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Nutrition 101 – Class 2

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Nutrition 101

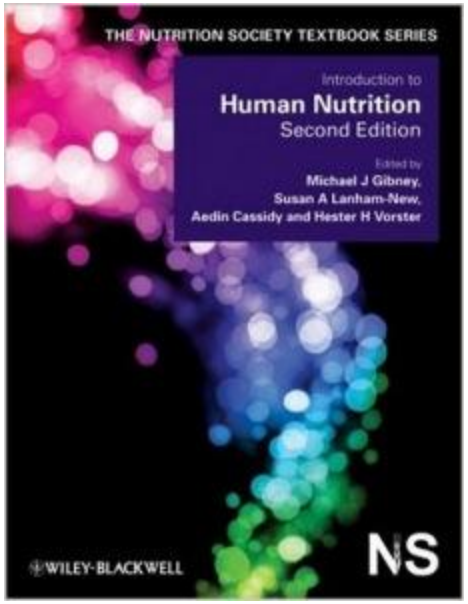
- Introduction to Human Nutrition" second edition

  Edited by Michael J. Gibney, Susan A. Lanham-New, Aedin Cassidy, and Hester H. Vorster

  May be purchased online

  but is not required for

  the class.



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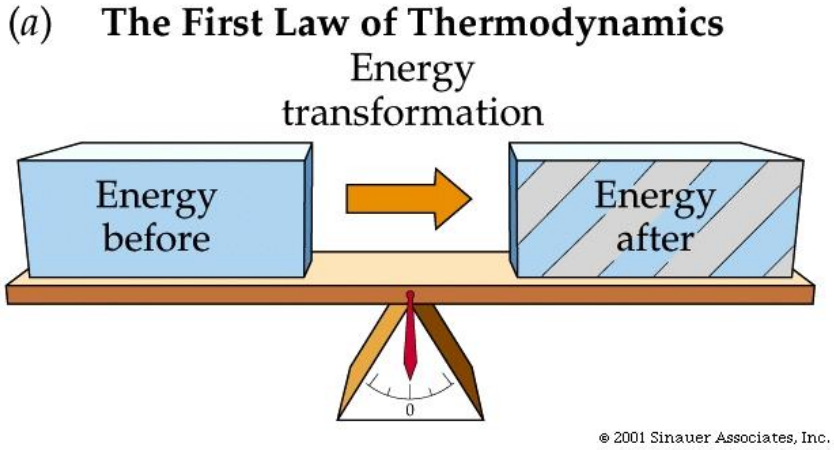
Energy Metabolism

- 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



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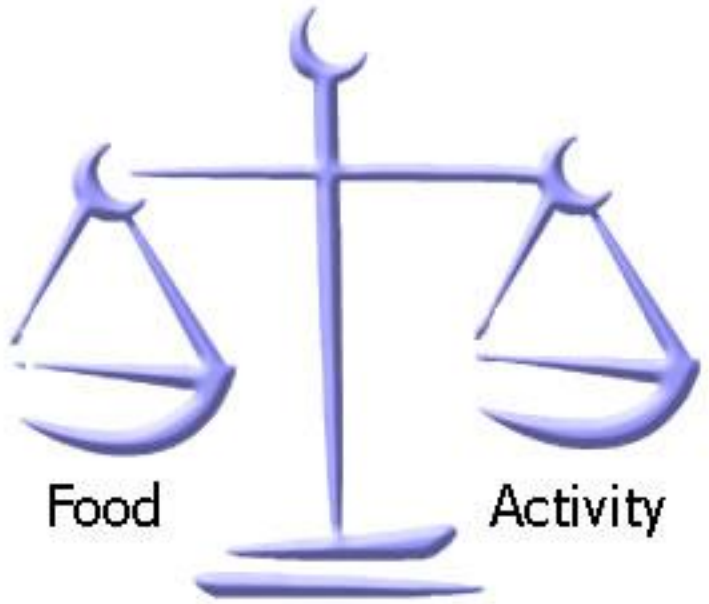
Components of Energy Balance

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



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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)

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Energy Store

- 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

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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

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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

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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

