# Chapter 2

# Historical Background, Terminology, Evolution of Recommendations, and Measurement

## Contents

## Contents, *continued*

# CHAPTER 2

# HISTORICAL BACKGROUND, TERMINOLOGY, EVOLUTION OF RECOMMENDATIONS, AND MEASUREMENT

## Introduction

> *The exercise boom is not just a fad; it is a return to 'natural' activity—the kind for which our bodies are engineered and which facilitates the proper function of our biochemistry and physiology. Viewed through the perspective of evolutionary time, sedentary existence, possible for great numbers of people only during the last century, represents a transient, unnatural aberration.* (Eaton, Shostak, Konner 1988, p. 168)

This chapter examines the historical development of physical activity promotion as a means to improve health among entire populations. The chapter focuses on Western (i.e., Greco-Roman) history, because of the near-linear development of physical activity promotion across those times and cultures leading to current American attitudes and guidelines regarding physical activity. These guidelines are discussed in detail in the last half of the chapter. To flesh out this narrow focus on Western traditions, as well as to provide a background for the promotional emphasis of the chapter, this chapter begins by briefly outlining both anthropological and historical evidence of the central, "natural" role of physical activity in prehistoric cultures. Mention is also made of the historical prominence of physical activity in non-Greco-Roman cultures, including those of China, India, Africa, and precolonial America.

Archaeologists working in conjunction with medical anthropologists have established that our ancestors up through the beginning of the Industrial Revolution incorporated strenuous physical activity as a normal part of their daily lives—and not only for the daily, subsistence requirements of their "work" lives. Investigations of preindustrial societies still intact today confirm that physical capability was not just a grim necessity for success at gathering food and providing shelter and safety (Eaton, Shostak, Konner 1988). Physical activity was enjoyed throughout everyday prehistoric life, as an integral component of religious, social, and cultural expression. Food supplies for the most part were plentiful, allowing ample time for both rest and recreational physical endeavors.

Eaton, Shostak, and Konner (1988) describe a "Paleolithic rhythm" (p. 32) observed among contemporary hunters and gatherers that seems to mirror the medical recommendations for physical activity in this report. This natural cycle of regularly intermittent activity was likely the norm for most of human existence. Sustenance preoccupations typically were broken into 1- or 2-day periods of intense and strenuous exertion, followed by 1- or 2-day periods of rest and celebration. During these rest days, however, less intense but still strenuous exertion accompanied 6- to 20-mile round-trip visits to other villages to see relatives and friends and to trade with other clans or communities. There or at home, dancing and cultural play took place.

As the neolithic Agricultural Revolution allowed more people to live in larger group settings and cities, and as the specialization of occupations reduced the amount and intensity of work-related physical activities, various healers and philosophers began to stress that long life and health depended on preventing illnesses through proper diet, nutrition, and physical activity. Such broad prescriptions for health, including exercise recommendations, long predate the increasingly specific guidelines of classical Greek philosophy and medicine, which are the predominant historical focus of this chapter.

In ancient China as early as 3000 to 1000 B.C., the classic *Yellow Emperor's Book of Internal Medicine* (Huang Ti 1949) first described the principle that human harmony with the world was the key to prevention and that prevention was the key to long life (Shampo and Kyle 1989). These principles grew into concepts that became central to the 6th century Chinese philosophy Taoism, where longevity through simple living attained the status of a philosophy that has guided Chinese culture through the present day. tai chi chuan, an exercise system that teaches graceful movements, began as early as 200 B.C. with Hua T'o and has recently been shown to decrease the incidence of falls in elderly Americans (Huard and Wong 1968; see Chapter 4).

In India, too, proper diet and physical activity were known to be essential principles of daily living. The *Ajur Veda,* a collection of health and medical concepts verbally transmitted as early as 3000 B.C., developed into Yoga, a philosophy that included a comprehensively elaborated series of stretching and flexibility postures. The principles were first codified in 600 B.C. in the *Upanishads* and later in the *Yoga Sutras* by Patanjali sometime between 200 B.C. and 200 A.D. Yoga philosophies also asserted that physical suppleness, proper breathing, and diet were essential to control the mind and emotions and were prerequisites for religious experience. In both India and China during this period, the linking of exercise and health may have led to the development of a medical subspecialty that today would find its equivalent in sports medicine (Snook 1984).

