JOHNS HOPKINS BLOOMBERG SCHOOL of PUBLIC HEALTH

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 $VO_{2\text{-max}}$, 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 (T_4) and thyronine (T_3) 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 CO_2 being produced
- IC can thus determine fuel mix being burned because specific fuels have different ratios of CO_2 produced to O_2 consumed (the respiratory quotient, or RQ):

Per gram of fuel (substrate) burned:

	O2 used	*CO2 produced*	RQ
CHO:	0.83L	0.83L	1.00
Protein:	1.01L	0.84L	0.83
Fat	2.02L	1.43L	0.71

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_2O)

- Uses the non-radioactive isotope $^2H_2O^{18}$
- O^{18} 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 O^{18} declines, but the other label (^2H) is stuck in H_2O
- The difference in the rate of turnover (loss) of the 2 labeled forms of H_20 (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_20 measures EE over the prior 14 days, not day-to-day EE

Thyroid Hormone Levels (T_4, TSH)

- Typical of the endocrine system, there are multiple levels of control of thyroid hormones
- T_3 is the final active hormone
- T_4 is converted to T_3
- 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