Nutrition 101 – Class 2

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Nutrition 101

*Introduction to Human Nutrition*” second edition
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May be purchased online but is not required for the class.
Energy Metabolism

- Energy balance in the body is the balance of how much energy is consumed and how much energy is expended.
- This is an example of homeostatic control.
- Results in maintenance of body weight and body energy stores.
First Law of Thermodynamics

- Energy can be neither destroyed nor created.
- This principle necessitates that when energy intake equals energy expenditure, body energy stores must remain constant.
Components of Energy Balance

- Energy Intake
- Energy Storage
- Energy Expenditure
- Energy Balance
Energy Intake

- The caloric or energy content of food as provided by the major sources of dietary energy:
  - Carbohydrate – 16.8kJ/g (4 cal/g)
  - Protein – 16.8kJ/g (4 cal/g)
  - Fat – 37.8kJ/g (9 cal/g)
  - Alcohol – 29.4kJ/g (7 cal/g)
The energy that is consumed in the form of food or drinks can either be used by the body to fuel energy-requiring events or be stored in the body in one of the following forms:

- Fat – major energy store
- Glycogen – short term energy/carbohydrate reserves
- Protein – rarely used by the body for energy except in severe cases of starvation and other wasting conditions
Energy Expenditure

- The largest use of energy is needed to fuel the basal metabolic rate (BMR), which is the energy expended by the body to maintain basic physiological functions.
- BMR is the minimum level of energy expended by the body to sustain life in the awake state.
- BMR can be measured after a 12 hour fast and the subject is resting quietly.
Resting Metabolic Rate (RMR)

- Slightly higher energy expended during RMR (3%) owing to less subject arousal and non-fasting conditions
- BMR and RMR are often used interchangeably
- RMR occurs in a continued process throughout a 24 hour day and remains relatively constant
- Basal or resting metabolic rate is the largest component of energy expenditure and makes up about 2/3 of total energy expenditure
Energy Expenditure

- Food intake increases energy expenditure
- Thermic effect of a meal – increased metabolic rate after food consumption (meal induced thermogenesis)
- Thermogenesis – energy that is expended to digest, metabolize, convert, and store ingested macronutrients
- Thermic effect of a meal is about 10% of the caloric content of the meal consumed
Physical activity is another source of energy expenditure

Includes physical activity and exercise

Physical Activity Energy Expenditure – (thermic effect of exercise) the increase in metabolic rate that is caused by use of skeletal muscles for any type of physical movement

This is the most variable component of daily energy expenditure
Three Major Components of Energy Expenditure

- Resting Metabolic Rate
- Thermogenesis
- Physical Activity Energy Expenditure
Other components of energy expenditure

- **Growth**
  - Small except during first few months of life

- **Adaptive thermogenesis**
  - Heat production during exposure to reduced temperatures
  - i.e., during fever

- **Environmental agents affecting thermogenesis**
  - Nicotine – 10% higher in heavy smokers
  - Caffeine – coffee, tea, chocolate
  - Capsaicin – hot chilies
Energy Balance

- Occurs when energy content of food is matched by the total amount of energy that is expended
- Positive energy balance – energy intake exceeds energy expenditure
- Negative energy balance – energy intake is lower than energy expenditure
- Also important to consider energy balance in terms of major sources of energy
  - Carbohydrate, protein, fat
  - Carbohydrate balance = carbohydrate ingested is balanced with that expended for energy
Energy Intake

Sources of dietary energy

- Carbohydrate – 16.8kJ/g
- Protein – 16.8kJ/g
- Fat – 37.8kJ/g
- Alcohol – 29.4kJ/g

4.2 kJ is the amount of heat that is required to raise the temperature of 1 liter of water by 1 degree Celsius
Regulation of Food Intake

- **Appetite** - learned response
  - Psychological desire to eat and is related to the pleasant sensations that are often associated with specific foods
  - Overall sensations related to food intake

