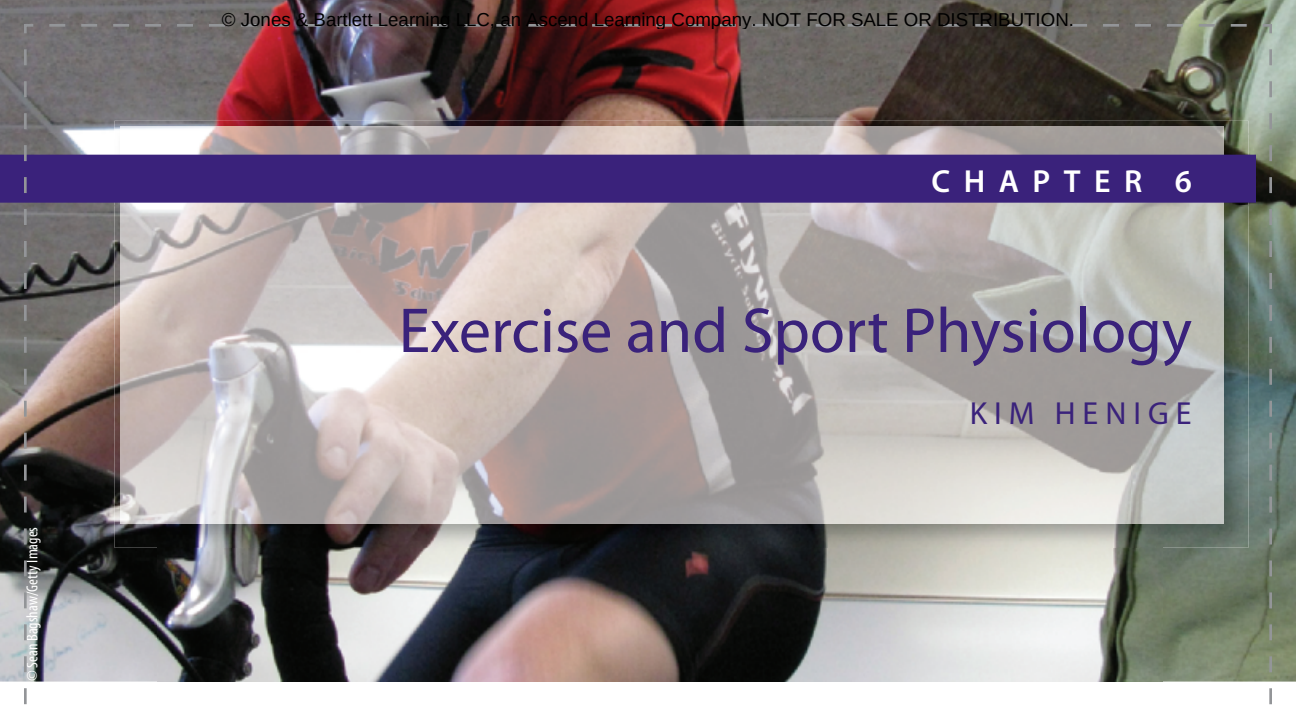

CHAPTER 6

Exercise and Sport Physiology

KIM HENIGE

LEARNING OBJECTIVES

1. Describe the general scope of the field of exercise and sport physiology.
2. Describe the general history and major events of the field of exercise physiology in the United States.
3. Describe the importance of exercise physiology as a component of the kinesiology educational curriculum.
4. Define key terminology within exercise physiology.
5. Explain the general principles that form the basis of exercise physiology.
6. Describe and provide examples of the health- and skill-related components of physical fitness.
7. List and explain the principles of exercise training.
8. Identify careers related to exercise physiology.

KEY TERMS

activities of daily living (ADLs)
acute exercise effects
acute physiological responses
adenosine triphosphate (ATP)
chronic exercise effects
demand
exercise
exercise physiology

exercise physiology
The study of how the body responds and adapts to physical stress.

sport physiology
The application of exercise physiology principles to guide training and enhance sport performance.

acute exercise effects
Sudden and immediate responses to exercise.

chronic exercise effects
Gradual and long-term responses to exercise.

health-related components of physical fitness
instrumental activities of daily living (IADLs)
physical activity (PA)
physical fitness
physiological mechanisms
physiological training adaptations
principle of overload
principle of progression
principle of reversibility
principles of exercise training
skill-related components of physical fitness
sport physiology
stress
supply
supply equals demand

What Is Exercise and Sport Physiology?

