized in 1956—one cal = 4.1868 Joules
Units of Energy

- **Joule**
  - Defined as the energy expended when one kg is moved one meter by a force of one Newton

- **Watt**
  - Expresses rate of energy expenditure per unit time, i.e., work (J/sec)
- 1 L of $O_2 = 4.825$ kcal
- 1 g/atom of $O_2 = 3$ mol of ATP
Bomb Calorimeter
## Energy Combustion

<table>
<thead>
<tr>
<th></th>
<th>( O_2 ) (ml)</th>
<th>( CO_2 ) (ml)</th>
<th>RQ</th>
<th>Energy (kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch</td>
<td>828</td>
<td>828</td>
<td>1.00</td>
<td>4.183</td>
</tr>
<tr>
<td>Fat</td>
<td>2019</td>
<td>1427</td>
<td>0.70</td>
<td>9.461</td>
</tr>
<tr>
<td>Protein</td>
<td>966</td>
<td>781</td>
<td>0.81</td>
<td>4.442</td>
</tr>
</tbody>
</table>
## Energy in Foods

<table>
<thead>
<tr>
<th></th>
<th>Kcal/g</th>
<th>Heat of Comb ustion</th>
<th>Availability</th>
<th>Loss</th>
<th>Net</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat</td>
<td>5.35</td>
<td>92%</td>
<td>1.25</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Butter</td>
<td>9.12</td>
<td>95%</td>
<td>—</td>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td>Starch</td>
<td>4.12</td>
<td>99%</td>
<td>—</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Ethanol</td>
<td>7.1</td>
<td>100%</td>
<td>tr.</td>
<td>7.0</td>
<td></td>
</tr>
</tbody>
</table>
Section B

Energy Balance and Measurement of Energy Expenditure
Energy Balance

Energy IN = Energy OUT
Measurement of Energy Balance

Energy Intake → 24 hrs → Energy Expenditure
Measurement of Energy Balance

Energy Intake
- Food freq. quest.
- 24-hr recall
- Food records
- Food weighing
- Direct observation

24 hrs

Energy Expenditure
Measurement of Energy Balance

Energy Intake
- Food freq. quest.
- 24-hr recall
- Food records
- Food weighing
- Direct observation

Energy Expenditure
- Gas exchange calorimetry
- Heart rate monitoring
- Estimated from activity
  - Motion sensors
  - Activity diary
  - Direct observation
- Doubly labeled water (D218O)
Components of EE

Basal Metabolic Rate (BMR, REE)
Components of EE

Thermic Effects of Food (TEF, FIT)

Basal Metabolic Rate (BMR, REE)
Components of EE

- Physical Activity (PA)
- Thermic Effects of Food (TEF, FIT)
- Basal Metabolic Rate (BMR, REE)
Daily Energy Balance

<table>
<thead>
<tr>
<th>Intake As total kcal</th>
<th>Range</th>
<th>Oxidation As % stores</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 kcal</td>
<td>Fat 125,000 kcal</td>
<td>0.8%</td>
</tr>
<tr>
<td>500 kcal</td>
<td>Protein 40,000 kcal</td>
<td>1.3%</td>
</tr>
<tr>
<td>1000 kcal</td>
<td>Carbohydrate 2000 kcal</td>
<td>50%</td>
</tr>
</tbody>
</table>

 (>650,000 kcal)
The Doubly-Labeled Water Method

$^{2}\text{H}_2^{18}\text{O} \rightarrow \text{Body Water}$

H loss:

$\text{H}_2 \text{O} \rightarrow \text{Water}$

O loss:

$\text{H}_2^{18}\text{O} \rightarrow \text{Water}$

$\text{C}^{18}\text{O}_2 \rightarrow \text{Carbon Dioxide}$

“Normal” water: $^{3}\text{H}_2^{16}\text{O}$
Disappearance Rates of DLW Tracers

![Graph showing the disappearance rates of deuterium and oxygen-18 over time.](image)

- **Deuterium**
- **Oxygen-18**

**Water Turnover**

**Water + CO₂ Turnover**

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**Graph Details**

- **Y-axis**: Remaining Isotope Enrichment, %
- **X-axis**: Time, days

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Section C

Energy Requirements
Frequency Distribution of Individual Requirements

Increasing Intake

EAR  2 s.d.  RDA
Determination of Dietary Energy Requirements: Factorial Method

- Total Energy Expenditure (TEE)
  - Physical Activity Allowance
  - Food-Induced Thermogenesis (ignored)
  - Basal Metabolic Rate (BMR) (measured/predicted)
Limitations of Previous Approach

- BMR not constant throughout the day
- Unreliable data on energy cost of physical activities, and only estimated for selected activities
- EPOC, fidgeting, other involuntary activities not accounted for
Selection of Approach for Current Revision

- Use energy expenditure to estimate dietary energy requirements
- Use total daily energy expenditure (TEE) measured by the doubly-labeled water technique
Adequacy Indicator

BMI

- Strengths
  - Recognized link to health outcomes
  - Reflects relationship of weight and height
  - Good population data in U.S. and other countries
Adequacy Indicator

BMI

- Limitations
  - Not best indicator of body adiposity
  - Cutoffs may not be valid across populations
  - Some difficulty in defining cutoff points in children and across populations/countries
Estimated Energy Requirement (EER)

- A level of dietary energy intake sufficient to maintain a stable healthy body weight and an adequate level of physical activity
- Differs from EAR in that it is not a distribution of intakes reflecting physiological variability
Normative DLW Database TEE by Age

![Graph showing TEE (kcal/d) by Age (y) for females and males.](Image)
Measures of Physical Activity

- **PAL**—TEE / BEE
- **MET**— $O_2$ consumption of 3.5 mL/kg/min
  (= 0.0175 kcal/kg/min)
- **PAL equivalents of METs**
  – 0.0175 x 1.15 / 0.9
### PAL Levels

<table>
<thead>
<tr>
<th>PA Category</th>
<th>Range</th>
<th>Mean</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
<td>1.0–1.39</td>
<td>1.23</td>
<td>1.29</td>
<td></td>
</tr>
<tr>
<td>Low Active</td>
<td>1.4–1.59</td>
<td>1.52</td>
<td>1.51</td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>1.6–1.89</td>
<td>1.74</td>
<td>1.74</td>
<td></td>
</tr>
<tr>
<td>Very Active</td>
<td>1.9–2.5</td>
<td>2.09</td>
<td>2.06</td>
<td></td>
</tr>
</tbody>
</table>

Data from Institute of Medicine/National Academy of Sciences
DLW Database: Distribution of PAL Levels

- Sedentary
- Low Active
- Active
- Very Active

n
0 10 20 30 40 50 60 70 80 90 100

Females
Males
Equation for Prediction of TEE: General Models

0–2 Years of Age
- TEE = 89 x Weight – 100

Ages 3 Years and Over
- TEE = A + B x Age + PA x (D x Weight + E x Height)
  - A—Constant term
  - B—Age coefficient
  - PA—Physical activity coefficient
  - D—Weight coefficient
  - E—Height coefficient
Energy Allowances +

- Desirable activity
- Catch-up growth
- Infection

Adapted by CTLT from Institute of Medicine/National Academy of Sciences
Factors Affecting Energy Requirements

Energy Requirements

- Food Security
- Food Aid
- Commodity Projections
- Impact of Urbanization
- Household Economy
- Food Demand Analysis
- Farming Systems
- Land Use Analysis
- Agricultural Development
- Impact of Structural Adjustments