

Chapter 2

Basics of Exercise Physiology

Learning Objectives

1. Understand the role exercise plays in maintaining good health.
2. Learn the components of an exercise prescription.
3. Learn what being fit means and how to become fit.
4. Understand where the energy to exercise comes from.
5. Distinguish among the various muscle fiber types and their roles.
6. Understand concepts involved in research in exercise pharmacology.
7. Describe the evidence pyramid.
8. Describe some of the issues involved in drug testing and what can happen if someone fails a drug test.

Chapter Outline

INTRODUCTION

CARDIOVASCULAR FITNESS

Table 2.1: Relationship between measures of VO_2 and exercise capacity

EXERCISE METABOLISM

Figure 2.1: ATP: The energy currency inside cells

Aerobic Metabolism

Figure 2.2: Basics of ATP production

Anaerobic Metabolism

Lipolysis

Figure 2.3: Structure of a triacylglycerol—a storage form of fat

Table 2.2: Percentage contributions of different energy sources at different workloads

Box: Glycerol levels as predictors of fitness levels

MUSCLE FIBER TYPES

(1) Slow twitch (oxidative) or Type I

Figure 2.4: Comparison of the heme-containing proteins myoglobin and hemoglobin, which bind oxygen

(2) Fast twitch (oxidative) or Type IIa

(3) Fast twitch (glycolytic) or Type IIx

Box: Exercise and muscle fiber remodeling

Figure 2.5: Role for calcium signaling in muscle cell remodeling

PRESCRIBING EXERCISE HEALTH

Table 2.3: Components of training program

Table 2.4: A basic exercise prescription

Box: A dose-response curve for exercise

Table 2.5: Results of a study showing an increase in fitness with increasing levels of exercise training.

RESEARCH IN EXERCISE PHARMACOLOGY

Research Approaches and Experimental Design

Blind versus double-blind studies

Choosing subjects

The protocol

Length of the study

Exercise component

Hierarchy of Evidence in Research

Figure 2.6: A modified version of the evidence pyramid.

POLICIES AND TESTING FOR DRUGS AND SUPPLEMENTS

Box: A quick glance at the history of performance-enhancing substances

Chapter Summary

1. Daily cardiovascular exercise and regular resistance training improve health and slow aging.
2. Fitness level is based on oxygen distribution and utilization, which can be quantified by determining $VO_2\text{max}$.
3. $VO_2\text{max}$ is directly related to heart rate, so exercise heart rate provides a relative measure of exercise intensity (as a fraction or percentage of $VO_2\text{max}$).
4. Training or regular exercise can increase $VO_2\text{max}$, which is primarily reflected by an increase in stroke volume.
5. Exercise causes changes in metabolism, and regular cardiovascular exercise can improve aerobic metabolism and influence the distribution of muscle fiber type.
6. Endurance training can increase the content of slow-twitch oxidative muscle and improve blood sugar control and insulin sensitivity.
7. The effect of drugs or supplements on exercise can be studied experimentally. A double-blind approach helps to eliminate a placebo effect.
8. Urine samples are tested for banned substances both in season and year-round for most competitive athletes. The detection of some drugs may require blood testing.

Selected Key Terms

adenosine triphosphate (ATP)

aerobic metabolism
anaerobic metabolism
blind study
cardiovascular fitness
case report
case-control study
cohort study
double-blind study
evidence pyramid
exercise capacity
exercise intensity
exercise prescription
fast-twitch glycolytic fibers
fast-twitch oxidative fibers
fermentation
glycogenolysis
lipolysis
maximum heart rate
meta-analysis
metabolic syndrome
oxidative phosphorylation
randomized controlled trial
slow-twitch oxidative fibers
substrate-level phosphorylation
systematic review
VO₂max

Suggested Readings

Aagaard, P, Andersen, JL, Bennekou, M, Larsson, B, Olesen, J.L, Crameri, R, ... Kjaer, M (2011). Effects of resistance training on endurance capacity and muscle fiber composition in young top-level cyclists. *Scand J Med Sci Sports* 21:e298–307

