Chapter 6

CARDIORESPIRATORY ENDURANCE

Objectives

- Define cardiorespiratory endurance (CR) and describe the benefits of CR training in maintaining health and well-being.
- Define aerobic and anaerobic exercise, and give examples.
- Be able to interpret the results of CR assessments according to health fitness and physical fitness standards.
- Explain the principles that govern CR exercise prescription: intensity, mode, duration, and frequency.
- Learn some ways to foster adherence to exercise.

Introduction

- Most important component of health-related physical fitness
  - However, older adults primarily need strength
- Cardiorespiratory (CR) endurance activities conditions the CV system and helps a person achieve and maintain a healthy weight
- Physical inactivity and our natural existence leads to Hypokinetic diseases
  - Hypertension, obesity, heart disease, LBP
Basic Cardiorespiratory Physiology

- **CR endurance**
  - The ability of the lungs, heart, and blood vessels to deliver adequate amounts of oxygen to the cells to meet the demands of prolonged physical activity

Basic Cardiorespiratory Physiology

- As a person breathe, part of the oxygen in the air is taken up by the air sacs (alveoli) in the lungs
- As blood passes through the alveoli, oxygen is picked up by an iron-containing compound (hemoglobin) and transported in the blood to the heart
- The heart pumps the oxygenated blood through the circulatory system to all organs and tissues of the body

Basic Cardiorespiratory Physiology

- [Diagram of the heart and lungs]
Basic Cardiorespiratory Physiology

- **Adenosine triphosphate (ATP)**
  - a high-energy chemical compound that the body uses for immediate energy
  - Oxygen is used to convert food substrates (carbohydrates and fats) through aerobic metabolism into ATP
  - ATP provides the energy for physical activity, body functions, and maintenance of constant internal equilibrium (homeostasis)
  - During physical exertion, the lungs, heart, and blood vessels have to deliver more oxygen to the muscle cells to supply ATP

Aerobic and Anaerobic Exercise

- **Aerobic exercise**: Exercise that requires oxygen to convert lipids to produce the necessary energy (ATP) to carry out the activity.
  - Walking, jogging, swimming, cycling, cross-country skiing, water aerobics, rope skipping, and aerobics
- **Anaerobic exercise**: Exercise that does not require oxygen to produce the necessary energy (ATP) to carry out the activity. Burns primarily carbohydrates.
  - Track and field (100, 200, 400 meters), swimming (100 meters), gymnastics routines, strength training
  - Anaerobic activities will not increase cardiorespiratory endurance significantly

Benefits of Aerobic Training

- Higher maximal oxygen uptake (VO$_{2\text{max}}$)
  - Maximum amount of oxygen the body is able to use per minute of physical activity, expressed in L/min or mL/kg/min; the best indicator of cardio-respiratory or aerobic fitness
  - A high capacity to deliver and utilize oxygen indicates a more efficient cardiorespiratory system
  - A low level of endurance indicates the heart has to work harder, less oxygen is delivered to the tissues, and the individual fatigues faster
Benefits of Aerobic Training

- Increase in oxygen-carrying capacity
- Decrease in resting heart rate (about 10-20 bpm) and an increase in cardiac muscle strength
  - Improves Cardiac output – Amount of blood pumped by the heart in one minute
  - Increases Stroke volume – Amount of blood pumped by the heart in one beat
  - Stroke Volume X Heart Rate = Cardiac Output
- Lower heart rate at given workloads (table 6.1)

Benefits of Aerobic Training

<table>
<thead>
<tr>
<th></th>
<th>Resting</th>
<th>Maximal</th>
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<tbody>
<tr>
<td></td>
<td>Cardiac Output (ml/min)</td>
<td>Stroke Volume (ml)</td>
</tr>
<tr>
<td>Sedentary</td>
<td>5-5</td>
<td>60 74</td>
</tr>
<tr>
<td>Trained</td>
<td>5-8</td>
<td>90 54</td>
</tr>
<tr>
<td>Highly Trained</td>
<td>5-6</td>
<td>110 65</td>
</tr>
</tbody>
</table>

Benefits of Aerobic Training

- Increase in number & size of mitochondria
- Increase in number of functional capillaries
- Faster recovery time
- Lower BP and blood lipids
- Increase in fat burning enzymes
Physical Fitness Assessment

- Purpose of assessment
  - Educate participants
  - Motivate individuals
  - Provide a starting point
  - Evaluate improvements
  - Monitor changes