- **Hunger** – intrinsic instinct
  - Subjective feeling that determines when food consumption is initiated and can be described as a nagging, irritating feeling that signifies food deprivation to a degree that the next eating episode should take place

- **Satiety** – intrinsic instinct
  - State of inhibition over eating that leads to the termination of a meals, and is related to the time interval until the next eating episode
Internal Factors that Regulate Hunger and Satiety

- Central Nervous System
  - Hypothalamus and vagus nerve
- Major Digestive Organs
  - Stomach, liver, and hormones
- Environmental Factors
  - Meal pattern and composition, food availability, smell and sight of foods, climate
- Emotional Factors
  - Stress
- Diseased States
  - Anorexia, trauma, infection
Factors Influencing Appetite

- **External**
  - Climate, weather
  - Specific appetite craving
  - Specific learned dislikes or avoidance
    - Alcohol
  - Intrinsic properties of food
    - Taste, palatability, texture
  - Cultural practices or preferences
  - Specific effects of some drugs and disease
  - Metabolic factors
    - Hormones and neurotransmitters
Factors Influencing Food Intake

- Digestive
- Central Nervous System
- Circulating
- Signals from the periphery
- External
Digestive Factors

- Gastrointestinal distension
- Cholecystokinin is produced by the stomach in response to food intake, which may regulate food intake
- Receptors in the intestine have been identified that recognize the presence of specific macronutrients
  - These receptors are linked to the brain and therefore can communicate directly with the central nervous system, resulting in regulation of energy balance
Hypothalamus is the main contributory factor in regulating food intake

- Linked to specific parts of the brain that modify feeding behavior
- These areas of the brain respond to neurotransmitters as well as sympathetic nervous system activity
- Food intake decreases as sympathetic nervous system activity increases and vice versa
Circulating Factors

After eating, food is broken down into its basic components and the circulating levels of some of these breakdown products increase in the blood:

- Carbohydrate → glucose
- Proteins → amino acids
- Fats or triglycerides → glycerol and fatty acids

Liver metabolizes glucose, amino acids, glycerol, and fatty acids for immediate energy.

This regulates food intake until nutrient levels fall and feelings of hunger return.

Vagus nerve signals from the liver to the brain.
Leptin is a hormone that is produced by fat cells and communicates with the CNS through leptin receptors in the hypothalamus.

Low levels of leptin may regulate food intake and play a key role in the etiology of rare forms of obesity.

Leptin, insulin and adiponectin are long acting signals reducing energy intake.

Ghrelin (hunger hormone) and CCK – satiety signals.
External Factors

- Psychological
  - Depression

- Environmental
  - Food availability

- Physical characteristics of the food
  - Taste, texture, color, temperature, presentation

- Cultural influences
  - Time of day, social factors, peer influence, cultural preferences
Concept of Energy Expenditure

- Energy expenditure and oxidation or combustion of food for energy in the body is similar to a woodstove that burns wood for heat.
- Wood is fed to the stove and is combusted in the presence of oxygen to release carbon dioxide, water vapor, and heat.
- Food consumed is oxidized in the presence of oxygen to release carbon dioxide, water, and heat.
Lavoisier – French Scientist

- Discovered a candle would only burn in the presence of oxygen
- Living organisms produce heat as they require oxygen for life and combust food as they release heat
- Built the first calorimeter – used to measure heat production
- Direct calorimetry – direct measurement of heat
Indirect calorimetry

- Measures energy production via respiratory gas analysis
- Based on oxygen consumption and carbon dioxide production that occurs during the combustion of protein, carbohydrate, fat, and alcohol
- Respiratory Quotient (RQ) – ratio of carbon dioxide production oxygen consumption
- RQ is indicative of type of substrate being oxidized
- CHO oxidation has RQ of 1.0
- Fat oxidation has RQ of 0.7
- Protein oxidation has RQ of 0.8
Resting Metabolic Rate

- Highly variable between individuals (+/- 25%)
- Very consistent within individuals (<5%)
- RMR occurs predominantly in muscle and the major organs of the body
- Fat-free mass (FFM) – total mass of the body that is not fat, explains 60-80% of variation in RMR between individuals
- The greater the fat-free mass, the greater the RMR
Fat-free mass is metabolically inert