[Read the abstract.](#)

Basal-Duby, RB, & Olson, EN (2006). Signaling pathways in skeletal muscle remodeling. *Annu Rev Biochem* 75:19–37

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Church, TS, Earnest, CP, Skinner, JS, & Blair, S.N. (2007). Effects of different doses of physical activity on cardiorespiratory fitness among sedentary, overweight or obese postmenopausal women with elevated blood pressure. *JAMA* 297:2081–2091

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Garber, C.E, Blissmer, B, Deschenes, M.R, Franklin, B.A, Lamonte, M.J, Lee, I.M, ... Swain, D.P.; American College of Sports Medicine. (2011). American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc* 43:1334–1359

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[Read the abstract.](#)

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[Read the abstract.](#)

Yan, Z, Okutsu, M, Akhtar, YN, & Lira, VA (2011). Regulation of exercise-induced fiber type transformation, mitochondrial biogenesis, and angiogenesis in skeletal muscle. *J Appl Physiol* 110:264–274

[Read the article.](#)

Responses to Chapter-Ending Review Questions

- 1. Bill is 60 years old and in reasonable shape. Working out on an elliptical machine, Bill sees that his heart rate is 135 bpm. Can you determine his approximate exercise intensity without hooking him to a metabolic cart? What is he primarily burning for energy?**

Yes, using the formula $[211 - 0.64(\text{age}) = \text{max HR}]$ will help determine exercise intensity.

$$211 - (0.64 \times 60) = 172.6$$

$$135 / 172.6 = 0.78, \text{ or } 78\% \text{ of max HR}$$

At 78% max HR, and using the information in Table 2.2, we can infer that the calories he is burning are less than 15% free fatty acids and 9% muscle-related fat. More than 18% of his calories are coming from blood glucose, and more than 58% derive from muscle glycogen.

- 2. Your mother asks your advice about starting an exercise program. She is in pretty good health but wants to drop some weight and improve her cardiovascular health. What kind of exercise plan would you recommend to get her started? How would you explain to her the benefits of such a plan? After the initial couple of weeks, would you recommend any changes that might help with her long-term fitness goals?**

Her immediate goal should be 150 minutes of cardiovascular activity per week at moderate intensity (55–60% max HR). You can help determine her max HR (question 1) and show her how to take her pulse. Moderate intensity walking is at a pace where talking is a bit of an effort. For weight loss, attention to diet is important. Diet is covered in more detail in Chapter 13, but calories consumed should be equal or less than calories burned on a daily basis. There is considerable evidence to support the 150 minute per week target, and middle-aged women see a marked improvement in their cardiovascular health as a result. Walking is a good starting point; if she enjoys it, some tweaks can increase the benefit. Increasing the walking speed and distance is the most obvious. Adding short intervals of jogging or “speed-walking” also are beneficial. Alternating walking with biking or swimming provides some cross-training and reliance on other muscle groups, another potential benefit. Resistance training is also important. If access to a gym with a weight room is not available, then using hand weights, elastic bands, or isometric exercises can provide a level of strength training—a very important component for good bone health in women.

- 3. Compare and contrast the three major muscle fiber types in terms of their metabolism and fuel preference.**

Type 1 fibers (slow twitch, red) are rich in mitochondria, highly oxidative/aerobic metabolism, use fatty acids, have high myoglobin content (generating the red color), and contain little glycogen. They are relatively fatigue-resistant, have slower contraction rates, and play an important role in endurance exercise.

Type IIa fibers (oxidative fast twitch) are intermediate in their amount of glycogen and mitochondria, also known as oxidative-glycolytic fibers. They are also intermediate in fatigue-resistance with limited glycogen. They can burn fatty acids and glucose. These fibers are also red due to myoglobin.