Though less directly concerned with physical health than with social and religious attainment, physical activity played a key role in other ancient non-Greco-Roman cultures. In Africa, systems of flexibility, agility, and endurance training not only represented the essence of martial arts capability but also served as an integral component of religious ritual and daily life. The Samburu and the Masai of Kenya still feature running as a virtue of the greatest prowess, linked to manhood and social stature.

Similarly, in American Indian cultures, running was a prominent feature of all major aspects of life (Nabokov 1981). Long before the Europeans invaded, Indians ran to communicate, to fight, and to hunt. Running was also a means for diverse American Indian cultures to enact their myths and thereby construct a tangible link between themselves and both the physical and metaphysical worlds. Among the Indian peoples Nabokov cites are the Mesquakie of Iowa, the Chemeheuvi of California, the Inca of Peru, the Zuni and other Pueblo peoples of the American Southwest, and the Iroquois of the American East, who also developed the precursor of modern-day lacrosse. Even today, the Tarahumarahe of northern Mexico play a version of kickball that involves entire villages for days at a time (Nabokov 1981; Eaton, Shostak, Konner 1988).

## Western Historical Perspective

Besides affecting the practice of preventive hygiene (as is discussed throughout this section), the ancient Greek ideals of exercise and health have influenced the attitudes of modern western culture toward physical activity. The Greeks viewed great athletic achievement as representing both spiritual and physical strength rivaling that of the gods (Jaeger 1965). In the classical-era Olympic Games, the Greeks viewed the winners as men who had the character and physical prowess to accomplish feats beyond the capability of most mortals. Although participants in the modern Olympic Games no longer compete with the gods, today's athletes inspire others to be physically active and to realize their potential—an inspiration as important for modern peoples as it was for the ancient Greeks.

### Early Promotion of Physical Activity for Health

Throughout much of recorded western history, philosophers, scientists, physicians, and educators have promoted the idea that being physically active contributes to better health, improved physical functioning, and increased longevity. Although some of these claims were based on personal opinions or clinical judgment, others were the result of systematic observation.

Among the ancient Greeks, the recognition that proper amounts of physical activity are necessary for healthy living dates back to at least the 5th century B.C. (Berryman 1992). The lessons found in the "laws of health" taught during the ancient period sound familiar to us today: to breathe fresh air, eat proper foods, drink the right beverages, take plenty of exercise, get the proper amount of sleep, and include our emotions when analyzing our overall well-being.

Western historians agree that the close connection between exercise and medicine dates back to three Greek physicians—Herodicus (ca. 480 B.C.), Hippocrates (ca. 460–ca. 377 B.C.), and Galen (A.D. 129–ca. 199). The first to study therapeutic gymnastics—or gymnastic medicine, as it was often called—was the Greek physician and former exercise instructor, Herodicus. His dual expertise united the gymnastic with the medical art, thereby preparing the way for subsequent Greek study of the health benefits of physical activity.

Although Hippocrates is generally known as the father of preventive medicine, most historians credit Herodicus as the influence behind Hippocrates' interest in the hygienic uses of exercise and diet (Cyriax 1914; Precope 1952; Licht 1984; Olivova 1985). *Regimen*, the longer of Hippocrates' two works dealing with hygiene, was probably written sometime around 400 B.C. In Book l, he writes:

> *Eating alone will not keep a man well; he must also take exercise. For food and exercise, while possessing opposite qualities, yet work together to produce health. For it is the nature of exercise to use up material, but of food and drink to make good deficiencies. And it is necessary, as it appears, to discern the power of various exercises, both natural exercises and artificial, to know which of them tends to increase flesh and which to lessen it; and not only this, but also to proportion exercise to bulk of food, to the constitution of the patient, to the age of the individual, to the season of the year, to the changes in the winds, to the situation of the region in which the patient resides, and to the constitution of the year.* (1953 reprint, p. 229)

