Energy Balance and Body Weight

KNH 406
Introduction

- Developing nations vs. developed nations
- Availability of food contributes to overweight and obesity
Energy Balance

Intake

- Measured in kilojoules (kJ) or kilocalories (kcal) – food energy
- Determined by bomb calorimeter
- Nutrition Facts label, food composition tables, dietary analysis software
Energy Balance

- 24-Hour Energy Expenditure (EE)
  - Resting energy expenditure (REE)
  - Thermic effect of food
  - Physical activity
Resting energy expenditure (REE)
- Sustain life, keep vital organs functioning
- 60–75% of EE, 1 kcal/kg body wt./hr
- factors affecting REE
  - Lean body mass (most metabolically active)
  - Male sex
  - Body temperature
  - Age
  - Energy restriction
  - Genetics

Basal energy expenditure (BEE)
- Difficult to measure
Thermic effect of food (TEF)
  - Measured for several hours postprandial
  - Digest, absorb, metabolize, store, and eliminate nutrients
  - 10% of EE
Physical Activity EE

- Most variable
- 20–25% of EE
- Influenced by body weight, number of muscle groups used, intensity, duration and frequency of activity
Methods

- Equations
- Indirect calorimetry
- Doubly-labeled water
- Direct calorimetry
Estimating Energy Expenditure

- Equations for estimating EE
  - Harris–Benedict
  - WHO
  - IOM DRI – estimated energy requirement (EER)
    - Includes physical activity (PA) coefficient
    - Separate calculations for overweight adults and overweight children and adolescents – based on BMI
### Table 14.1

Examples of Equations for Estimating Resting Energy Expenditure in Healthy Persons

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Harris-Benedict</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Females</strong></td>
<td>( \text{REE} = 655.096 + 9.563 W + 1.850 S - 4.676 A )</td>
<td></td>
</tr>
<tr>
<td><strong>Males</strong></td>
<td>( \text{REE} = 66.473 + 13.752 W + 5.003 S - 6.755 A )</td>
<td></td>
</tr>
<tr>
<td><strong>Harris-Benedict (Values Rounded for Simplicity)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Females</strong></td>
<td>( \text{REE} = 655.1 + 9.6 W + 1.9 S - 4.7 A )</td>
<td></td>
</tr>
<tr>
<td><strong>Males</strong></td>
<td>( \text{REE} = 66.5 + 13.8 W + 5.0 S - 6.8 A )</td>
<td></td>
</tr>
<tr>
<td><strong>World Health Organization (WHO)</strong></td>
<td>( \text{SD}^2 )</td>
<td></td>
</tr>
<tr>
<td><strong>Females</strong></td>
<td>3–9 years old</td>
<td>(22.5 W + 499)</td>
</tr>
<tr>
<td></td>
<td>10–17 years old</td>
<td>(12.2 W + 746)</td>
</tr>
<tr>
<td></td>
<td>18–29 years old</td>
<td>(14.7 W + 496)</td>
</tr>
<tr>
<td></td>
<td>30–60 years old</td>
<td>(8.7 W + 829)</td>
</tr>
<tr>
<td></td>
<td>&gt;60 years old</td>
<td>(10.5 W + 596)</td>
</tr>
<tr>
<td><strong>Males</strong></td>
<td>3–9 years old</td>
<td>(22.7 W + 495)</td>
</tr>
<tr>
<td></td>
<td>10–17 years old</td>
<td>(17.5 W + 651)</td>
</tr>
<tr>
<td></td>
<td>18–29 years old</td>
<td>(15.3 W + 679)</td>
</tr>
<tr>
<td></td>
<td>30–60 years old</td>
<td>(11.6 W + 879)</td>
</tr>
<tr>
<td></td>
<td>&gt;60 years old</td>
<td>(13.5 W + 487)</td>
</tr>
</tbody>
</table>

1 \( W = \text{weight in kilograms}; A = \text{age in years}; S = \text{stature in cm.} \)

2 \( \text{SD} = \text{standard deviation of the differences between actual and computed values}—68\% \text{ of the time actual REE will be within } \pm 1 \text{ standard deviation of the predicted REE.} \)
<table>
<thead>
<tr>
<th>TABLE 14.2</th>
<th>Equations for Calculating Estimated Energy Requirement (EER) in Kilocalories Per Day¹</th>
</tr>
</thead>
</table>

