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Lecture 4: Metabolism and Dieting

Critical Analysis of Popular Diets and Supplements

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Components of Metabolic Rate

- **Terminology:**
  - Basal metabolic rate (BMR) or Resting metabolic rate (RMR or REE)
  - Thermic effect of feeding (TEF)
  - Activity energy expenditure (EE_{act})
  - Total daily energy expenditure (TEE/TDEE)
Resting Metabolic Rate

What comprises RMR?
- Organs with high energy needs total only 5% of body weight, yet use 58% of REE:
  - liver = 21% of total RMR; brain 20%; heart 9%; kidneys 8% (heart and kidneys=highest EE/g)
- Muscle EE is only 3% of heart’s g/g at rest, but in total comprises 22% of RMR at rest
- Adipose tissue is even lower g/g, and is always at rest: 4% of RMR in lean, up to 10+% in obese
- Remaining 16% is from skin, GI, lungs, bones, etc
Gender, Age, Body Composition

- Women have lower RMR than men of same weight and height
- RMR of child > adult > senior
- % body lean determines RMR more than % body fat
RMR Differences

- Key point: obese often have higher RMRs than expected because they have excess muscle as well as excess fat.

- Of note: even after adjusting for differences in muscle, fat-free mass (FFM), and VO$_2$-max, women have 3-10% lower RMR than men.

- Causes are unclear: ? hormonal influence; diffs in muscle fiber type, Na-K-ATPase activity, neoglucogenesis activity, SympNS, core temp.
Hormonal influences on RMR

- Catecholamines (adrenaline/epinephrine, NE) increase RMR by ~20%, via muscle, heart adrenergic receptor stimulation
- Thyroxine (T₄) and thyronine (T₃) can increase RMR by up to 80% (days delay)
- Leptin also can increase RMR and EE_{act}
Implications of Low/High RMR

- In Pima Indians (genetically prone to obesity and type-2 diabetes):
  - Risk of weight gain is much greater in those with low-normal RMR c/w high-normal RMR

- Genetic influences on RMR: present
  - Adjusted for weight, the 95% CI in populations of normal adults spans +/- 250 kcal/d
Thermic Effect of Feeding (TEF)-1

- Also called DIT (diet-induced thermogenesis)
- It is the energy cost of digestion, absorption, processing and storage of nutrients
- Comprises about 10% of TEE in sedentary
- There are no significant age or gender diffs
- But obese seem to have lower TEFs
Thermic Effect of Feeding (TEF)-2

- TEF increases with amount eaten, meal frequency
- TEF can be determined and varies by macronutrient: macronutrient-specific TEFs (by % of energy in the food used as TEF when the food is completely metabolized):
  - CHO: glucose 8%, starch slightly higher
  - Protein 20-30%
  - Fat 2%
  - Ethanol 22%
Energy Cost of Interconversion and Storage

- All macronutrients can be interconverted
- If it’s not used for fuel, conversion of CHO to fat burns/wastes 23% of the ATP energy in the CHO
- Storing fat burns only 3% of the energy in the fat
Measurement of Metabolism

- Prediction equations
- Indirect calorimetry
- Direct calorimetry
- Doubly-labeled water
- Thyroid hormone levels ($T_4$, $TSH$)
Prediction equations
Indirect calorimetry (IC)

- Most accessible measure of actual physiology of an individual; usually performed after overnight fast
- Can determine RMR, TEF, EE_{act}
- Immediate response, as O_2 is not stored

Based on the observation that burning a mixed fuel (absorbed food) produces 20.3 kJ of E for every liter of O_2 consumed at STP (dry):

\[ M = 20.3 \text{ kJ/L} \times (V_{O_2 \max}) \text{ in L/min} \]

*Where* M = metabolic rate, in kJ/min
Indirect Calorimetry-2

- Only O2 consumption is needed to calculate EE, but IC also measures CO2 being produced.
- IC can thus determine fuel mix being burned because specific fuels have different ratios of CO2 produced to O2 consumed (the respiratory quotient, or RQ):

<table>
<thead>
<tr>
<th></th>
<th>O2 used</th>
<th>CO2 produced</th>
<th>RQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHO</td>
<td>0.83L</td>
<td>0.83L</td>
<td>1.00</td>
</tr>
<tr>
<td>Protein</td>
<td>1.01L</td>
<td>0.84L</td>
<td>0.83</td>
</tr>
<tr>
<td>Fat</td>
<td>2.02L</td>
<td>1.43L</td>
<td>0.71</td>
</tr>
</tbody>
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Direct calorimetry (DC)

- Measures heat losses, not heat produced
- DC measures heat loss via radiation, conduction, convection, and evaporation in a specially-constructed, insulated room
- Heat production begins ~20 min into a meal
- Heat loss begins later, so body temp rises then falls after a meal
- At steady state, heat production = heat loss
Doubly-Labeled Water (DL H$_2$O)

- Uses the non-radioactive isotope $^{2}$H$^{18}$O
- $^{18}$O rapidly exchanges between the O in water and the O in CO$_2$ (courtesy of carbonic anhydrase)
- CO$_2$ is exhaled, so the concentration of the body’s $^{18}$O declines, but the other label ($^2$H) is stuck in H$_2$O
- The difference in the rate of turnover (loss) of the 2 labeled forms of H$_2$O (doubly vs singly-labeled) is thus a measure of the production rate for CO$_2$
- This loss is gauged by taking a saliva sample at day 14 and measuring the ratio of water isotopes
- Thus, DL H$_2$O measures EE over the prior 14 days, not day-to-day EE
Thyroid Hormone Levels (T4, TSH)

- Typical of the endocrine system, there are multiple levels of control of thyroid hormones
- T3 is the final active hormone
- T4 is converted to T3
- The pituitary gland produces TSH (thyroid-stimulating hormone) which regulates T4/T3
- The hypothalamus produces TRH (thyroid releasing hormone) which regulates TSH
- We measure TSH mostly: a high TSH = slow thyroid function, hypothyroidism (high because the pituitary attempts to flog a sluggish thyroid gland)
Effect of weight loss on TEE

- With weight loss, **RMR** declines in proportion to the decline in fat-free mass
  - This decline can be blunted by preserving muscle mass through resistance training
- **TEF** declines during a diet (less food eaten)
  - TEF recovers once diet returns to normal
- **EE_{act}** declines as E cost of movement declines
  - This decline can be blunted by increasing activity level