Hippocrates was a major influence on the career of Claudius Galenus, or Galen, the Greek physician who wrote numerous works of great importance to medical history during the second century. Of these works, his book entitled *On Hygiene* contains the most information on the healthfulness of exercise. Whether by sailing, riding on horseback, or driving, or via cradles, swings, and arms, everyone, even infants, Galen said, needed exercise (Green 1951 trans., p. 25). He further stated:

> *The uses of exercise, I think, are twofold, one for the evacuation of the excrements, the other for the production of good condition of the firm parts of the body. For since vigorous motion is exercise, it must needs be that only these three things result from it in the exercising body—hardness of the organs from mutual attrition, increase of the intrinsic warmth, and accelerated movement of respiration. These are followed by all the other individual benefits which accrue to the body from exercise; from hardness of the organs, both insensitivity and strength for function; from warmth, both strong attraction for things to be eliminated, readier metabolism, and better nutrition and diffusion of all substances, whereby it results that solids are softened, liquids diluted, and ducts dilated. And from the vigorous movement of respiration the ducts must be purged and the excrements evacuated.* (p. 54)

The classical notion that one could improve one's health through one's own actions—for example, through eating right and getting enough sleep and exercise—proved to be a powerful influence on medical theory as it developed over the centuries. Classical medicine had made it clear to physicians and the lay public alike that responsibility for disease and health was not the province of the gods. Each person, either independently or in counsel with his or her physician, had a moral duty to attain and preserve health. When the Middle Ages gave way to the Renaissance, with its individualistic perspective and its recovery of classical humanistic influences, this notion of personal responsibility acquired even greater emphasis. Early vestiges of a "self-help" movement arose in western Europe in the 16th century. As that century progressed, "laws of bodily health were expressed as value prescriptions" (Burns 1976, p. 208).

More specifically, "orthodox Greek hygiene," as Smith (1985, p. 257) called it, flourished as part of the revival of Galenic medicine as early as the 13th century. The leading medical schools of the world—Italy's Salerno, Padua, and Bologna—taught hygiene to their students as part of general instruction in the theory and practice of medicine . The works of Hippocrates and Galen dominated a system whereby "the ultimate goal was to be able to practise medicine in the manner of the ancient physicians" (Bylebyl 1979, p. 341).

Hippocrates' *Regimen* also became important during the Renaissance in a literature that Gruman (1961) identified as "prolongevity hygiene" and defined as "the attempt to attain a markedly increased longevity by means of reforms in one's way of life" (p. 221). Central to this literature was the belief that persons who decided to live a temperate life, especially by reforming habits of diet and exercise, could significantly extend their longevity. Beginning with the writings of Luigi Cornaro in 1558, the classic Greek preventive hygiene tradition achieved increasing attention from those wishing to live longer and healthier lives.

Christobal Mendez, who received his medical training at the University of Salamanca, was the author of the first printed book devoted to exercise, *Book of Bodily Exercise* (1553). His novel and comprehensive ideas preceded developments in exercise physiology and sports medicine often thought to be unique to the early 20th century. The book consists of four treatises that cover such topics as the effects of exercise on the body and on the mind. Mendez believed, as the humoral theorists did, that the physician had to clear away excess moisture in the body. Then, after explaining the ill effects of vomiting, bloodletting, purging, sweating, and urination, he noted that "exercise was invented and used to clean the body when it was too full of harmful things. It cleans without any of the above-mentioned inconvenience and is accompanied by pleasure and joy (as we will say). If we use exercise under the conditions which we will describe, it deserves lofty praise as a blessed medicine that must be kept in high esteem" (1960 reprint, p. 22).

In 1569, Hieronymus Mercurialis' *The Art of Gymnastics Among the Ancients* was published in Venice. Mercurialis quoted Galen extensivly and provided a descriptive compilation of ancient material from nearly 200 works by Greek and Roman authors. In general, Mercurialis established the following exercise principles: people who are ill should not be given exercise that might aggravate existing conditions; special exercises should be prescribed on an individual basis for convalescent, weak, and older patients; people who lead sedentary lives need exercise urgently; each exercise should preserve the existing healthy state; exercise should not disturb the harmony among the principal humors; exercise should be suited to each part of the body; and all healthy people should exercise regularly.

