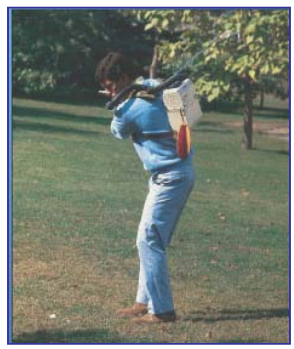
Energy Expenditure

& VO_2

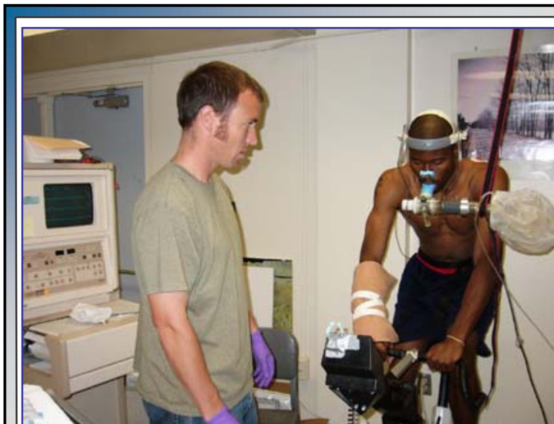
Current & Common Methods of Measuring Heat Production

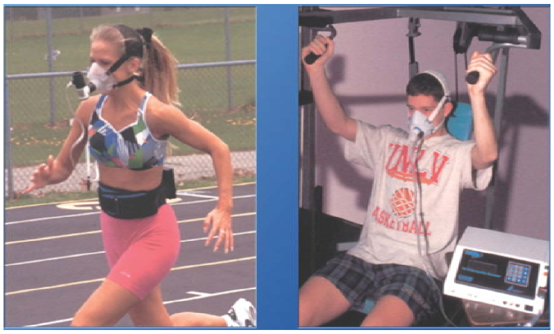
- Direct & Indirect Calorimetry
  - a) *Applied Indirect Principle*: all energy releasing reactions in the body ultimately depend upon <u>oxygen</u>.
- Open-circuit spirometry
  1. Bag technique
     - ✓ Air is collected in a large bag (Douglas Bag)
     - ✓ Small sample is measured for gas concentrations
  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





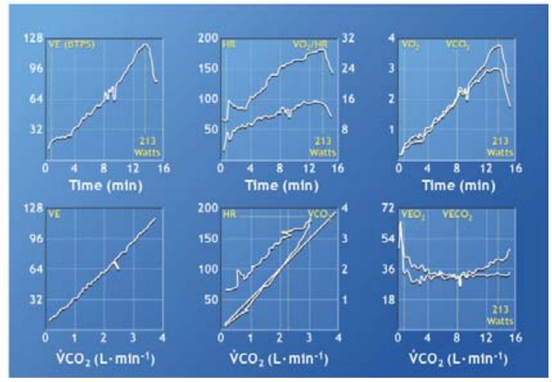


Figure 8.5a

The Respiratory Quotient (RQ)

- RQ = CO_2 produced / O_2 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 O_2 and CO_2