Exercise physiology is the study of how the body responds and adapts to physical stress. **Sport physiology** is the application of exercise physiology principles to guide training and enhance sport performance. Exercise and sport physiology overlap significantly, and therefore are generally considered together. For the remainder of this chapter, the term *exercise physiology* will be used to encompass the areas of both exercise and sport physiology. Exercise is an intentional physical stress placed upon the body, producing both acute and chronic effects that can be studied. **Acute exercise effects** are sudden and immediate, whereas **chronic exercise effects** are gradual and long term. When you start jogging, the systems in your body (cardiovascular, respiratory, nervous, endocrine, etc.) immediately respond with acute changes (e.g., increased heart rate and breathing rate) that permit your body to meet the demands of the stress and perform the processes necessary for you to jog. If you jog regularly, the stress is placed upon the body chronically, and the body's systems respond over time with long-term physiological adaptations. Physiological adaptations result in less stress on the body's systems, greater efficiency of the systems, and improved physical performance during exercise and other types of physical activity.

The History of Exercise Physiology in the United States

STOP AND THINK

How do you think exercise physiology relates to your specific career area of interest?

Exercise physiology is relatively new as a formal discipline; however, evidence suggests that individuals have been studying the physiological responses to physical activity as far back as ancient Greece. This historical review is a capsule summary and will focus on the modern history of exercise physiology, which first became formalized in the United States in the early 1800s when physiology textbooks began to appear.

In the earliest years of the field in the United States, one of the first texts published was *The Principles of Physiology Applied to the Preservation of Health and to the Improvement of Physical and Mental Education* by A. Combe in 1843. It included a limited amount of information on exercise. In 1855, William H. Byford published the first research paper on the physiology of exercise. In 1861, Edward Hitchcock at Amherst College was the first to collect anthropometric data before and after physical training.

Arguably one of the most significant years in the history of exercise physiology was the year 1886, when the American Association for the Advancement of Physical Education was founded. In the years following, exercise physiology began to enter the college curriculum at a number of colleges and universities. In the 1890s, Thomas Wood at Stanford University established a 4-year degree program in physical training and hygiene, which included exercise physiology as a major component. Around the same time, students majoring in physical education at Harvard, Stanford, and Oberlin were required to take exercise physiology courses.

In 1891, George W. Fitz at Harvard University was the first to establish a formal research laboratory for physical education in the United States. The name of the department was *Anatomy, Physiology, and Physical Training*. Part of the Lawrence Scientific School, it offered a 4-year Bachelor of Science (B.S.) degree and included both lecture and laboratory courses in exercise physiology. In 1900, the title of the department was changed to *Anatomy and Physiology*, and the focus shifted away from exercise physiology.

In 1898, the first edition of the *American Journal of Physiology* was published. In the early 1900s, several researchers began exploring exercise physiology and publishing information in the field. Exercise physiology labs began to open around the country, such as those founded at the

FIGURE 6-1 This is David Bruce ("DB") Dill. He was the founding director of Harvard's Fatigue Laboratory and he served as President of the American Physiological Society (APS).

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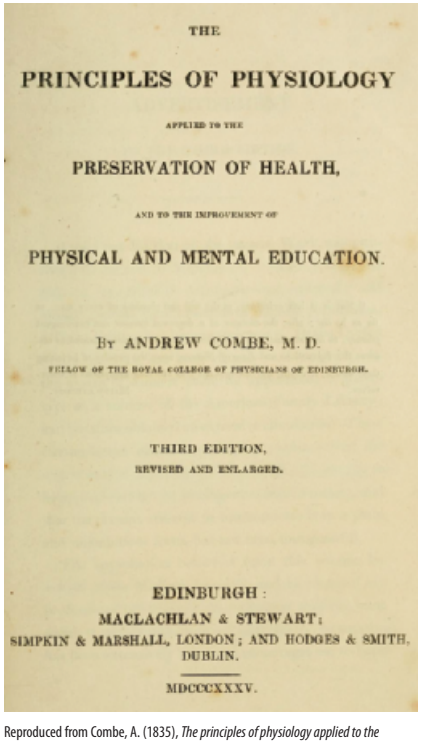

THE

PRINCIPLES OF PHYSIOLOGY

APPLIED TO THE

PRESERVATION OF HEALTH,

AND TO THE IMPROVEMENT OF

PHYSICAL AND MENTAL EDUCATION.

By ANDREW COMBE, M. D.

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS OF EDINBURGH.

THIRD EDITION,
REVISED AND ENLARGED.

EDINBURGH:
MACLACHLAN & STEWART;
SIMPKIN & MARSHALL, LONDON; AND HODGES & SMITH, DUBLIN.