More active individuals have a higher RMR than inactive individuals

FFM, fat mass, age, gender, and physical activity explain 80-90% of the variance in RMR

Increased thyroid hormones increase metabolic rate
Harris-Benedict formulae predict RMR from age, height, and weight

More recent equations predict RMR from weight in kg

**Men**
- 18-30 years: \((15.3 \times \text{wt}) + 679\)
- 30-60 years: \((11.6 \times \text{wt}) + 879\)
- >60 years: \((13.5 \times \text{wt}) + 487\)

**Women**
- 18-30 years: \((14.7 \times \text{wt}) + 496\)
- 30-60 years: \((8.7 \times \text{wt}) + 829\)
- >60 years: \((10.5 \times \text{wt}) + 596\)
Thermic Effect of Feeding

- Influenced by the quantity and macronutrient quality of the ingested calories
- Metabolic rate increases after meal ingestion
- Higher for carbohydrate and protein than fat
Physical Activity Energy Expenditure

- Includes all activity
- Determinants of the metabolic rate of physical activity
  - Amount or duration of activity – time
  - Type of physical activity – walking, running
  - Intensity of the activity
Metabolic Equivalents

Metabolic cost of physical activities is expressed as metabolic equivalents (METs), which represent multiples of RMR

- Sitting quietly = 1.0 MET
- Gardening = 5.0 MET
- Walking = 3.0-5.0 MET
- Running = 8.0-18.0 MET
AT HOME ACTIVITIES

- Sweeping carpet: 3.3, 99-124 cal / 30 min
- Gardening: 4.0, 120-150 cal
- Playing with dog (moderate): 4.0, 120-150 cal
- Wash & wax car: 4.5, 135-168 cal
- Playing with Kids (vigorous): 5.0, 150-188 cal
- Moving furniture: 6.0, 180-225 cal

Better for lighter workouts and beginners.
FORMAL EXERCISE

- Intro Pilates class: 3.5 units / 105-131 cal / 30 min
- Walking 4.0 mph (very briskly): 5.0 units / 150-188 cal
- Weightlifting (vigorous): 6.0 units / 180-225 cal
- Swimming front crawl (slow pace): 8.0 units
- Boot camp / Calisthenics (vigorous): 8.0 units
- Running 9:00 / mile: 11.0 units / 330-413 cal

Better for lighter workouts and beginners

Better for harder workouts and experienced exercisers
Total Energy Expenditure

- Integrated sum of all components of energy expenditure
- Metabolic chamber – 24 hours
- Doubly labeled water (DLW) technique
  - Ingest small amount of “heavy” water
  - 7-14 days
  - Non-invasive
  - Free-living conditions
- Disadvantages are expense of isotope, expensive equipment, and periodic non-availability of isotope
Energy Requirements

- Energy needs of the body to maintain energy balance must be equal to total daily energy expenditure.

- Total energy expenditure is often compared across groups or individuals using the ratio of one’s total energy expenditure to RMR, or physical activity level (PAL).
  - Example: if total energy expenditure is 12.6 MJ/day and the RMR was 6.3 MJ/day, the PAL factor would be 2.0.
  - This is twice the RMR.
  - Cyclists in Tour de France had a PAL of 5.0, that is 5 times their RMR!
  - Migrating birds can have a PAL up to 20.0.
Sedentary people usually have a PAL around 1.4

Light active people may have a PAL around 1.6 (sedentary people in an urban environment)

Physically active people – 1.75 PAL

PAL of 1.8 protects against development of obesity

Increasing your PAL from 1.6 → 1.8 requires 30 min of daily vigorous activity or 60 min of light activity
Infancy and Childhood

Existing recommendations may overestimate true energy needs, based on measurement of total energy expenditure of infants.
Aging

- Two problems in energy balance
  - Decline in food intake that is associated with dynamic changes in body composition where there is a tendency to lose FFM, which leads to loss in functionality
  - Gain fat mass, which increases the risk for obesity, cardiovascular disease, and noninsulin-dependent diabetes

 These two opposing patterns suggest that the ability to self-regulate whole body balance may diminish with aging
Special Considerations in the Elderly

Alzheimer’s and Parkinson’s disease lead to malnourished states and a diminishing of body weight
Physically Active Groups

- Regular participation in exercise is traditionally thought to elevate energy requirements through the additional direct cost of the activity, as well as through an increase in RMR.