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

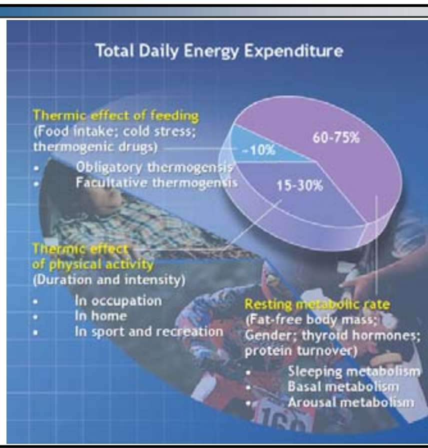


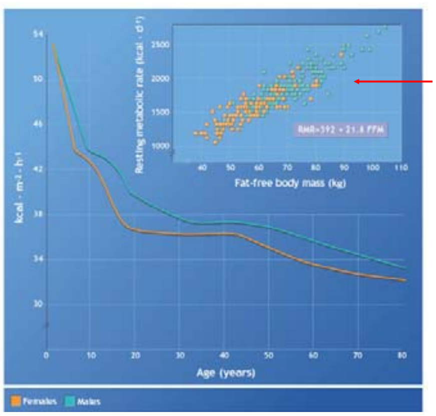
Figure 9.1

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



Body mass or Body surface area

Figure 9.3

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

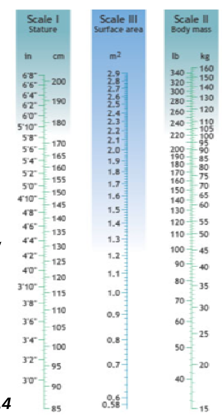


Figure 9.4

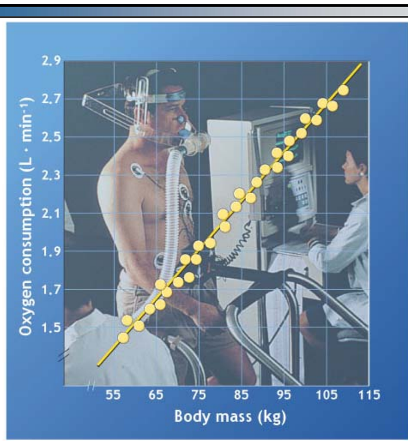


Figure 9.5

Estimating Resting Daily Energy Expenditure

RDEE = BMR x 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 RMR**
   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
     ✓5kcals ~ 1 L O_2 consumed
  b) 1 MET = 3.5 ml O_2 x kg^{-1} x min^{-1}
  c) Exercise intensity described relative to resting rate
  d) Used to guide or prescribe exercise intensity

TABLE 9.4 ➤ **FIVE-LEVEL CLASSIFICATION OF PHYSICAL ACTIVITY BASED ON EXERCISE INTENSITY**

LEVEL	ENERGY EXPENDITURE*			
	Men			
	$kcal \cdot min^{-1}$	$L \cdot min^{-1}$	$mL \cdot kg^{-1} \cdot min^{-1}$	METs
Light	2.0–4.9	0.40–0.99	6.1–15.2	1.6–3.9
Moderate	5.0–7.4	1.00–1.49	15.3–22.9	4.0–5.9
Heavy	7.5–9.9	1.50–1.99	23.0–30.6	6.0–7.9
Very heavy	10.0–12.4	2.00–2.49	30.7–38.3	8.0–9.9
Unduly heavy	≥12.5	≥2.50	≥38.4	≥10.0
	Women			
Light	1.5–3.4	0.30–0.69	5.4–12.5	1.2–2.7
Moderate	3.5–5.4	0.70–1.09	12.6–19.8	2.8–4.3
Heavy	5.5–7.4	1.10–1.49	19.9–27.1	4.4–5.9
Very heavy	7.5–9.4	1.50–1.89	27.2–34.4	6.0–7.5
Unduly heavy	≥9.5	≥1.90	≥34.5	≥7.6

*$L \cdot min^{-1}$ based on 5 kcal per liter of oxygen; $mL \cdot kg^{-1} \cdot min^{-1}$ based on 65-kg man and 55-kg woman; one MET equals the average resting oxygen consumption.

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	

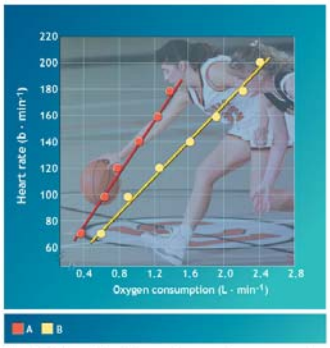


Figure 9.6. Linear relationship between heart rate and oxygen consumption for two women collegiate basketball players of different aerobic fitness levels. Measurements made during a graded exercise test on a motor-driven treadmill. (From Laboratory of Applied Physiology, Queens College, NY)

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

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: **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 downhills require energy to “brake”
    - ✓ Uphill grades require more energy
- Footwear
- Handheld and ankle weights
- Race Walking
  a) Poor economy but high expenditure