MDCCCXXXV.

Reproduced from Combe, A. (1835), *The principles of physiology applied to the preservation of health, and to the improvement of physical and mental education.* Maclachlan and Stewart.

University of Illinois, Springfield College, and Williams College. Exercise physiology established itself firmly as an academic discipline in 1927 when L. J. Henderson and G. E. Mayo established the Harvard Fatigue Laboratory (**FIGURE 6-1**) and named David Bruce "D.B." Dill the director. This lab became prominent and productive, publishing 50 papers in 20 years. Arguably, no lab since has obtained the same level of prestige. In the 1930s, several exercise physiology textbooks and the first issue of the physical education journal *Research Quarterly* were published.

The years from 1946 to 1962 have been termed the "embryonic years" of the exercise physiology discipline (Massengale & Swanson, 1997). As evidence of this growth, in 1946 there were 14 exercise/exertion citations in 5 professional journals and manuscripts, and by 1962 there were 128 citations in 51 professional journals and manuscripts. And as evidence of the increasing rigor

and scientific basis of the field, in 1946 the Federation of American Societies for Experimental Biology (FASEB) national conference had a session dedicated to exercise physiology.

STOP AND THINK

What were some of the significant events that occurred during the early years of exercise physiology?

In 1947, the Harvard Fatigue Laboratory was closed because the president of the university, James B. Conant, felt that the lab would lose its value after the end of World War II. Many of the professors, staff, and graduate students from the lab went on to establish new exercise physiology labs across the United States. This event resulted in the expansion of exercise physiology labs across the country. The increase in the number of labs led to more research, and thus the need for new journals. In 1948, the American Physiological Society (APS) began publishing the *Journal of Applied Physiology*.

During this period, physical fitness emerged as a national concern. Thomas K. Cureton from Springfield College established the Physical Fitness Research Laboratory at the University of Illinois. Many of Cureton's graduates went on to research and leadership positions in physical education departments across the United States. Largely due to Cureton and his graduates, exercise physiology was recognized for its potential contribution to fitness.

George Williams College in Illinois and Springfield College in Massachusetts became known for their emphasis on exercise physiology in physical education and for their preparation of students for careers in the YMCA. Many graduates of these colleges went on to become important leaders in university and state organizations, significantly impacting exercise physiology as an academic discipline.

In 1954, the American College of Sports Medicine (ACSM) was established. The 11 founding members were physical educators and physicians, including A. H. Steinhaus from George Williams College and P. V. Karpovich from Springfield College, and one woman, Josephine L. Rathbone from Teachers College, Columbia University. ACSM was, and continues to be, instrumental in increasing the visibility and growth of the discipline of exercise physiology.

In 1956, the President's Council on Youth Fitness was established by President Dwight D. Eisenhower when it was discovered that 57% of American children had failed fitness tests. The name of the council has

STOP AND THINK

- Based on the events from 1946 to 1962, why do you think this period has been referred to as the "embryonic years"?
- What do you think was the most significant event of this time period? Why?

been changed several times over the years, most recently by President Barack Obama, who changed the name to the President's Council on Fitness, Sports & Nutrition in 2010 to reflect the expansion of the council's mission to include nutrition.

In 1960, the first exercise physiology textbook for graduate students, *Science and Medicine of Exercise and Sport*, was published. In 1961, the first exercise physiology project was funded by the National Institutes of Health (NIH). The project was entitled "Human Adaptation to Environmental and Exercise Stress."

The years from 1963 to 1976 have been termed the "formative years" (Massengale & Swanson, 1997). During this period, the visibility and credibility of exercise physiology continued to improve, and the number of textbooks, journals, and journal articles related to exercise physiology increased significantly.

In 1963, J. B. Conant published the Conant Report. The former president of Harvard University was critical of teacher training in the United States. In particular, he singled out physical education for its lack of academic rigor. In 1964, programs at large universities in the Pac-10 and Big 10 (and Penn State) began to implement more rigorous graduate programs and added exercise physiology emphases. Physical education departments began to collaborate with other science departments, and joint appointments for faculty were established. The academic credibility and recognition of exercise physiology improved significantly. However, immediate changes were not made to the curricula of undergraduate programs, and as a result, students were forced to take several science courses, not yet required by the undergraduate major, in order to qualify for graduate admission to exercise physiology programs.

Also in 1964, the NIH established the Applied Physiology Study Section to accommodate the increasing number of proposals for funding of physical fitness and exercise physiology research. Funding subsequently increased, which resulted in increased financial support for graduate students in exercise physiology. In 1969, the ACSM established a journal entitled, *Medicine and Science in Sports and Exercise*. The majority of the articles in this journal were to be related to exercise physiology.

