Principles of Aerobic Exercise

Key Terms and Concepts

Physical Activity

- any **bodily movement** produced by the contraction of skeletal muscles that result in a substantial increase over resting energy expenditure.

Exercise

- **Planned and structured physical activity** designed to improve or maintain physical fitness.

Physical Fitness

- **ability to perform physical work**
- Performing physical work requires cardiorespiratory functioning, muscular strength and endurance, and musculoskeletal flexibility
- Fitness levels can be described on a continuum from poor to superior based on **energy expenditure** during a bout of physical work.
- These ratings are often based on direct or indirect measurement of the body's maximum oxygen consumption (VO2 MAX)

Maximum Oxygen Consumption

- *Maximum oxygen consumption (**VO2 max*** is a measure of the **body's capacity to use oxygen**
- It is usually measured when performing an exercise that uses many **large muscle groups** such as swimming, walking, and running.
- It is the maximum amount of oxygen consumed per minute when the individual **has reached maximum effort**.
- It is usually expressed relative to **body weight, as milliliters of oxygen per kilogram of body weight per minute (mL/kg per minute).**
- It is dependent on the transport of oxygen, the oxygen-binding capacity of the blood, cardiac function, oxygen extraction capabilities, and muscular oxidative potential.

Endurance

- *Endurance (a measure of fitness) is the **ability to work for prolonged periods of time and the ability to resist fatigue.***
- It includes muscular endurance and cardiovascular endurance.
- **Muscular endurance** refers to the ability of an isolated muscle group to perform repeated contractions over a period of time,
- **cardiovascular endurance** refers to the ability to perform large muscle dynamic exercise, such as walking, swimming, and/or biking for long periods of time.

Aerobic Exercise Training (Conditioning)

- *Aerobic exercise training, or conditioning, is **augmentation of the energy utilization** of the muscle by means of an exercise program*
- The improvement of the muscle's ability to use energy is a direct result of increased levels of oxidative enzymes in the muscles, increased mitochondrial density and size, and an increased muscle fiber capillary supply.

- Training is dependent on exercise of sufficient frequency, intensity, and time.
- Training produces cardiovascular and/or muscular **adaptation** and is reflected in an individual's endurance.
- Training for a particular sport or event is dependent on the ***specificity principle***
- that is, the individual improves in the exercise task used for training and may not improve in other tasks. For example, swimming may enhance one's performance in swimming events but may not improve one's performance in treadmill running.

Adaptation

- The cardiovascular system and the muscles used *adapt to the training stimulus over time*
- Significant changes can be measured in as little as **10 to 12 weeks**.

- *Adaptation results in **increased efficiency** of the cardiovascular system and the active muscles.*
- *Adaptation represents a variety of **neurological, physical, and biochemical changes** in the cardiovascular and muscular systems.*
- *Performance improves in that the same amount of work can be performed after training but at a **lower physiological cost.***

Myocardial Oxygen Consumption

- *Myocardial oxygen consumption is a measure of the oxygen consumed by the myocardial muscle.*
- The need or demand for oxygen is determined by the **heart rate (HR), systemic blood pressure, myocardial contractility, and afterload.**

- Afterload is determined by **the left ventricular wall tension and central aortic pressure**.
- It is the **ventricular force required to open the aortic valve at the beginning of systole**.
- Left ventricular wall tension is primarily determined by **ventricular size and wall thickness.**

The ability to supply the myocardium with oxygen is dependent on the

- **Arterial oxygen content** (blood substrate),
- **Hemoglobin oxygen dissociation**,
- **Coronary blood flow**, which is determined by aortic diastolic pressure, duration of diastole, coronary artery resistance, and collateral circulation.

- In a healthy individual, **a balance between myocardial oxygen supply and demand** is maintained during maximum exercise. When the demand for oxygen is greater than the supply, myocardial ischemia results

Deconditioning

- *Deconditioning occurs with **prolonged bed rest**, and its effects are frequently seen in the patient who has had **an extended, acute illness or long-term chronic condition**.*

- Decreases **in maximum oxygen consumption, cardiac output (stroke volume), and muscular strength** occur rapidly.
- These effects are also seen, although possibly to a lesser degree, in the individual who has **spent a period of time on bed rest** without any accompanying disease process and in the individual who is **sedentary** because of lifestyle and increasing age.

BOX 7.2 Deconditioning Effects Associated with Bed Rest[3]

- ↓ Muscle mass
- ↓ Strength
- ↓ Cardiovascular function
- ↓ Total blood volume
- ↓ Plasma volume
- ↓ Heart volume
- ↓ Orthostatic tolerance
- ↓ Exercise tolerance
- ↓ Bone mineral density

Energy Systems, Energy Expenditure, and Efficiency

Energy Systems

- Energy systems are metabolic systems involving a series of biochemical reactions resulting in the formation of **adenosine triphosphate (ATP**), carbon dioxide, and water.
- The cell uses the energy produced from the conversion of ATP to adenosine diphosphate (ADP) and **phosphate (P)** to perform metabolic activities.
- Muscle cells use this energy for **actinmyosin cross-bridge formation** when contracting.
- There are **three major energy systems**.
- The intensity and duration of activity determine when and to what extent each metabolic system contributes.

Three major energy systems.