Responders vs. Nonresponders

- A wide variation in physiological responses exists between individuals who follow similar training programs
- Heredity plays a crucial role in how each person responds and improves following an exercise program
- **Principle of individuality:**
  - Studies have documented that some individuals readily experience improvements in fitness (responders), whereas others exhibit small or no improvements at all (nonresponders) following similar exercise training programs

Responders vs. Nonresponders

- As an average, VO\textsubscript{2max} increases between 15% and 20% following several months of aerobic training
- Individual responses can range from 0% (in a few selected cases) to more than 50% improvement
- Nonresponders constitute less than 5% of exercise participants
- Lack of cardiorespiratory endurance improvements among nonresponders might be related to low levels of leg strength
- A lower body strength-training program has been shown to help nonresponders improve VO\textsubscript{2max} through aerobic exercise
Assessment of Cardiorespiratory Endurance

- Maximal oxygen utilized per minute of physical activity - VO$_{2\text{max}}$
  - Expression
    - Liters per minute (L/min)
    - Milliliters per kilogram per minute (mL/kg/min)
    - Most often used to express VO$_{2\text{max}}$ because it takes into account one's body weight
  - Factors influencing VO$_{2\text{max}}$
    - Genetics, training, gender, age, and body composition

Assessment of Cardiorespiratory Endurance

Components of Oxygen Uptake

- Heart rate
  - Ranges from ~40 to 200 bpm (Maximal heart rate (MHR))
- Stroke volume
  - Ranges from 50mL in deconditioned to 200mL in highly trained athletes
  - Increases significantly with endurance training
- Amount of oxygen removed from blood
  - Arterial-venous oxygen difference (a-vO$_2$ diff)
  - Venous O$_2$ can range from 5mL/100cc at rest to 15mL/100cc (or more) during exercise

Assessment of Cardiorespiratory Endurance

Using these three factors we can compute VO$_2$ using the following equation:

$$\text{VO}_2 \text{ in L/min} = \frac{\text{HR} \times \text{SV} \times \text{a-vO}_2 \text{ diff}}{100,000}$$

Resting Oxygen Uptake Example

- SV = 79 mL
- HR = 76 bpm
- a-vO$_2$ diff = 5 mL/100cc

$$\text{VO}_2 \text{ in L/min} = \frac{(76 \times 79 \times 5)}{100,000} = 0.3 \text{ L/min}$$
Assessment of Cardiorespiratory Endurance

- We can use the same equation to figure Maximal Oxygen Uptake (VO₂max).

  Example
  - SV = 120 mL
  - HR = 190 bpm
  - a-vO₂diff = 15 mL/100 cc

- VO₂max in L/min =
  \[
  \frac{(190 \times 120 \times 15)}{100,000} = 3.42 \text{ L/min}
  \]

Assessment of Cardiorespiratory Endurance

- Computing VO₂ can also be determined through gas analysis.
  - Computing VO₂ through the previous methods are impractical or too costly for most fitness settings, so Submaximal tests are used.

Test to Estimate VO₂max

- 1.5-Mile Run Test
  - Most frequently used test
  - Maximal exercise test
  - Based on time needed to run 1.5 miles
  - Figure 6.2 for directions
**Test to Estimate VO\textsubscript{2max}**

- **1.0-Mile Walk Test**
  - Must walk at a pace to produce a heart rate of at least 120 bpm
  - Use pulse at the carotid or radial artery
  - Use prediction equation to estimate VO\textsubscript{2max}
  - Figure 6.3 for directions

- **Step Test**
  - Submaximal workload
  - Takes 3 minutes
  - Not preferable for those with lower joint issues
  - Figure 6.4 for directions

- **Astrand-Ryhming Test**
  - Bicycle ergometer
  - Submaximal workload
  - Most can complete

- **12-Minute Swim Test**
  - Considered more of a maximal test
  - Not practical test for everyone because of:
    - Skill level
    - Conditioning
    - Body composition
  - Figure 6.6 for directions
Interpreting the Results of Your Maximal Oxygen Uptake

- After obtaining your VO\textsubscript{2max}, you can determine your current level of cardiorespiratory fitness

| Cardiorespiratory Fitness Category According to Maximal Oxygen Uptake (VO\textsubscript{2max}) |
|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| Under 22.9 L/min                 | 22.9-30.5 L/min                 | 30.6-37.0 L/min                 | 37.1-53.9 L/min                 | Over 53.9 L/min                 |
| 50-54                           | 50-54                           | 50-54                           | 50-54                           | 50-54                           |
| Male                             | Male                             | Male                             | Male                             | Male                             |
| Female                           | Female                           | Female                           | Female                           | Female                           |