In the early 1970s, physical education departments began changing their names (e.g., to kinesiology or exercise science) to better define their objectives and highlight the increasing emphasis on science-related courses and activities.

The years from 1977 to the present have been termed the "recognition years" (Massengale & Swanson, 1997). In 1977, the APS established a membership section for exercise physiologists. In 1983, it published a handbook of physiology dedicated to muscle physiology, and in 1996 it published a handbook of exercise physiology.

AMERICAN COLLEGE of SPORTS MEDICINE

Courtesy of ACSM

Several new organizations related to exercise physiology were also established during this period. In 1978, the National Strength and Conditioning Association (NSCA) was established. In 1985, the American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR) was founded. In 1997, the American Society of Exercise Physiologists (ASEP) was established. Reflecting the field's rigor and focus on experimentation, in 2005 the ACSM was admitted into the Federation of American Societies for Experimental Biology (FASEB).

Women also began to take on more leadership roles in the field. In 1988, the ACSM elected its first female president, Barbara Drinkwater, from the Department of Medicine at Pacific Medical Center in Seattle, Washington. In 2002, the APS elected its first female president, Barbara Horwitz, from the University of California, Davis.

STOP AND THINK

- Based on the events from 1963 to 1976, why do you think this period has been referred to as the "formative years"?
- What do you think was the most significant event of this period? Why?

In 2007, ACSM spearheaded its Exercise Is Medicine (EIM) initiative, based on the efforts of two physicians, Robert Sallis and Ronald Davis. The objective of EIM is "To make physical activity and exercise a standard part of a global disease prevention and treatment medical paradigm" (ACSM | EIM, n.d.). This initiative has resulted in a significant increase in the mainstream appreciation and attention given to the benefits of physical activity and the application of the principles of exercise physiology.

Why Study Exercise Physiology?

physical activity (PA)
Any type of bodily movement.

activities of daily living (ADLs)
The basic personal tasks individuals perform on a daily basis.

instrumental activities of daily living (IADLs)
Daily activities involved in maintaining a household.

exercise
A specific type of physical activity that is planned and structured with the explicit purpose of improving physical fitness.

Exercise physiology is one of many topics traditionally taught within the core of physical education, Kinesiology, and exercise science programs. Exercise physiology is an essential part of the curriculum because knowledge and understanding of the principles of exercise physiology enable physical education teachers, athletes, coaches, dance teachers, fitness trainers, and other sport and exercise science professionals to enhance physical performance and health through the application of the principles.

It is important to note that exercise physiology is not limited to the study of exercise and sport; it includes the study of the effects of any type of physical activity on the systems of the body. **Physical activity (PA)** includes any type of bodily movement, including **activities of daily living (ADLs)** and **instrumental activities of daily living (IADLs)**. ADLs are the basic personal tasks individuals perform on a daily basis, including dressing, bathing, grooming, using the toilet, eating, and moving around (**FIGURE 6-2**). IADLs are the daily activities involved in maintaining a household, including cooking, cleaning, and shopping (**FIGURE 6-3**). **Exercise**, a subset of physical activity, is planned and structured physical activity with the explicit purpose of improving physical fitness. Exercise physiology is not limited to improving performance during sport and exercise; it is also used to help individuals attain and maintain optimal health and independence through the life stages.

The American Society of Exercise Physiologists (ASEP, n.d.) classifies the scope of responsibilities of professional exercise physiologists into four

STOP AND THINK

- Based on the events of 1977 to the present, why do you think this period has been referred to as the "recognition years"?
- What do you think was the most significant event of this period? Why?

Courtesy of Exercise is Medicine

FIGURE 6-2 Getting dressed requires a certain amount of strength and flexibility.

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FIGURE 6-3 Housework requires a certain amount of muscle endurance and aerobic capacity.

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categories: (1) to promote health and wellness, (2) to prevent illness and disability, (3) to restore health, and (4) to help athletes reach their potential in sports training and performance.