Although Galenism and the humoral theory of medicine were displaced by new ideas, particularly through the study of anatomy and physiology, the Greek principles of hygiene and regimen continued to flourish in 18th century Europe. For some 18th century physicians, such nonintervention tactics were practical alternatives to traditional medical therapies that employed bloodletting and heavy dosing with compounds of mercury and drugs—"heroic" medicine (Warner 1986), in which the "cure" was often worse than the disease.

George Cheyne's *An Essay of Health and Long Life* was published in London in 1724. By 1745, it had gone through 10 editions and various translations. Cheyne recommended walking as the "most natural" and "most useful" exercise but considered riding on horseback as the "most manly" and "most healthy" (1734 reprint, p. 94). He also advocated exercises in the open air, such as tennis and dancing, and recommended cold baths and the use of the "flesh brush" to promote perspiration and improve circulation.

John Wesley's *Primitive Physic,* first published in 1747, was influenced to a large degree by George Cheyne. In his preface, Wesley noted that "the power of exercise, both to preserve and restore health, is greater than can well be conceived; especially in those who add temperance thereto" (1793 reprint, p. iv). William Buchan's classic *Domestic Medicine,* written in 1769, prescribed proper regimen for improving individual and family health. The book contained rules for the healthy and the sick and stressed the importance of exercise for good health in both children and adults.

During the 19th century, both the classical Greek tradition and the general hygiene movement were finding their way into the United States through American editions of western European medical treatises or through books on hygiene written by American physicians. The "self-help" era was also in full bloom during antebellum America. Early vestiges of a self-help movement had arisen in western Europe in the 16th century. As that century progressed, "laws of bodily health were expressed as value prescriptions" (Burns 1976, p. 208). Classical Greek preventive hygiene was part of formal medical training through the 18th century and continued on in the American health reform literature for most of the 19th century. During the latter period, an effort was made to popularize the Greek laws of health, to make each person responsible for the maintenance and balance of his or her health. Individual reform writers thus wrote about self-improvement, self-regulation, the responsibility for personal health, and self-management (Reiser 1985). If people ate too much, slept too long, or did not get enough exercise, they could only blame themselves for illness. By the same token, they could also determine their own good health (Cassedy 1977; Numbers 1977; Verbrugge 1981; Morantz 1984).

A.F.M. Willich's *Lectures on Diet and Regimen* (1801) emphasized the necessity of exercise within the bounds of moderation. He included information on specific exercises, the time for exercise, and the duration of exercise. The essential advantages of exercise included increased bodily strength, improved circulation of the blood and all other bodily fluids, aid in necessary secretions and excretions, help in clearing and refining the blood, and removal of obstructions.

John Gunn's classic *Domestic Medicine, Or Poor Man's Friend*, was first published in 1830. His section entitled "Exercise" recommended temperance, exercise, and rest and valued nature's way over traditional medical treatment. He also recommended exercise for women and claimed that all of the "diseases of delicate women" like "hysterics and hypochondria, arise from want of due exercise in the open, mild, and pure air" (1986 reprint, p. 109). Finally, in an interesting statement for the 1830s if not the 1990s, Gunn recommended a training system for all: "The advantages of the training systems are not confined to pedestrians or walkers—or to pugilists or boxers alone; or to horses which are trained for the chase and the race track; they extend to man in all conditions; and were training introduced into the United States, and made use of by physicians in many cases instead of medical drugs, the beneficial consequences in the cure of many diseases would be very great indeed" (p. 113).

## Associating Physical Inactivity with Disease

Throughout history, numerous health professionals have observed that sedentary people appear to suffer from more maladies than active people. An early example is found in the writings of English physician Thomas Cogan, author of *The Haven of Health* (1584); he recommended his book to students who, because of their sedentary ways, were believed to be most susceptible to sickness.