- However, in some situations energy requirements are not necessarily altered by participation in regular physical activity.

- Can not be assumed that energy requirements are elevated by participation in activity programs.

- Ultimate change in energy requirements may be dictated by the intensity of the training program and the net sum of change in individual components of energy expenditure.
Other Factors Effecting Energy Metabolism

- Pregnancy and lactation – positive energy balance
- Disease or Trauma – under feeding and overfeeding of critically ill patients can lead to metabolic complications
- Burn injury – increases RMR
- Anorexia Nervosa – normal energy requirements
- Cystic Fibrosis – increased energy expenditure
Obesity

- Most common form of a disruption in energy balance and now one of the major and most prevalent disorders of nutrition
- Obesity is now considered a disease because of the strong relationship between obesity and health risks
- Preferential storage of excess calories as fat
Storage Capacity

- **Alcohol**
  - no storage capacity
  - Immediately oxidized for energy

- **Protein**
  - Very limited storage capacity
  - Protein metabolism is very well regulated

- **Carbohydrates**
  - Very limited storage capacity in the form of glycogen
  - Glycogen – very small and short-term energy store, which can easily be depleted after an overnight fast or bout of exercise
  - Most is immediately used for energy
Carbohydrates

- Humans cannot convert excess carbohydrate intake to fat
- Excess carbohydrates → body adapts by preferentially increasing its use of carbohydrate as fuel, in effect, burning off any excessive carbohydrate consumption
- If excess fat is consumed → accumulate the excess fat as an energy store in the body
- Body prefers to store fat than glycogen
Glycogen requires 3 g of water of each gram of glycogen, fat does not.

For each gram of glycogen stored, the body has to store an additional 3 g of water.
Obesity

- Excess accumulation of body energy, in the form of fat or adipose tissue
- Disease of positive energy balance
- Body mass index (BMI) is weight in kilograms divided by height squared in meters
  - 18.5-24.9 BMI $\rightarrow$ normal
  - 25-30 BMI $\rightarrow$ overweight
  - $>30$ BMI $\rightarrow$ obese

*Does not distinguish between excess muscle weight and excess fat weight*
Other Anthropometric Indices of Body Shape

- **Waist-to-hip ratio**
  - Upper vs. lower body-fat distribution

- **Waist circumference**
  - Best index of central body-fat pattern and increased risk of obesity-related conditions
  - Location → midpoint between lowest point of the rib cage and the iliac crest
  - Increased risk with waist circumference >94cm for men and >80 cm for women
Etiology of Obesity

- Overeating
- Lack of physical activity
- No one single cause
- Genetic, cultural, hormonal
- Unlikely that the increased global prevalence of obesity has been driven by a dramatic change in the genetic gene pool
- Increased reliance on high-fat and energy-dense fast foods
Obesity Etiology

- Decreased physical activity
  - Automatic transport rather than walking or cycling
  - Central heating and automated household equipment like dishwasher and washing machines
  - Reduced physical activity in workplace due to computers, e-mail, etc
  - Increased TV and computer entertainment at home
  - Use of elevators and escalators instead of stairs
  - Fear of crime reduces children playing outside
  - Poor urban planning – no bicycle lanes or sidewalks
Perspectives on the Future

- There is a need to develop more cost-effective methods that can be used in field studies and to determine the energy cost of specific activities of people throughout the life cycle in developing countries.

- Obesity has been defined as a disease by the World Health Organization.
Questions, Comments
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