Energy Expenditure & $\text{VO}_2$

Current & Common Methods of Measuring Heat Production

- **Direct & Indirect Calorimetry**
  - *Applied Indirect Principle:* all energy releasing reactions in the body ultimately depend upon oxygen.

- **Open-circuit spirometry**
  1. Bag technique
     - Air is collected in a large bag (Douglas Bag)
     - Small sample is measured for gas concentrations
  2. Portable spirometry
     - Spirometer is small and is carried in a pack
     - Air volume is metered
     - Sample is collected to measure concentrations of gases

Current & Common Methods of Measuring Heat Production (cont.)

3. Computerized instrumentation
   - Air flow is measured for volume
   - Gas analyzers measure concentrations of oxygen and carbon dioxide
The Respiratory Quotient (RQ)

- RQ = CO₂ produced / O₂ consumed
  a) RQ for carbohydrate = 1.0
  b) RQ for fat = 0.70
  c) RQ for protein = 0.82

- RQ – assumes that oxygen consumption and carbon dioxide production measured at mouth reflect activity in tissues
  a) Accurate for rest and steady-state conditions

Respiratory Exchange Ratio (RER)

- RER – under nonsteady state conditions
- Calculation of RER is the same as RQ

Metabolic Calculations (Appendix D)

a) Calculating energy expenditure during exercise
b) Volume of air
c) Concentrations of O₂ and CO₂

Energy Expenditure at Rest

Total Daily Energy Expenditure:

a) Resting Metabolic Rate or Basal Metabolic Rate
b) Thermogenic effect of food consumed
c) Physical activity & recovery

Energy Expenditure
Resting States
**Energy Expenditure at Rest**

**Total Daily Energy Expenditure:**
- a) Resting Metabolic Rate or Basal Metabolic Rate
- b) Thermogenic effect of food consumed
- c) Physical activity & recovery

- Basal metabolic rate (BMR)
  - a) Energy to maintain vital functions in the waking state
  - b) Resting metabolic rate (RMR)
    - Energy to maintain vital functions plus digestion
    - Measured 3–4 hours following a meal

**Metabolism at Rest**

- Resting energy metabolism varies in proportion to the body’s surface area &/or lean body mass

**Nomogram used to measure body surface area**

**Estimating Resting Daily Energy Expenditure**

\[
\text{RDEE} = \text{BMR} \times M^2
\]

- BMR (Table 9.1, p.191); Surface Area (nomogram, figure 9.4)
- Contribution of diverse tissues (Table 9.3)
  - a) Muscle is more active than fat mass
  - b) The brain has a high metabolic rate
  - c) During exercise muscle metabolism may increase nearly 100 times
Metabolism at Rest

- Effects of regular exercise:
  a) Resistance training increases BMR by increasing FFM
  b) Endurance training increases BMR without increasing FFM
  c) Exercise can offset the age-related decline in BMR

Factors that affect energy expenditure:

1. Physical activity
   a) Largest variable in daily energy expenditure
      ✓ 15 – 30% average

2. Diet-induced thermogenesis (DIT)
   a) Calorigenic effect of food on exercise metabolism
      ✓ Beneficial to eat prior to exercise – boosts BMR
   b) Energy required to digest, absorb, and assimilate nutrients

3. Climate
   a) Hot or Cold environments increase energy expenditure

4. Pregnancy
   a) Increases BMR due to added weight gained during pregnancy

Classification of physical activities by energy expenditure

- The Met
  a) MET = metabolic equivalent
     ✓ 5 kcal/L O₂ consumed
  b) 1 MET = 3.5 ml O₂ x kg⁻¹ x min⁻¹
  c) Exercise intensity described relative to resting rate
  d) Used to guide or prescribe exercise intensity

Energy Expenditure in Physical Activity

- Energy cost of household, industrial, and recreational activities

- Effect of body mass
  a) Weight-bearing exercise
  b) Weight-supported exercise

Heart Rate to Estimate Energy Expenditure

- Heart rate and oxygen consumption
  a) Linear relationship exists
     ✓ Linearity is not identical for everyone!

- Other factors altering heart rate:
  Temperature  Humidity
  Food intake  Static vs. Dynamic work
  Muscle groups worked  Body position
  Emotions
Measurement of Energy Expenditure & Exercise

Gross Versus Net Energy Expenditure

• **Gross energy expenditure**
  a) Total energy required for an activity

• **Net energy expenditure**
  a) Gross energy expenditure - Resting energy expenditure

• Mechanical **efficiency & economy** of movement
  a) Ratio energy output:energy input
  b) Reflects the amount of energy transferred into doing work

Energy Cost: **Walking**

• Influence of body mass
  a) Equations may be used to calculate energy expenditure
  b) Speed or pace is an important factor
  c) Mass is factored in as resistance
  d) Individuals with a larger mass expend more energy at the same pace