**EER for Infants and Young Children**

<table>
<thead>
<tr>
<th>Age</th>
<th>EER Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–3 months</td>
<td>( (89 \times \text{weight} - 100) + 175 )</td>
</tr>
<tr>
<td>4–6 months</td>
<td>( (89 \times \text{weight} - 100) + 56 )</td>
</tr>
<tr>
<td>7–12 months</td>
<td>( (89 \times \text{weight} - 100) + 22 )</td>
</tr>
<tr>
<td>13–35 months</td>
<td>( (89 \times \text{weight} - 100) + 20 )</td>
</tr>
</tbody>
</table>

**EER for Males 3 through 8 Years**

\[ \text{EER} = \text{TEE} + \text{Tissue Deposition} \]

\[ \text{EER} = 88.5 - 61.9 \times \text{age} + \text{PA} \times (26.7 \times \text{weight} + 903 \times \text{height}) + 20 \]

Where \( \text{PA} \) is the physical activity coefficient:

- \( \text{PA} = 1.00 \) for sedentary
- \( \text{PA} = 1.13 \) for low active
- \( \text{PA} = 1.26 \) for active
- \( \text{PA} = 1.42 \) for very active

**EER for Males 19 Years of Age and Older**

\[ \text{EER} = \text{TEE} \]

\[ \text{EER} = 662 - 9.53 \times \text{age} + \text{PA} \times (15.91 \times \text{weight} + 539.6 \times \text{height}) \]

Where \( \text{PA} \) is the physical activity coefficient:

- \( \text{PA} = 1.00 \) for sedentary
- \( \text{PA} = 1.11 \) for low active
- \( \text{PA} = 1.25 \) for active
- \( \text{PA} = 1.48 \) for very active

**EER for Females 19 Years of Age and Older**

\[ \text{EER} = \text{TEE} \]

\[ \text{EER} = 354 - 6.91 \times \text{age} + \text{PA} \times (9.36 \times \text{weight} + 726 \times \text{height}) \]

Where \( \text{PA} \) is the physical activity coefficient:

- \( \text{PA} = 1.00 \) for sedentary
- \( \text{PA} = 1.12 \) for low active
- \( \text{PA} = 1.27 \) for active
- \( \text{PA} = 1.45 \) for very active

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EER for Females 3 through 8 Years

EER = TEE + Tissue Deposition
EER = 135.3 − 30.8 × age + PA × (10.0 × weight + 934 × height) + 20
Where PA is the physical activity coefficient:
PA = 1.00 for sedentary
PA = 1.16 for low active
PA = 1.31 for active
PA = 1.56 for very active

EER for Males 9 through 18 Years

EER = TEE + Tissue Deposition
EER = 88.5 − 61.9 × age + PA × (26.7 × weight + 903 × height) + 25
Where PA is the physical activity coefficient:
PA = 1.00 for sedentary
PA = 1.13 for low active
PA = 1.26 for active
PA = 1.42 for very active

EER for Females 9 through 18 Years

EER = TEE + Tissue Deposition
EER = 135.3 − 30.8 × age + PA × (10.0 × weight + 934 × height) + 25
Where PA is the physical activity coefficient:
PA = 1.00 for sedentary
PA = 1.16 for low active
PA = 1.31 for active
PA = 1.56 for very active

EER for Pregnancy

EER = EER for age + Pregnancy Energy Needs + Tissue Deposition
1st trimester = EER for age + 0
2nd trimester = EER for age + 160 + 180
3rd trimester = EER for age + 272 + 180

EER for Lactation

EER = EER for age + Milk Energy Output − Weight Loss
1st six months = EER for age + 500 − 170
2nd six months = EER for age + 400 − 0

1 EER = Estimated Energy Requirement; TEE = Total Energy Expenditure; PA = Physical Activity Coefficient; age is in years; height is in meters; weight is in kilograms.
2 Tissue Deposition represents the energy cost of growth during infancy, childhood, adolescence, and pregnancy as measured in kilocalories.
3 Pregnancy Energy Needs represents the additional energy required to support the metabolic demands of pregnancy.
4 Milk Energy Output represents the energy needed to produce the milk during lactation. Milk output is somewhat greater in the first six months than in the second six months of breastfeeding.
5 Weight Loss represents a average decline in EER of 170 kcal/day that well-nourished lactating women experience during the first six months postpartum, resulting in an average weight loss of 0.8 kg/month.
<table>
<thead>
<tr>
<th>TABLE 14.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equations for Calculating Total Energy Expenditure (TEE) for Weight Maintenance in Kilocalories Per Day for Overweight and Obese Adults and for Overweight Children and Adolescents¹</td>
</tr>
</tbody>
</table>

**TEE for Overweight and Obese Males Aged 19 Years and Older**

\[
TEE = 1086 - 10.1 \times \text{age} + \text{PA} \times (13.7 \times \text{weight} + 416 \times \text{height})
\]