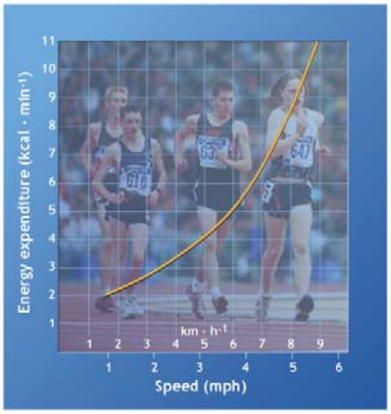


Figure 10.2

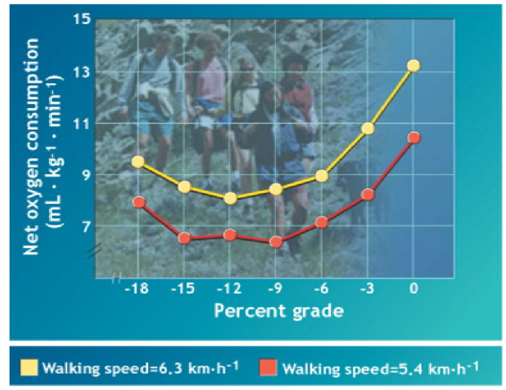


Figure 10.3

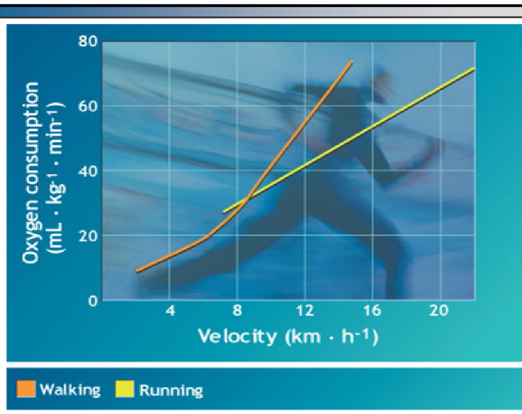


Figure 10.4

*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

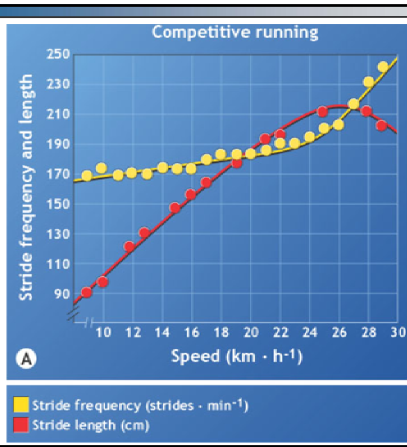
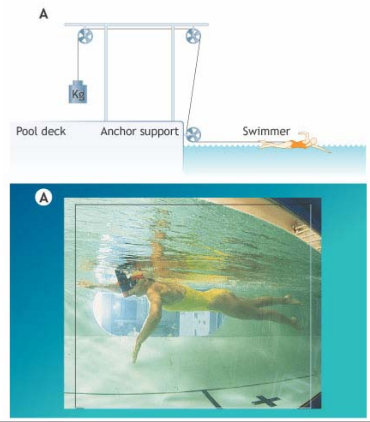


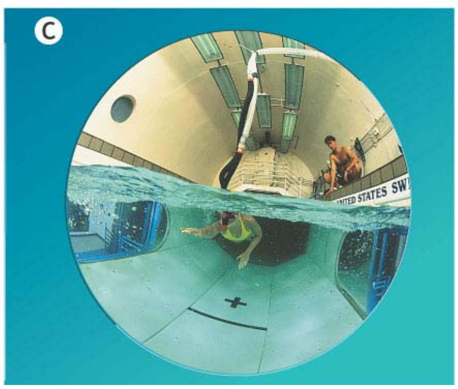
Figure 10.6

- 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

Individual Variation & Measurement of EE

Biochemically & Metabolically

Review of Energy Transfer & Exercise

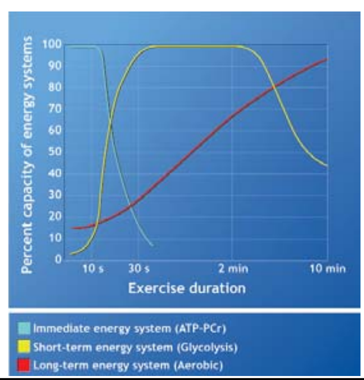


Figure 11.2

Evaluation of Immediate Energy Systems

- Power tests:
  a) Tests generally < 6 seconds
  b) Power = **force x distance**
  time

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

Sport specificity

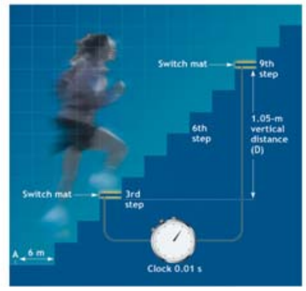


Figure 11.3

• Time to sprint up 6 steps, 3 at a time

Power = kg body wt x distance in meters
time in seconds

• **Vertical tests (Sargent jump-and-reach test)**

Does not technically evaluate PCr or ATP!

***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

Wingate Test

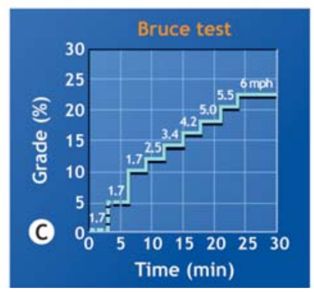
Evaluation of Aerobic Energy Systems

- 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_2max
  - 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

- Max O_2 Consumption Tests
  - a) Modes



- GXT should generally have the subject peak between 6–12 minutes

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

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