The Principles of Exercise Physiology

There are many sources of stress on the body, referred to as *stressors*, including anxiety, physical trauma, illness, and disease. **Stress** is the body's response to a stressor that interferes with normal physiology. Physical activity and exercise are also stressors on the body. When the body performs increasing intensities of physical activity, the stress level and demands on the body increase because it must do more work. The normal physiology is disrupted because in order for the body to be able to do more work, it must produce and use more energy:

↑ PA → ↑ Work → ↑ Energy (ATP) DEMAND

The body's most basic demand is energy. The body is efficient, and therefore produces (and supplies) just enough energy to meet the current demand (**supply equals demand**). **Supply** and **demand** are central themes in exercise physiology. The fuel the body uses to provide energy to do work is called **adenosine triphosphate (ATP)**. Food nutrients from your diet and oxygen (O_2) from the environment are used within the processes that produce most of the ATP used by your body. Therefore, as demand for ATP increases, demand for oxygen also increases:

↑ PA → ↑ Work → ↑ Energy (ATP) DEMAND → ↑ O_2 DEMAND

As an example, when you begin to jog, your PA intensity level increases and the amount of work being done by the body increases. Therefore, your body must produce more ATP by using more oxygen.

One of the two major areas within exercise physiology is the study of the specific **acute physiological responses** that occur within the body's systems in order to help meet the demands of increased physical activity. The concept is simple. When the stress of exercise is placed on the body, the demands on the body increase, and the body responds acutely to increase the supply to meet the increased demand (i.e., supply = demand). During exercise, the greatest increase in demand is on the skeletal muscles (the muscles that cause bone and limb movement). For example, when you

stress
Response of the body to a stressor that interferes with normal physiology.

supply equals demand
When the amount of resources needed are matched by the amount made available; for example, when the amount of ATP needed is matched by the amount of ATP produced.

supply
Amount of resources made available; for example, the production of ATP.

demand
Amount of resources needed; for example, the need for ATP to do the required work.

adenosine triphosphate (ATP)
The body's fuel source.

acute physiological responses
The immediate effects on the body's systems in response to the stress of exercise.

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STOP AND THINK

- Why is knowledge and understanding of exercise physiology important for different careers? Provide specific examples.
- What is the difference between physical activity (PA) and exercise? Provide an example of each.
- How do activities of daily living (ADLs) and instrumental activities of daily living (IADLs) differ? Provide an example of each.
- According to the ASEP, what are the four items in the scope of responsibility of professional exercise physiologists? Why do you think ASEP chose each of these items?

start to jog, your breathing and heart rates increase. Did you ever stop to wonder why? One purpose of the increased breathing rate is to bring more oxygen into your lungs, and one purpose of the increased heart rate is to deliver the oxygen (carried in your blood) to the muscles at a faster rate (oxygen supply). Faster supply of oxygen to the muscles allows them to produce and use (supply) ATP at a faster rate in order to meet the higher demand for ATP so that the muscles can do more work:

↑ PA → ↑ Work → ↑ Energy (ATP) DEMAND → ↑ O_2 DEMAND
↑ Breathing Rate → ↑ O_2 Intake into Lungs
↑ Heart Rate → ↑ O_2 Delivery to Muscles
↑ O_2 Intake & Delivery → ↑ O_2 SUPPLY → ↑ ATP Production & Usage → ↑ ATP SUPPLY
SUPPLY = DEMAND

Exercise physiology explains why the breathing and heart rates increase during exercise, the **physiological mechanisms** the body uses to cause these increases, and the mechanisms the body uses to precisely match supply with demand.

physiological mechanisms Interacting processes within the body that bring about one or more effects.

The second major area of study in exercise physiology is how the body responds to repeated stress through chronic physiological adaptations. The body resists stress, so when a stress becomes chronic, as with regular exercise, the body finds ways to resist the stress. Stress resistance is accomplished with physiological changes within the systems; these changes are referred to

physiological training adaptations Long-term changes within the systems of the body in response to the stress of exercise.

as *physiological adaptations*. After these adaptations occur, the body's systems experience less stress in response to the stressor (i.e., physical activity). In exercise physiology, **physiological training adaptations** are those adaptations that occur in response to the stress of exercise. Returning to our previous example, your heart rate increases when you start to jog. One reason the heart rate increases is to increase the delivery rate of oxygen to the muscles so they can make and use more ATP (increased supply to meet the increased demand). An increased heart rate stresses the cardiovascular system. If you jog on a regular basis, adaptations within the cardiovascular system result in a lower heart rate while jogging at the same intensity. This means that the body is able to meet the same demand (i.e., same jogging intensity, same demand for ATP and oxygen) with less stress. The lower heart rate means that there is less stress on the cardiovascular system, and therefore the body has accomplished its goal, which was to reduce the stress caused by the stressor. Exercise physiology explains the mechanisms the body's systems use to respond to chronic stress with physiological adaptations that resist future stress.