Where PA is the physical activity coefficient:

- PA = 1.00 for sedentary
- PA = 1.12 for low active
- PA = 1.29 for active
- PA = 1.59 for very active

**TEE for Overweight and Obese Females Aged 19 Years and Older**

\[
TEE = 448 - 7.95 \times \text{age} + \text{PA} \times (11.4 \times \text{weight} + 619 \times \text{height})
\]

Where PA is the physical activity coefficient:

- PA = 1.00 for sedentary
- PA = 1.16 for low active
- PA = 1.27 for active
- PA = 1.44 for very active
TEE for Overweight Males Aged 3 through 18 Years

$$TEE = -114 - 50.9 \times \text{age} + \text{PA} \times (19.5 \times \text{weight} + 1161.4 \times \text{height})$$

Where PA is the physical activity coefficient:

- PA = 1.00 for sedentary
- PA = 1.12 for low active
- PA = 1.24 for active
- PA = 1.45 for very active

TEE for Overweight Females Aged 3 through 18 Years

$$TEE = 389 - 41.2 \times \text{age} + \text{PA} \times 15.0 \times \text{weight} + 701.6 \times \text{height}$$

Where PA is the physical activity coefficient:

- PA = 1.00 for sedentary
- PA = 1.18 for low active
- PA = 1.35 for active
- PA = 1.60 for very active

¹TEE = Total Energy Expenditure; PA = Physical Activity Coefficient; age is in years; height is in meters; weight is in kilograms. In persons age 19 years and older overweight is defined as a BMI between 25.0 kg/m² and 29.9 kg/m² and obese is defined as a BMI ≥30.0 kg/m². In persons age 3 to 18 years, overweight is defined as a BMI for age and sex ≥95th percentile.
Indirect Calorimetry

- Metabolic research or critically ill patients
- Measures inspired and expired air by minute ventilation
- EE proportional to oxygen consumption and carbon dioxide production
Doubly Labeled Water
- “Gold standard”
- 2 stable isotope forms of water
- Rate at which isotopes disappear is measured in urine over 2–week period
Direct Calorimetry
- Chamber which measures heat expired through evaporation, convection, and radiation
- Rarely available
Interaction of nervous and endocrine systems
  ◦ Orexigenic
  ◦ Anorexigenic
  ◦ Adaptive thermogenesis
Regulation of Energy Balance

- Appetite stimulated by hypothalamus
  - Secretions of pancreatic and GI hormones
  - Increase and decrease appetite and food intake
  - Pradar–Willi syndrome
Hormones affecting appetite & food intake

- Insulin
- Glucagon
- Amylin
- Cholecystokinin (CCK)
- Glucagon like peptide−1
- Peptide YY
- Ghrelin
Adipose Tissue

- Adipocyte – fat cell; mostly TG
- Storage site – 90% energy reserves
- Other functions
- White fat (WAT) vs. brown fat (BAT)
- Lipogenesis
Newly imported triglycerides first form small droplets at the periphery of the cell, then merge with the large, central globule.

As the central globule enlarges, the fat cell membrane expands to accommodate its swollen contents.
Adipose Tissue

- Adiponectin and leptin stimulate storage
- Hypertrophy and hyperplasia of cells
- “Adiposity rebound”
Body Composition

- “Two compartment model” – fat vs. fat-free mass
- Use of height and weight – BMI commonly used to assess obesity
  - Does not directly measure fatness
  - Clinical judgment should be used
Body Composition

- Body Mass Index (BMI)
  - Obese $\geq 30$
    - calculation and classifications
- BMI percentiles
  - CDC growth charts
  - Pediatric population
  - $\geq 95\%$th percentile = obesity
  - $\geq 85\%$th percentile = overweight
Body Fat Distribution

- Important predictor of health status
- Abdominal/central body fat
  - Apple, android
- Lower body fat
  - Hips and thighs, pear, gynoid
- Measured by waist circumference and waist-to-hip ratio
Body Fat Distribution

- Waist circumference
  - Increased risk of type 2 DM, htn., dyslipidemia, CHD, metabolic syndrome
  - > 40 in. males, > 35 in. females – “high risk”
Body Fat Distribution

- **Waist-to-hip ratio (WHR)**
  - Waist circumference/hip circumference
  - Disease risk increases with WHR > 0.95 in males and >0.8 in females

- Key concept: fat deep within abdomen and around intestines and liver increases disease risk
# Table 14.5