Phosphagen, or ATP-PC, System

The ATP-PC system (**adenosine triphosphate-phosphocreatine**) has the following characteristics.

- Phosphocreatine and ATP are stored in the muscle cell.
- **Phosphocreatine is the chemical fuel source.**
- **No oxygen is required (anaerobic).**
- When muscle is rested, the supply of ATP-PC is regenerated.
- **The maximum capacity of the system is small (0.7 mol ATP).**
- **The maximum power of the system is great (3.7 mol ATP/min).**
- The system provides energy for **short, quick bursts of activity**.
- It is the major source of energy during **the first 30 seconds of intense exercise.**

Anaerobic Glycolytic System

The anaerobic glycolytic system has the following characteristics.

- Glycogen (**glucose**) is the fuel source (glycolysis).
- **No oxygen is required (anaerobic).**
- ATP is resynthesized in the muscle cell.
- **Lactic acid is produced (by-product of anaerobic glycolysis).**
- The **maximum capacity** of the system is **intermediate (1.2 mol ATP).**
- The **maximum power** of the system **is intermediate (1.6 mol** ATP/min).
- The systems provide energy for activity of moderate intensity and short-duration.
- It is the **major source of energy from the 30th to 90th second of exercise.**

Aerobic System

- The aerobic system has the following characteristics.
- Glycogen, fats, and proteins are fuel sources and are utilized relative to their availability and the intensity of the exercise.
- **Oxygen is required (aerobic**).
- ATP is resynthesized in the mitochondria of the muscle cell. The ability to metabolize oxygen and other substrates is related to the number and concentration of the mitochondria and cells.
- The maximum **capacity of the system is great (90.0 mol ATP).**
- **The maximum power of the system is small (1.0 mol ATP/min).**
- The system predominates over the other energy systems after the **second minute of exercise.**

Recruitment of Motor Units

- Recruitment of motor units is dependent on the rate of work. Fibers are recruited selectively during exercise.

Slow-twitch fibers (type I)

- *are characterized by a **slow contractile response**,*
- *are rich in **myoglobin and mitochondria**, have a **high oxidative capacity** and a **low anaerobic capacity,***
- *and are recruited for **activities demanding endurance.***
- *These fibers are supplied by small neurons with a low threshold of activation and are used preferentially in **lowintensity exercise.***

Fast-twitch fibers (type IIB)

- *are characterized by a **fast contractile response**,*
- *have a **low myoglobin content and few mitochondria**, have a high glycolytic capacity, and are recruited for activities requiring **power.***

Fast-twitch fibers (type IIA)

- *have characteristics of both type I and type IIB fibers and are recruited for both anaerobic and aerobic activities*

Functional Implications

- ***Bursts of intense activity*** *lasting only* ***seconds*** *develop muscle strength and stronger tendons and ligaments.* ***ATP is supplied by the phosphagen system.***
- ***Intense activity lasting 1 to 2 minutes*** *repeated after 4 minutes of rest or mild exercise enhances* ***anaerobic power****.* ***ATP is supplied by the phosphagen and anaerobic glycolytic system.***
- Activity with *large muscles, which is less than maximum intensity for* ***3 to 5 minutes*** *repeated after rest or mild exercise of similar duration, may develop* ***aerobic power and endurance capabilities****. ATP is supplied by the phosphagen, anaerobic glycolytic, and aerobic systems.*
- Activity of ***submaximum intensity lasting 20 to 30 minutes*** *or more taxes a high percentage of the aerobic system and develops endurance.*

Energy Expenditure

- Energy is expended by individuals engaging in physical activity and is often expressed in **kilocalories**.
- Activities can be categorized as **light, moderate, or heavy** by determining the energy cost.
- The energy cost of any activity is affected by mechanical efficiency and body mass.
- **Factors that affect both walking and running are terrain, stride length, and air resistance.**

Quantification of Energy Expenditure

- Energy expended is computed from the **amount of oxygen consumed**.
- Units used to quantify energy expenditure are **kilocalories and METs.**

kilocalorie

- A *kilocalorie is a measure expressing the* ***energy value of food****.*
- *It is the amount of heat necessary to raise 1 kilogram (kg) of water 1°C.*
- *A kilocalorie (kcal) can be expressed in oxygen equivalents.*
- ***Five kilocalories equal approximately 1 liter of oxygen consumed (5 kcal = 1 liter O2)***

MET

- A *MET is defined as the oxygen consumed* ***milliliters) per kilogram of body weight per minute (mL/kg).***
- *It is equal to approximately* ***3.5 mL/kg per minute***

Classification of Activities

- **LIGHT**
- **MODERATE**
- **HEAVVY**

- ***Light work*** *for the average male (65 kg) requires 2.0 to 4.9 kcal/min, or 6.1 t o 15.2 mL O*/kg per minute, or 1.6 t o 3.9 MET s.
- Strolling 1.6 km/hr , or 1.0 mph, is considered light work .

- ***Heavy work*** *for the average male (65 kg) requires 7.5 t o 9.9 kcal/min, or 23.0 to 30.6 mL O*/kg per minute, or 6.0 t o 7.9 MET s. Jogging 8.0 km/hr , or 5.0 mph, requir es 25 to 28 mL O2/kg per minute and is considered heavy work