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Energy Expenditure

- 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

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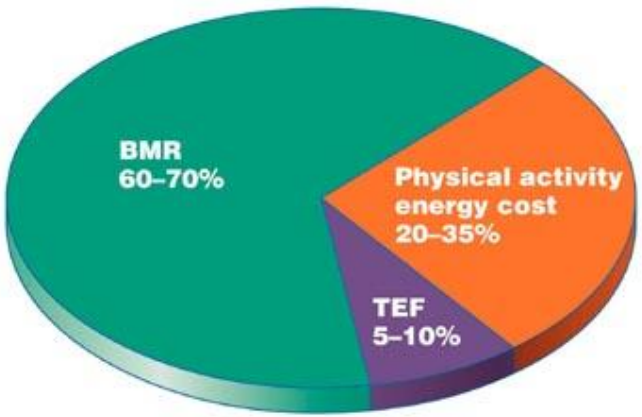
Three Major Components of Energy Expenditure

- Resting Metabolic Rate
- Thermogenesis
- Physical Activity Energy Expenditure



Components of energy expenditure

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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

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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

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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

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Regulation of Food Intake

- Appetite - learned reponse
  - 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

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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

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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

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Factors Influencing Food Intake

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

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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

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Central Nervous System Factors

- 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

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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

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Signals from the Periphery

- 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

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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

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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

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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

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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

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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

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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

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RMR Prediction Equations

- 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 x wt) + 679
    - 30-60 years (11.6 x wt) + 879
    - >60 years (13.5 x wt) + 487
  - Women
    - 18-30 years (14.7 x wt) + 496
    - 30-60 years (8.7 x wt) + 829
    - >60 years (10.5 x wt) +596

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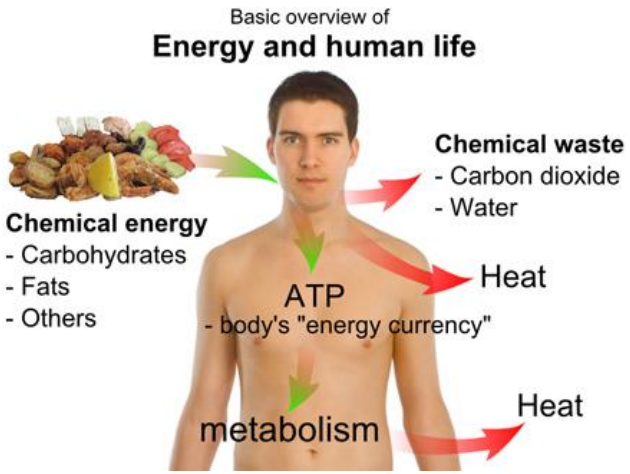
Thermic Effect of Feeding

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



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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

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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

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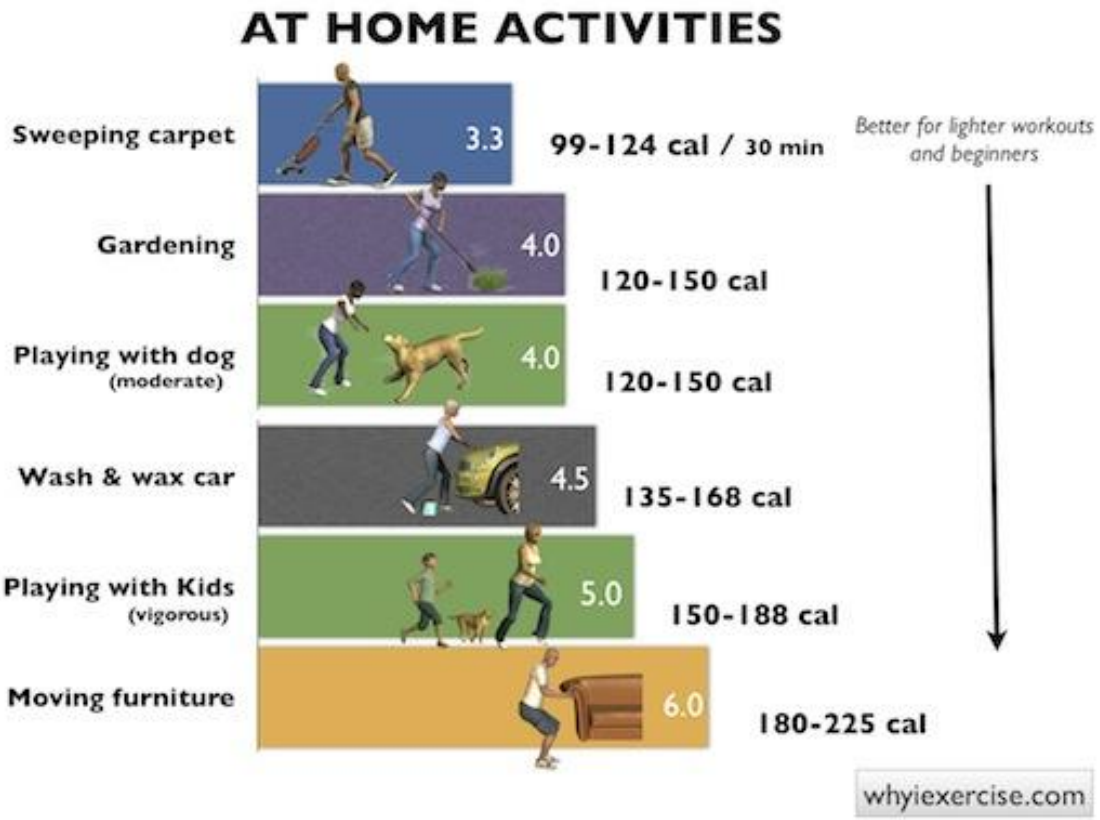