**Classification of Overweight and Obesity by BMI, Waist Circumference, and Associated Disease Risk**

<table>
<thead>
<tr>
<th>BMI (kg/m²)</th>
<th>Obesity Class</th>
<th>Disease Risk¹ (Relative to Normal Weight and Waist Circumference)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Men ≤ 40 in (≤ 102 cm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Women ≤ 35 in (≤ 88 cm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Men &gt; 40 in (&gt; 102 cm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Women &gt; 35 in (&gt; 88 cm)</td>
</tr>
<tr>
<td>Underweight</td>
<td>&lt; 18.5</td>
<td>—</td>
</tr>
<tr>
<td>Normal²</td>
<td>18.5–24.9</td>
<td>—</td>
</tr>
<tr>
<td>Overweight</td>
<td>25.0–29.9</td>
<td>Increased</td>
</tr>
<tr>
<td>Obesity</td>
<td>30.0–34.9</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>35.0–39.9</td>
<td>Very high</td>
</tr>
<tr>
<td>Extreme Obesity</td>
<td>≥ 40.0</td>
<td>Extremely high</td>
</tr>
</tbody>
</table>

¹ Disease risk for type 2 diabetes, hypertension, and cardiovascular disease.

² Increased waist circumference can also be a marker for increased risk even in persons of normal weight.
Epidemiology of Overweight & Obesity

- “Globesity,” “epidemic”
- In the U.S. – NHANES data
  - Significant increases
- Canada
- Europe
- By race, ethnicity, SES, age
Adverse Consequences

“The age of caloric anxiety”
Type 2 diabetes
High blood pressure
CHD
Cancer
Mortality
Etiology of Obesity

- Chronic energy intake exceeding energy expenditure
- Key contributors:
  - Medical disorders and treatment
  - Genetics
  - Obesigenic environment
Etiology of Obesity

- Medical disorders and treatment
  - Cushings syndrome, hypothyroidism, Prader–Willi
  - Pharmacological agents
  - Smoking cessation
  - Night eating syndrome
  - Binge eating
**TABLE 14.6**

*Medical Conditions and Pharmacologic Agents Known to Cause Obesity*

<table>
<thead>
<tr>
<th>Congenital Causes</th>
<th>Neuroendocrine Disorders</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Prader-Willi syndrome</td>
<td>• Alstrom syndrome</td>
</tr>
<tr>
<td>• Down syndrome</td>
<td>• Cohen syndrome</td>
</tr>
<tr>
<td>• Bardet-Biedel syndrome</td>
<td>• Carpenter syndrome</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pharmacologic Agents</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Psychiatric Medications</em></td>
<td></td>
</tr>
<tr>
<td>• Olanzapine, clozapine</td>
<td>• Gabapentin</td>
</tr>
<tr>
<td>• Selective serotonin reuptake</td>
<td>• Valproate</td>
</tr>
<tr>
<td>inhibitors</td>
<td>• Carbamazepine</td>
</tr>
<tr>
<td>• Monoamine oxidase inhibitors</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Steroid Hormones</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Hormonal contraceptives</td>
<td>• Progestational agents</td>
</tr>
<tr>
<td>• Corticosteroids</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Antidiabetic Agents</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Insulin</td>
<td>• Thiazolidinediones</td>
</tr>
<tr>
<td>• Sulfonylureas</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Miscellaneous</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Antihistamines</td>
<td>• β-adrenergic inhibitors</td>
</tr>
<tr>
<td>• α-adrenergic inhibitors</td>
<td>• Protease inhibitors</td>
</tr>
</tbody>
</table>
Etiology of Obesity

Genetics
- 40–50% of BMI explained by genetics
- Influences taste, appetite, intake, expenditure, NEAT, storage
- “Set-point” theory
- Multiple genes
- Predictive in families – parents & twins
  - 80% of offspring with 2 obese parents
  - 40% of offspring with 1 obese parent
  - MZ twins more likely than DZ twins
Etiology of Obesity

- **Obesigenic environment**
  - “Toxic food environment” – convenient availability of low-cost, tasty, energy-dense foods in large portions
  - Evidence supports low-energy-dense foods for satiety
    - Soups, fruits, vegetables, cooked whole grains
    - Barriers – cost and convenience
# Table 14.7


<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Adult Females</td>
<td>1,542 kcal</td>
<td>1,877 kcal</td>
<td>+335 kcal (22%)</td>
</tr>
<tr>
<td>U.S. Adult Males</td>
<td>2,450 kcal</td>
<td>2,618 kcal</td>
<td>+168 kcal (7%)</td>
</tr>
</tbody>
</table>
Treatment