Type IIx fibers (fast twitch, glycolytic, white) have fast contraction speed but low fatigue-resistance, have the most stored glycogen, lack myoglobin, and have relatively few mitochondria. They use much less fat as an energy source. Type IIx fibers are used for power.

4. You are a graduate student working in an exercise physiology lab. You see a claim in a bodybuilding magazine about a supplement that rapidly increases power, strength, and muscle mass. How would you set up an experiment to test whether these claims are true?

Research Project

Four groups are needed:

1. Placebo / No exercise
2. Drug /No exercise
3. Placebo / Exercise
4. Drug / Exercise

Subjects should be administered a drug or placebo in a double blind protocol, and matched regarding health, fitness, sex, age. Or use a cross-over design in which the same group of subjects is used for all four tests at different times. Drug dose and administration should be consistent with standard practice for that agent. You may need to research drug half-life and TI to set dose and determine time of predicted peak blood levels.

Exercise protocol should match the drug target (i.e., endurance, speed, or power). and target sub max or max VO_2 . In this case, a weight-lifting protocol to determine maximum lift or number of lifts to failure could be used. Measurement of muscle size before and after would also be helpful. In some cases, RPE can be determined. The goal is to determine if drug is ergogenic or ergolytic.

5. Obesity is now considered by some to be reaching epidemic proportions. What is contributing to this trend, and what can be done about it?

Although this subject is discussed in greater detail in Chapter 12, in the current context diet and level of physical activity can be stressed. Many people consume considerably more calories than they use on a daily basis, resulting in weight gain. Processed or fast-food often has a high caloric content with low nutritional value. Combined with low levels of physical activity, close to 70% of the population is now considered overweight or obese. Educating the public on the benefits of a health diet needs to continue, and access and affordability of healthy food choices are needed. In addition, the population needs to embrace 150 minutes per week, minimum, of cardiovascular exercise.

Quiz Questions

1. Which of the following is NOT part of an exercise prescription?
 - a. Intensity
 - b. Duration
 - c. Anti-inflammatory drugs
 - d. Warm up/stretching
 - e. Frequency
2. How do you determine if you are becoming more fit?
 - a. Running faster up hills
 - b. Increasing VO_2 max
 - c. Increasing the maximum weight of an arm curl
 - d. Eating more protein shakes
 - e. Decreasing time to completion for certain tasks
3. When exercising at close to VO_2 max, where is energy mostly coming from?
 - a. Fats from adipose tissue (fat cells)
 - b. Fats stored in muscle tissue
 - c. Glucose being taken up in the gut
 - d. Muscle glycogen
 - e. Fats released from serum proteins

For questions 4–8, choose from the following answer choices:

- a. Type 1 muscle fibers
 - b. Type IIa muscle fibers
 - c. Type IIx muscle fibers
 - d. Types 1 and IIa muscle fibers
 - e. Types IIa and IIx muscle fibers
4. Have sufficient mitochondria for oxidative metabolism
 5. Are white due to lack of myoglobin
 6. Effectively use fatty acids as an energy source
 7. Have fast-twitch activity
 8. Are slow twitch and fatigue resistant
 - 9 **True or False?** The placebo effect means the subject has responded to taking a pill, even if the pill contains only an inert substance.
 - 10 **True or False?** Exercise pharmacology studies can only be done in healthy volunteers.

11. **True or False?** One way to avoid a positive drug test and possible suspension is to refuse to take the test.
12. **True or False?** For most drugs on the Prohibited List, a complex test involving a blood sample is required.
13. **True or False?** Athletes have used performance enhancing substances for centuries.
14. **True or False?** Regular endurance training can effect the composition of muscle fiber types.
15. **True or False?** A meta-analysis draws upon many different research articles, effectively increasing the number of subjects for a particular outcome.

Answer Key

1. c
2. b
3. d
4. d
5. c
6. d
7. e
8. a
9. True
10. False
11. False
12. False
13. True
14. True
15. True