Physiological training adaptations occur because the body resists stress. The adaptations do, in fact, reduce stress on the body systems, but they also have other positive side effects. As a result of training adaptations, the body becomes more efficient, which means it can perform the same amount of work with less energy. Training adaptations, including better efficiency result in an increased ability to perform physical activity, which can improve an athlete's performance in his or her sport or an older adult's ability to carry his or her own groceries. In addition, exercise adaptations strengthen the body's systems, making them more resistant to illness and disease, resulting in a lower risk for many diseases and better general overall health.

STOP AND THINK

- Use complete sentences to explain the following relationships:

  ↑ PA → ↑ Work → ↑ Energy (ATP) DEMAND → ↑ O_2 DEMAND

  ↑ Breathing Rate → ↑ O_2 Intake into Lungs

  ↑ Heart Rate → ↑ O_2 Delivery to Muscles

  ↑ O_2 Intake & Delivery → ↑ O_2 SUPPLY → ↑ ATP Production & Usage → ↑ ATP SUPPLY

  SUPPLY = DEMAND
- What is adenosine triphosphate (ATP)? What is its role in enabling physical activity?
- When PA intensity level increases, what happens to the demand for ATP? Why?
- When PA intensity level increases, what happens to the demand for oxygen (O_2)? Why?
- What are some of the acute physiological responses within the body that contribute to an increased supply of O_2?
- Define and explain *physiological mechanisms*.
- What are physiological training adaptations?
- Why does the body adapt? What are the benefits to the body?

The Components of Physical Fitness

When you exercise, probably without realizing it, you intentionally place stress on your body, hoping that it will respond and adapt. When you say you want to become more "fit," you are usually expressing your desire to improve one or more of your health-related components of fitness through physiological adaptation. **Physical fitness** is a set of physiological attributes that reflect the ability of the systems of the body to support physical activity. The **health-related components of physical fitness** are those components that have been shown to have a relationship with good physical health and the prevention of many types of disease (**TABLE 6-1**).

Another category of fitness components that generally receive less consideration in a general exercise program, but that are still affected by physiological adaptation, are the **skill-related components of physical fitness** (**TABLE 6-2**). The skill-related components of physical fitness are related to sport and motor-skill performance.

physical fitness Physiological attributes that reflect the ability of the systems of the body to support physical activity.

health-related components of physical fitness The components of physical fitness that are associated with good physical health, including body composition, muscular strength, muscular endurance, aerobic capacity, and flexibility.

TABLE 6-1 Health-Related Components of Physical Fitness

Component	Description
Aerobic capacity	The ability to perform prolonged, large-muscle, dynamic exercise at moderate to high levels of intensity
Body composition	The proportion of total body weight made up of fat mass and fat-free mass
Flexibility	The ability of the joints to move freely through their normal range of motion
Muscular endurance	The ability of skeletal muscles to repeatedly generate force
Muscular strength	The ability of skeletal muscles to generate force

TABLE 6-2 Skill-Related Components of Physical Fitness

Component	Description
Agility	The ability to change body position quickly and accurately
Balance	The ability to maintain steady body posture
Coordination	The ability to perform physical tasks smoothly and accurately
Power	The ability of the muscles to generate force quickly
Reaction time	The ability to respond to a stimulus quickly
Speed	The ability to move quickly

STOP AND THINK

- Define *physical fitness*.
- Identify the health-related components of physical fitness.
  - For each component, provide an example of a specific sport skill and/or exercise that depends on the component.
- Identify the skill-related components of physical fitness.
  - For each component, provide an example of a specific sport skill and/or exercise that depends on the component.

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skill-related components of physical fitness
The components of physical fitness that are associated with good sport and motor-skill performance.

principles of exercise training
Foundational guidelines for planning an exercise program that successfully leads to the desired physiological adaptations without causing undo stress and/or injury.

The Principles of Exercise Training

As stated previously, one of the reasons people exercise is to improve their physical fitness. The **principles of exercise training** are the foundational guidelines for planning an exercise program so that it successfully leads to the desired improvements without causing undue stress and/or injury. The principles of exercise training have been established from evidence-based

scientific knowledge of the stimuli and physiological responses that lead to physiological adaptations, and therefore improvements in fitness. Whether you are a physical education teacher, sport coach, strength and conditioning coach, dance teacher, fitness trainer, or fitness instructor, knowledge, understanding, and application of these principles are essential for your professional success.

