Chapter 6

Measurement of Work, Power & Energy Expenditure

Objectives

1. Define the terms *work*, *power*, *energy*, and *net efficiency*.
2. Give a brief explanation of the procedure used to calculate work performed during: (a) cycle ergometer exercise and (b) treadmill exercise.
3. Describe the concept behind the measurement of energy expenditure using: (a) direct calorimetry and (b) indirect calorimetry.
4. Discuss the procedure used to estimate energy expenditure during horizontal treadmill walking and running.

Objectives

5. Define the following terms: (a) kilogram-meter, (b) relative VO_2, (c) MET, and (d) open-circuit spirometry.
6. Describe the procedure used to calculate net efficiency during steady-state exercise.

Units of Measure

- Metric system is the standard system of measurement for scientists
  - Used to express mass, length, & volume
- System International units or SI units
  - For standardizing units of measurement

Important SI Units

Units for Quantifying

Human Exercise	SI Unit
Mass	kilogram (kg)
Distance	meter (m)
Time	second (s)
Force	Newton (N)
Work	joule (J)
Energy	joule (J)
Power	Watt (W)
Velocity	meters per second ($m \cdot s^{-1}$)
Torque	newton-meter ($N \cdot m$)

Table 6.2

Work and Power

- Work = force x distance
  - Example:
    - Lifting a 5 kg (5 kp*) weight up a distance of 2 m
      - * 5 kp is the force acting on a 5 kg mass

    5 kp x 2 m = 10 kpm
- Power = work ÷ time
  - Example:
    - Performing 2,000 kgm of work in 60 sec

    2,000 kgm ÷ 60s = 33.33 $kgm \cdot s^{-1}$
    - Expressed in SI Units:

    1 Watt (W) = 0.102 $kpm \cdot s^{-1}$, so 326.8 W

Measurement of Energy Expenditure

- Direct calorimetry
  - Measurement of heat production as an indication of metabolic rate

    $\text{Foodstuffs} + O_2 \rightarrow \text{ATP} + \text{heat}$
    (ATP → cell work; heat → Heat)
- Indirect calorimetry
  - Measurement of O_2 consumption as an estimate of resting metabolic rate

    $\text{Foodstuffs} + O_2 \rightarrow \text{Heat} + CO_2 + H_2O$
  - Open-circuit spirometry

Diagram of a Simple Calorimeter

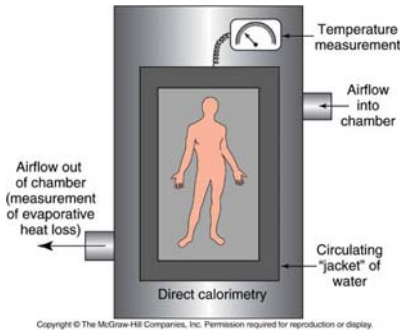

Figure 6.3

Open-Circuit Spirometry

Figure 6.4

Estimation of Energy Expenditure

- Energy cost of horizontal treadmill walking or running
  - O_2 requirement increases as a linear function of speed
- Expression of energy cost in METs
  - 1 MET = energy cost at rest
  - 1 MET = 3.5 ml•kg^{-1}•min^{-1}

Relationship b/n Walking or Running Speed & VO_2

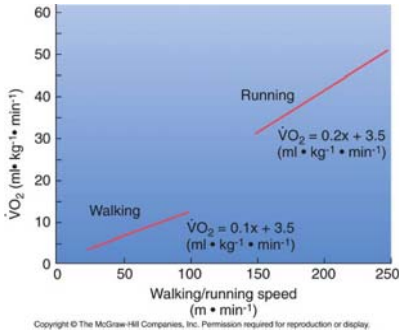

Figure 6.5

Relationship b/n Work Rate & VO_2 for Cycling

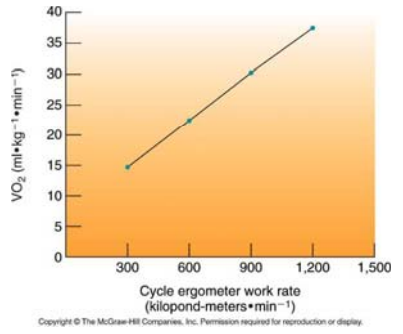

Figure 6.6

Calculation of Exercise Efficiency

- Net efficiency
  - Ratio of work output divided by energy expended above rest

$$\% \text{ net efficiency} = \frac{\text{Work output}}{\text{Energy expended above rest}} \times 100$$

- Net efficiency of cycle ergometry
  - 15-27%

Factors that Influence Exercise Efficiency

- Exercise work rate
  - Efficiency ↓s as work rate ↑s
- Speed of mvt
  - There is an optimum speed of mvt & any deviation reduces efficiency
- Muscle fiber type
  - Higher efficiency in muscles w/ greater percentage of slow fibers

Relationship b/n EE & Work Rate

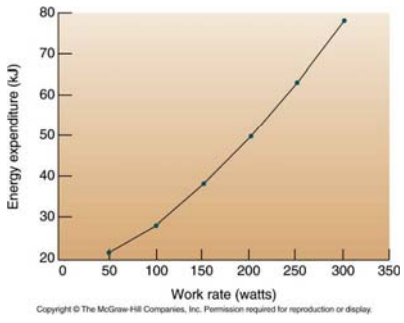

Figure 6.9

Effect of Speed of Mvt of Net Efficiency

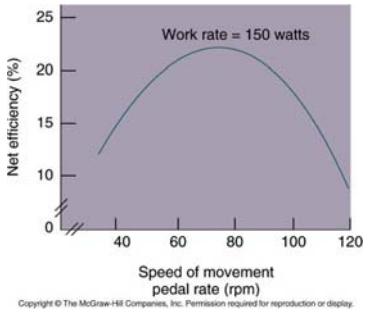

Figure 6.10