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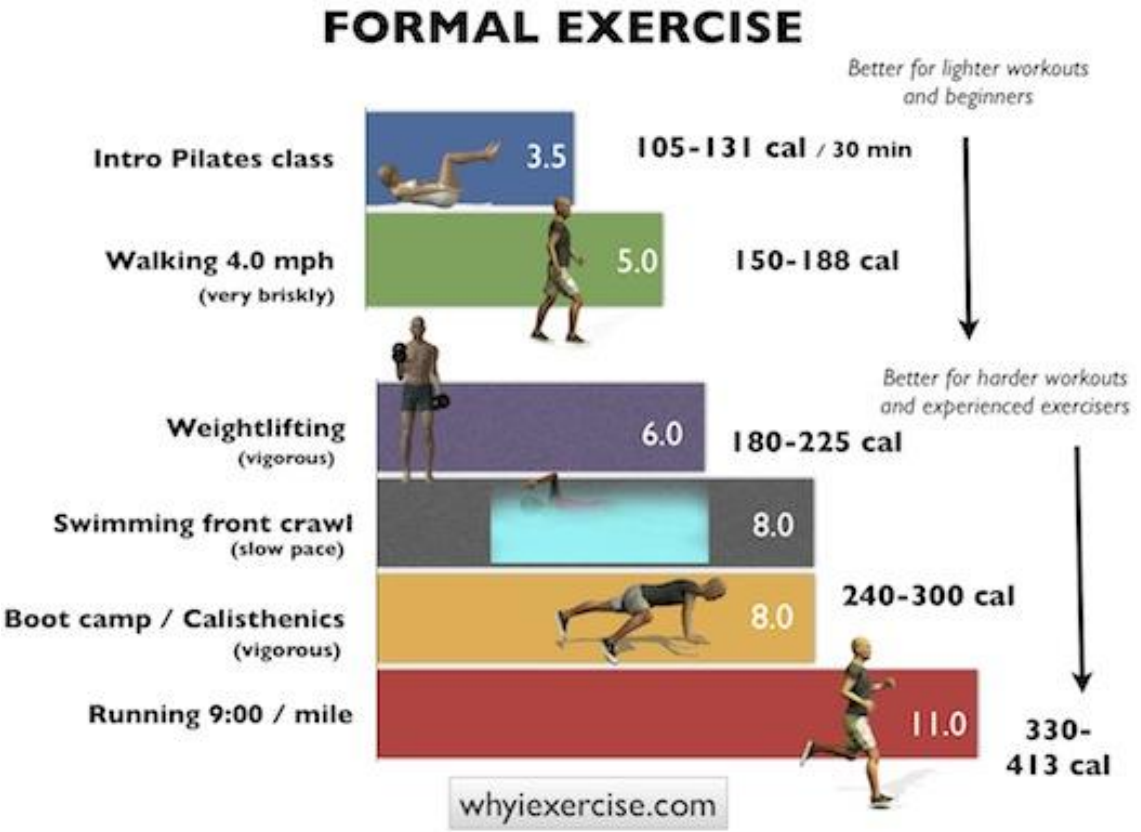

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Total Energy Expenditure

- 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

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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

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PAL

- 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

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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

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Special Considerations in the Elderly

- Alzheimer's and Parkinson's disease lead to malnourished states and a diminishing of body weight

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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

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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

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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

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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

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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

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Carbohydrates and Fats

- 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

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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 → normal
  - 25-30 BMI → overweight
  - >30 BMI → obese
  - *Does not distinguish between excess muscle weight and excess fat weight*

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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

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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

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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

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Questions, Comments

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