The primary, overarching principle of exercise training is the **principle of overload**, which states that the body must be stressed to a level beyond which it is normally accustomed in order to stimulate physiological training adaptations. Overload is essentially the stress that we discussed earlier. The body is stressed when it is forced to do something that it is not accustomed to. When the body and its systems are stressed regularly, the body detects the pattern of stress and responds by making physiological changes (adaptations) to resist the stress. For each fitness component, tests can be used to measure physiological adaptations to exercise. For example, one test of cardiorespiratory endurance is the step test. During the step test, we measure the heart rate response to stepping up and down for 3 minutes. When you first start a jogging program, the cardiovascular system is overloaded because it is forced to deliver oxygen at a rate that is higher than it is accustomed to. Part of the overload in this situation is that the heart has to contract (beat) faster. The high heart rate puts stress on the heart, and if the heart rate is raised long and often enough, the cardiovascular system will respond with physiological adaptations that result in a lower heart rate when jogging at the same intensity. This training adaptation can be measured by performing the step test again, after several weeks of training.

principle of overload
The body must be stressed to a level beyond that to which it is normally accustomed in order to stimulate physiological training adaptations.

It is important to note that not all physical activity causes overload, because your body is "accustomed" to activities you do often. For example, if you walk 1–2 miles around campus every day, walking this distance will not overload your body and stimulate physiological changes. However, if someone is sedentary and moves around very little each day, walking 1–2 miles will likely cause an overload, and if done regularly will result in adaptations. If you want your exercise program to result in training adaptations, it must consist of physical activity that your body is not accustomed to. In addition, as you exercise regularly over time, your body adapts, plateaus, and eventually becomes "accustomed" to the exercise. When that occurs you must increase the intensity of the exercise stress such that it, again, becomes a physical activity that your body is not accustomed to. This is called the

STOP AND THINK

- Explain each of the principles of exercise training.
- Provide examples of following and not following each principle within an exercise program.

principle of progression
As the body adapts to exercise, the exercise intensity must be increased in order to continue to stimulate physiological training adaptations.

principle of reversibility
When an exercise stress is removed, the physiological training adaptations to that stress are lost.

principle of progression. You must progress the overload as your body adapts. For example, the stress of jogging can be increased many ways, including increasing the speed, grade (run up hills), duration (more minutes per session), or frequency (more sessions per week).

Just as the body recognizes a pattern of stress and subsequently adapts, it also recognizes when that stress has been removed. If you jog regularly over time, adapt, lowering your exercise heart rate, and then stop your jogging routine, your body will reverse its adaptations. As mentioned earlier, the body adapts to resist tress, but if the stress is no longer present, the physiological systems no longer maintain the adaptations, and therefore they are lost. Because it strives for efficiency, the body will not exert its energy and resources to maintain an unnecessary physiological adaptation. This is called the **principle of reversibility**, which is sometimes referred to by the saying "use it or lose it."

Other exercise training principles exist, but they are beyond the scope of this chapter. In other courses, you will learn more about the principles explained above, as well as other principles, such as the principles of specificity, individuality, and overtraining. All of these principles come from evidence-based scientific data about the physiological responses to exercise.

What Can You Do with a Degree in Exercise Physiology?

Students typically struggle in their quest to discover career options related to exercise physiology because job titles are rarely labeled "exercise physiologist." However, exercise physiology concepts make up the basis for understanding the human body and how it responds to the stresses of life, including exercise and disease. Therefore, individuals with a degree in exercise physiology are employed in a wide variety of career areas that can be categorized as clinical, fitness, research, sport, and teaching. See **TABLE 6-3** for a list of some of these careers and **TABLE 6-4** for a list of research areas related to exercise physiology.

Although there are many exercise physiology–related careers, many of the career paths require additional schooling and/or certification beyond

TABLE 6-3 Career Areas Related to Exercise Physiology

Career Area	Career
Clinical	Athletic trainer Cardiac rehabilitation specialist Chiropractor Massage therapist Medical doctor/osteopathic doctor Nurse/nurse practitioner Occupational therapist Occupational therapy assistant Physical therapist Physical therapy assistant Physician assistant Podiatrist Pulmonary rehabilitation specialist Recreational therapist
Fitness	Adapted physical activity specialist Business owner/entrepreneur Community physical activity specialist Corporate fitness specialist Director of wellness and health promotion Fitness consultant Fitness writer Group fitness trainer Master trainer Personal trainer Public health physical activity specialist Senior fitness specialist Wellness coach Wellness director
Research	Academia Military Olympic Training Center Pharmaceuticals Sports equipment companies

(*continues*)

TABLE 6-3 Career Areas Related to Exercise Physiology (*continued*)

Career Area	Career
Sport	Athlete Coach Dance teacher Sports nutritionist Strength and conditioning specialist
Teaching	College Fitness workshop presenter Health educator High school teacher

a bachelor's degree. Students should research the various career options early (as freshmen and sophomores) to evaluate practicality and feasibility in terms of personal interest and strengths. Early preparation also provides time to plan appropriately for graduate schooling and certification, if necessary.