• Terrain and walking surface
  a) Energy expenditure is greater on soft surfaces
     - Sand
     - Snow
  b) Slope or grade influences energy expenditure
     - Downhill walking requires less energy
     - Very steep downhill require energy to “brake”
     - Uphill grades require more energy

• Footwear
• Handheld and ankle weights
• Race Walking
  a) Poor economy but high expenditure

Economy of Human Movement

• Economy of movement refers to the energy required to maintain a constant velocity of movement
  a) More skilled athletes perform the same activity with a reduced energy requirement.
**Energy Cost: Running**

- Economy of running fast or slowly
  - a) Net energy cost values for running a set distance are similar for different speeds
- Stride length, stride frequency, and speed
  - a) Running
    - ✔️ Speed is dependent upon stride length and frequency
  - b) Optimum stride length
    - ✔️ Level of minimum effort
    - ✔️ No “best” style

- Running economy: Children and adults
  - a) Children have lower running economy than adults
  - b) Children require 20–30% more oxygen per unit of mass to run at the same pace as an adult

- Air resistance
  - a) Factors that effect air resistance
    - ✔️ Air density
    - ✔️ Runner’s projected surface area
    - ✔️ Square of runner’s velocity
  - b) Drafting
    - ✔️ Decreases resistance

- Treadmill versus track running
**Energy Cost: Swimming**

- Methods of measurement
  - a) Portable metabolic systems may be worn
  - b) Subjects may be tethered
  - c) Subjects may swim in a flume

- Energy cost and drag
  - a) Total drag force
    - Wave drag
    - Skin friction drag
    - Viscous pressure drag
  - b) Ways to reduce effects of drag force
    - Wet suits
    - Drafting

- Energy cost, swimming velocity, and skill
- Effects of water temperature
- Effects of buoyancy: Men versus women

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**Individual Variation & Measurement of EE**

*Biochemically & Metabolically*

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**Review of Energy Transfer & Exercise**

![Graph showing energy transfer and exercise duration](image)
**Evaluation of Immediate Energy Systems**

- Power tests:
  - a) Tests generally < 6 seconds
  - b) Power = \( \text{force} \times \frac{\text{distance}}{\text{time}} \)

1. Stair-sprinting power tests
2. Jumping-power tests

**Sport specificity**

- **Vertical tests** (Sargent jump-and-reach test)
  
  *Does not technically evaluate PCr or ATP!*

**Figure 11.3**

- Time to sprint up 6 steps, 3 at a time
  
  \( \text{Power} = \frac{\text{kg body wt} \times \text{distance in meters}}{\text{time in seconds}} \)

**Physiologic & Biochemical Measures**

- a) Size of intramuscular ATP-PCr pool
- b) Depletion rate of ATP and PCr in all-out short duration exercise
- c) \( O_2 \) deficit calculated from initial phase of exercise \( O_2 \) consumption curve
  - Accumulated oxygen deficit
- d) Lactate or pH recovery

**Evaluation of Power (physiologically & biochemically)**

- After a few seconds work, glycolysis generates increasingly more energy for ATP resynthesis
- As the rate of glycolysis increases, lactate accumulates
- Blood lactate levels provide the most common indicator of glycolytic activity
  - a) pH

**Anaerobic Power & Performance Capability Tests**

- Performance that substantially activates glycolysis require maximum exercise for up to 3 minutes
  - a) The influence of:
    - Age
    - Gender
    - Body Size
    - Skill
    - Motivation
    - Also training & enhanced buffering capacities

- **Figure 11.3**
  
  - Time to sprint up 6 steps, 3 at a time
  
  \( \text{Power} = \frac{\text{kg body wt} \times \text{distance in meters}}{\text{time in seconds}} \)
Wingate Test

Evaluation of Aerobic Energy Systems

- Maximal oxygen capacity plays a large role in determining endurance performance
- Attaining a high VO$_2$ max requires integration of pulmonary, CV, and neuromuscular function
- VO$_2$ max is a fundamental measure of physiologic functional capacity for exercise

Criteria for Max O$_2$ Consumption

- A leveling off in O$_2$ consumption despite an increase in exercise intensity generally assures VO$_2$ max has been reached
- Secondary Criteria for VO$_2$ max
  a) RER or $> 1.15$
  b) Blood lactate 70–80 mg/dl or 8–10 mmol
  c) Attain age predicted max HR
- VO$_2$ max Vs. VO$_2$ peak

Factors that Affect Max O$_2$ Consumption

1. Mode of exercise
2. Heredity
3. State of training
4. Gender
5. Body size and composition
6. Age

Max O$_2$ Consumption Tests

a) Modes

Submaximal Tests

1. Decrease cost
2. Decrease time
3. Decrease risk

- Tests: walking, step tests, endurance tests
- Prediction equations
  a) All prediction tests contain error known as the standard error of estimate (SEE)
- Predictions Based on HR