Predicting Oxygen Uptake & Caloric Expenditure

- The human body burns about 5 calories for each liter of oxygen consumed
- A person with a VO\textsubscript{2max} of 3.5 L/min exercising at 60% of maximum uses 2.1 (3.5 x .60) liters of oxygen per minute and burns 10.5 (2.1 x 5) calories per minute of physical activity
- If the activity lasts 30 minutes, 315 calories have been burned (10.5 x 30)
- Using this principle, one can determine the total caloric expenditure of a given session of physical activity

- For people concerned about weight management, these computations are valuable in determining energy expenditure
- One pound of fat represents 3,500 calories
- At 10.5 calories per minute, a person needs to exercise for a total of 333 minutes (3,500/10.5) to burn the equivalent of one pound of fat
Principles of CR Exercise Prescription

- A low percentage of the U.S. population is committed to exercise.
  - More than half of those who begin to exercise drop out during the first 3–6 months.
  - Only about 19% of adults in the U.S. meet minimum recommendations of the ACSM for the improvement and maintenance of cardiorespiratory fitness.

Are you ready to begin an exercise program?

- Completing four to six weeks of an exercise program increases your likelihood of success.
- Benefits of exercise come from a lifetime program of activity.
- Do your reasons to exercise outweigh your reasons not to exercise?

See Lab 6C for a questionnaire to evaluate your readiness to commit to an exercise program.

Guidelines for CR Exercise Prescription

- To develop the cardiorespiratory system, the heart muscle must be overloaded to increase in size, strength, and efficiency.
- Four FITT variables govern exercise prescription: frequency, intensity, type (mode), and time (duration).
- Symptomatic individuals should undergo a medical exam prior starting or testing.
Intensity of Exercise

- Health and cardiorespiratory fitness benefits occur when the person is working between 30% & 85% of heart rate reserve (HRR) with appropriate frequency and duration
- Health benefits occur when training at 30% to 60% for a longer time
- Greater improvements in cardiorespiratory fitness occur through a vigorous-intensity program
  - 60-85% as defined by ACSM
- Training intensity levels for unconditioned to healthy
  - Low = 30% to 40%
  - Moderate = 40% to 60%
  - High (Vigorous) = 60% to 85%

Recommended Aerobic Training Pattern

Insert figure 6.6 from page 209 here

Intensity of Exercise

- Lab 6D
- Example: 20 yr old with RHR of 68
  - MHR: 207 – (.70 x 20) = 193 bpm
  - HRR = 193 – 68 = 125 beats
  - 30% TI = (125 x .30) + 68 = 106 bpm
  - 40% TI = (125 x .40) + 68 = 118 bpm
  - 50% TI = (125 x .50) + 68 = 130 bpm
  - 60% TI = (125 x .60) + 68 = 143 bpm
  - 85% TI = (125 x .85) + 68 = 174 bpm
- Low-intensity training zone: 106 to 118 bpm
- Moderate-intensity training zone: 118 to 143 bpm
- Vigorous (optimal) training zone: 143 to 174 bpm
Moderate- Vs. Vigorous-Intensity Exercise

- Vigorous-intensity programs yield higher improvements in VO\(_{2max}\) than do moderate-intensity programs.
- Higher levels of aerobic fitness are associated with lower cardiovascular mortality.
- Therefore, creating higher levels of CV fitness through vigorous-intensity has a greater benefit than just being more active (Moderate-intensity)

Relative Risk of CVD Based on Weekly Volume of PA

- During the first few weeks of an exercise program, you should monitor your exercise heart rate regularly to make sure you are training in the proper zone.
  - Wait until you are about 5 min+ into the aerobic phase of your exercise session before taking your first reading
  - Count your pulse for 15 seconds and multiply by 4 to get the per minute pulse rate
- Consider personal fitness goals in determining TI
- Cross-check target zone with perceived exertion
Physical activity perceived exertion (H-PAPE) scale

- Rate of perceived exertion (RPE): A perception scale to monitor or interpret the intensity of aerobic exercise.
- You have to associate your own inner perception of the task with the phrases given on the scale.
- Cross check your target zone with your RPE during the first few weeks of your program.
- After several weeks, you should be able to predict your exercise heart rate just by your own perceived exertion of the intensity of exercise.