STOP AND THINK

- For each career area in Table 6-3, choose one specific career you think you would enjoy the most and explain why.
- For each career area in Table 6-3, choose one specific career that you think you would be most successful at and explain why.
- Can you think of any other careers related to exercise physiology that are not listed in Table 6-3?

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Areas of Research in Exercise Physiology

TABLE 6-4 Areas of Research in Exercise Physiology (*continued*)

Area of Research	Example Research Topics
Exercise testing	Fitness assessment Performance assessment Physical activity assessment
Exercise training	Aerobic training Anaerobic training Athletic performance training Exercise prescription Flexibility training Muscular endurance training Muscular strength training
Bioenergetics and muscle metabolism	Carbohydrate metabolism Energy expenditure Lipid metabolism
Body composition	Energy balance Obesity Weight control
Clinical exercise physiology	Clinical exercise prescription Clinical exercise testing Exercise epidemiology Exercise immunology
Disease	Alzheimer's disease Arthritis Cancer Depression Heart disease Hypertension Stroke Type II diabetes
Environmental physiology	Altitude Diving Space travel Thermoregulation

(*continues*)

TABLE 6-4 Areas of Research in Exercise Physiology (*continued*)

Area of Research	Example Research Topics
Fatigue	Central nervous system fatigue Muscular fatigue Neuromuscular fatigue
Gender differences	Performance differences Training differences
Lifespan	Senior fitness and aging Youth fitness and development
Occupational physiology	Fire and rescue Law enforcement Military
Physical activity and health promotion	Community health Public health Schools Workplace health
Rehabilitation	Cardiac rehabilitation Occupational therapy Physical therapy Respiratory therapy
Sports nutrition	Ergogenic aids In-competition nutrition Precompetition nutrition Recovery nutrition Supplements
Systems exercise physiology	Bone and connective tissue physiology Cardiovascular physiology Cellular and molecular physiology Endocrine physiology Neural physiology Respiratory physiology Skeletal muscle physiology

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STOP AND THINK

- For each area of research in Table 6-4, what are some specific issues related to exercise physiology that may be studied?
- Can you think of any other research areas related to exercise physiology that are not listed in Table 6-4?

CHAPTER SUMMARY

In this chapter, you have learned that exercise physiology is the study of how the body responds and adapts to physical stress. Exercise is an intentional physical stress placed upon the body. Within the field, both acute and chronic exercise effects are studied. Although exercise physiology is relatively new as a formal discipline, it has likely been studied as far back as the ancient Greeks. Currently, exercise physiology is one of many topics traditionally taught within the core of physical education, kinesiology, and exercise science programs. Exercise physiology is an essential part of the curriculum because knowledge and understanding of it permits physical education teachers, athletes, coaches, dance teachers, fitness trainers, and other sport and exercise science professionals to enhance physical performance and health through the application of exercise physiology principles. Some of the core principles that form the basis of exercise physiology include stress and supply and demand as they relate to physical activity, energy (ATP) use, and physiological training adaptations. The principles of exercise are the foundational guidelines, based on evidence-based science, for planning a successful exercise program. The principles of overload, progression, and reversibility were also discussed in this chapter. Individuals with a degree in exercise physiology are employed in a wide variety of career areas that can be categorized as clinical, fitness, research, sport, and teaching.

DISCUSSION QUESTIONS

1. Describe the study of exercise physiology and explain how it differs from sport physiology.
2. Briefly explain the evolution of exercise physiology as a discipline in the United States.

3. Why is exercise physiology a core curricular component of most kinesiology programs?
4. Explain the terms stress, demand, supply, response, mechanism, and adaptation as they relate to the basic underlying principles of exercise physiology.
5. What is the difference between acute and chronic exercise effects?
6. What is the difference between the health- and skill-related components of physical fitness?
7. What is the purpose of the principles of exercise training?
8. For each career area in Table 6-3, randomly choose a specific career and describe the characteristics you think an individual must have in order to be successful in that career and explain why you think those characteristics are important.
9. Why do you think it is important to both enjoy and be good at your career? What would be some of the consequences if you did not like your career or were not good at it? Consider the consequences for you, your coworkers, your patients/clients, and your family.

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OTHER RESOURCES

www.acsm.org
www.asep.org
www.healthinaging.org/resources/resource:eldercare-at-home-problems-of-daily-living/
www.nsca.org
www.the-aps.org