- Two-step process
  - Assessment
  - Management
  - NIH algorithm for treatment
Treatment

- **Assessment**
  - BMI & waist circumference
  - Current chronic diseases
  - Diet and physical activity habits
  - Patient’s readiness to lose weight
  - Identify and address barriers, coping skills, self-efficacy
  - Behavioral assessment
Management

- Use of recommended therapies
- Control of factors known to increase risk of morbidity
- Therapies include – diet, physical activity, behavioral therapy, bariatric surgery, pharmacologic treatment
- Lose 10% in 6 mo.
# TABLE 14.8

A Guide to Selecting Treatment of Overweight and Obesity

<table>
<thead>
<tr>
<th>Treatment</th>
<th>BMI Category (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25.0–26.7</td>
</tr>
<tr>
<td>Diet, physical activity, and behavioral therapy</td>
<td>with comorbidites</td>
</tr>
<tr>
<td>Pharmacotherapy</td>
<td>with comorbidites</td>
</tr>
<tr>
<td>Surgery</td>
<td></td>
</tr>
</tbody>
</table>

Prevention of weight gain with lifestyle therapy is indicated in any patient with a BMI ≥ 25 kg/m², even without comorbidities, while weight loss is not necessarily recommended for those with a BMI of 25–29.9 kg/m² or a high waist circumference, unless they have two or more comorbidities.

Combined therapy with a low-kcalorie diet (LCD), increased physical activity, and behavior therapy provide the most successful intervention for weight loss and weight maintenance. Consider pharmacotherapy only if a patient has not lost 1 pound per week after 6 months of combined lifestyle therapy. The + represents the use of indicated treatment regardless of comorbidities.
Treatment

- **Nutrition therapy**
  - Reduce intake 500–1000 kcal/d.
  - Lose 1–2 lbs./week
  - NIH low-kcalorie diet
  - Minimize CVD risk factors – NCEP Therapeutic Lifestyle Changes diet
  - 1000–1200 kcal/d women, 1200–1600 kcal/d men minimum
  - Unclear whether altering macronutrient levels is beneficial
# TABLE 14.9

Low-Calorie Diet (LCD) Recommended by the National Institutes of Health

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Recommended Intake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories(^1)</td>
<td>Approximately 500 to 1,000 kcal/day reduction from usual intake</td>
</tr>
<tr>
<td>Total fat(^2)</td>
<td>30% or less of total calories</td>
</tr>
<tr>
<td>Saturated fatty acids(^3)</td>
<td>8%–10% of total calories</td>
</tr>
<tr>
<td>Monounsaturated fatty acids</td>
<td>Up to 15% of total calories</td>
</tr>
<tr>
<td>Polyunsaturated fatty acids</td>
<td>Up to 10% of total calories</td>
</tr>
<tr>
<td>Cholesterol(^3)</td>
<td>&lt;300 mg/day</td>
</tr>
<tr>
<td>Protein(^4)</td>
<td>Approximately 15% of total calories</td>
</tr>
<tr>
<td>Carbohydrate(^5)</td>
<td>55% or more of total calories</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>No more than 100 mmol/day (approximately 2.4 g of sodium or approximately 6 g of sodium chloride)</td>
</tr>
<tr>
<td>Calcium(^6)</td>
<td>1,000 to 1,500 mg/day</td>
</tr>
<tr>
<td>Fiber(^5)</td>
<td>20 to 30 g/day</td>
</tr>
</tbody>
</table>
Treatment

- Physical Activity
  - Crucial for weight maintenance
  - Minimum 30–45 min moderate activity 3–5 days/week
  - Initiate slowly and gradually
  - Can be programmed or lifestyle activities
Treatment

- Behavior Therapy
  - Techniques for identifying and overcoming barriers
    - Self-monitoring
    - Stimulus control
    - Rewards
Pharmacologic Treatment

- BMI $\geq 30$ or $\geq 27$ with risk factors
- Consider cost and side effects, and rebound weight gain
- Long-term use
  - Sibutramine (Meridia)
  - Orlistat (Xenical)
- Others for short-term use
Treatment

- Surgery
  - Bariatric surgery – BMI ≥ 40 or ≥ 35 with risk factors
  - Roux–en Y gastric bypass, vertical banded gastroplasty, adjustable band gastroplasty
  - Assess benefits vs. risks
  - Preoperative screening & education important
In vertical banded gastroplasty, the surgeon constructs a small stomach pouch and restricts the outlet from the stomach to the intestine.

In gastric bypass, the surgeon constructs a small stomach pouch and creates an outlet directly to the jejunum.