Mode of Exercise

- Aerobic activities
  - It must be aerobic (involving the major muscle groups, rhythmic and continuous) to stimulate a cardiorespiratory response.
  - Examples: walking, jogging, aerobic dance, swimming, water aerobics, cross-country skiing, rope skipping, cycling, racquetball, stair climbing, and stationary running or cycling.
- Choose using personal preferences and physical limitations.
- Some activities first require skill development and base conditioning before the TI can be maintained.

Duration of Exercise

- Approximately 20–60 minutes per session is generally recommended.
- Even though a continuous 30 minutes of exercise stimulates greater increases in aerobic power, three sessions of at least 10 minutes each provide significant cardiorespiratory benefit.
  - To prevent weight gain: accumulate 60 minutes of moderate-intensity physical activity most days of the week.
  - To prevent weight regain: 60 to 90 minutes of daily moderate-intensity activity.
- Exercise sessions should always be preceded by a 5–10 minute warm-up and followed by a 10-minute cool-down period (Fig 6.6).
Frequency of Exercise

- Recommended = 3 to 5 days per week
  - When exercising at 60%-85% of HRR, three 20- to 30-minute sessions on nonconsecutive days is sufficient to improve or maintain VO$_{2\text{max}}$
  - Training at a lower intensity requires 30-60 minutes more than three days a week
  - Further VO$_{2\text{max}}$ improvements are minimal when training is conducted more than 5 days per week
  - For health benefits, accumulate 30 minutes of moderate-intensity physical activity on most days of the week

Decrease sitting time

- Those who meet the minimum exercise guidelines are still at risk for premature death if they sit for most of the day
- To minimize risk, enhance nonexercise activity thermogenesis (NEAT):
  - The energy expended doing everyday activities not related to exercise
  - Stand as much as possible
  - Use a stability ball for a chair
  - Take a 10-minute break for every hour you sit at the computer

Summary

- Fig. 6-11

Mode: Moderate- or vigorous-intensity aerobic activity (examples):
- Walking, jogging, stair climbing, elliptical activity, aerobics
- Water aerobics, cycling, stair climbing, swimming, cross-country skiing, racquetball, basketball, and soccer

Intensity: 30% to 65% of heart rate reserve (the training intensity is based on age, health status, initial fitness level, exercise tolerance, and exercise program goals)

Duration: Be active 20 to 60 minutes. At least 20 minutes of continuous vigorous-intensity or 30 minutes of moderate-intensity aerobic activity (the latter may be accumulated in segments of at least 10 minutes in duration each over the course of the day)

Frequency: 3 to 5 days per week for vigorous-intensity aerobic activity to accumulate at least 70 minutes per week, or 5 days per week of moderate-intensity aerobic activity for a minimum total of 100 minutes weekly

Rate of progression:
- Start with three training sessions per week of 15 to 20 minutes
- Increase the duration by 5 to 10 minutes per week and the frequency up to that by the fourth or fifth week you are exercising five times per week
- Progressively increase frequency, duration, and intensity of exercises until you reach your fitness goal prior to exercise maintenance
The Physical Activity Pyramid

Fitness Benefits of Aerobic Activities

- Beginners should start with low-intensity activities (Table 6.10)
- High-impact aerobics and rope skipping - risk for injuries remains high even with conditioned participants
  - These activities should be supplemental only and not the sole mode of exercise
- Rhythmic and continuous activities that involve large amounts of muscle mass are most effective in burning calories
- High-intensity activities increase caloric expenditure
- Walking is a good exercise mode for weight management if carried out for 45-60 minutes five or six times per week

Apps that can Keep You Motivated...

- Winners of the 2012 app health challenge
- Lose it! In the category of fitness/physical activity
  - Fit Friendy and MapMyFitness also recognized
- GoodGuide and Fooducate in the category of nutrition/healthy eating
- Healthy Habits in the category of integrative health
Once you have determined your exercise prescription, the difficult part begins…

- starting and sticking to a lifetime exercise program
- Lifelong dedication and perseverance are necessary to reap and maintain good fitness

The Tips to Enhance Exercise Compliance box have been used successfully to help change behavior and adhere to a lifetime exercise program.

Staying with a physical fitness program long enough brings about positive physiological and psychological changes.

- Four weeks of aerobic training can be completely reversed in two consecutive weeks of physical inactivity.
- If you have been exercising regularly for months or years, two weeks of inactivity will not hurt you as much as it will someone who has exercised only a few weeks.