In his 1713 book *Diseases of Workers*, Bernardino Ramazzini, an Italian physician considered the father of occupational medicine, offered his views on the association between chronic inactivity and poor health. In the chapter entitled "Sedentary Workers and Their Diseases," Ramazzini noted that "those who sit at their work and are therefore called 'chair-workers,' such as cobblers and tailors, suffer from their own particular diseases." He concluded that "these workers . . . suffer from general ill-health and an excessive accumulation of unwholesome humors caused by their sedentary life," and he urged them to at least exercise on holidays "so to some extent counteract the harm done by many days of sedentary life" (1964 trans., pp. 281–285).

Shadrach Ricketson, a New York physician, wrote the first American text on hygiene and preventive medicine (Rogers 1965). In his 1806 book *Means of Preserving Health and Preventing Diseases*, Ricketson explained that "a certain proportion of exercise is not much less essential to a healthy or vigorous constitution, than drink, food, and sleep; for we see that people, whose inclination, situation, or employment does not admit of exercise, soon become pale, feeble, and disordered." He also noted that "exercise promotes the circulation of the blood, assists digestion, and encourages perspiration" (pp. 152–153).

Since the 1860s, physicians and others had been attempting to assess the longevity of runners and rowers. From the late 1920s (Dublin 1932; Montoye 1992) to the landmark paper by Morris and colleagues (1953), observations that premature mortality is lower among more active persons than sedentary persons began to emerge and were later replicated in a variety of settings (Rook 1954;

Brown et al. 1957; Pomeroy and White 1958; Zukel et al. 1959). The hypothesis that a sedentary lifestyle leads to increased mortality from coronary heart disease, as well as the later hypothesis that inactivity leads to the development of some other chronic diseases, has been the subject of numerous studies that provide the major source of data supporting the health benefits of exercise (see Chapter 4).

## Health, Physical Education, and Fitness

The hygiene movement found further expression in 19th century America through a new literature devoted to "physical education." In the early part of the century, many physicians began using the term in journal articles, speeches, and book titles to describe the task of teaching children the ancient Greek "laws of health." As Willich explained in his *Lectures on Diet and Regimen* (1801), "by *physical education* is meant the bodily treatment of children; the term *physical* being applied in opposition to *moral*" (p. 60). In his section entitled "On the Physical Education of Children," he continued to discuss stomach ailments, bathing, fresh air, exercise, dress, and diseases of the skin, among other topics. Physical education, then, implied not merely exercising the body but also becoming educated about one's body.

These authors were joined by a number of early 19th century educators. For example, an article entitled "Progress of Physical Education" (1826), which appeared in the first issue of *American Journal of Education,* declared that "the time we hope is near, when there will be no literary institution unprovided with the proper means to healthful exercise and innocent recreation, and when literary men shall cease to be distinguished by a pallid countenance and a wasted body" (pp. 19–20). Both William Russell, who was the journal's editor, and Boston educator William Fowler believed that girls as well as boys should have ample outdoor exercise. Knowledge about one's body also was deemed crucial to a well-educated and healthy individual by several physicians who, as Whorton has suggested, "dedicated their careers to birthing the modern physical education movement" (p. 282).

Charles Caldwell held a prominent position in Lexington, Kentucky's, Transylvania University Medical Department. Although he wrote on a variety of medical topics, his *Thoughts on Physical Education* in 1834 gained him national recognition. Caldwell defined physical education as "that scheme of training, which contributes most effectually to the development, health, and perfection of living matter. As applied to man, it is that scheme which raises his whole system to its summit of perfection. . . . Physical education, then, in its philosophy and practice, is of great compass. If complete, it would be tantamount to an entire system of Hygeiene. It would embrace every thing, that, by bearing in any way on the human body, might injure or benefit it in its health, vigor, and fitness for action" (pp. 28–29).

During the first half of the 19th century, systems of gymnastic and calisthenic exercise that had been developed abroad were brought to the United States. The most influential were exercises advanced by Per Henrik Ling in Sweden in the early 1800s and the "German system" of gymnastic and apparatus exercises that was based on the work of Johan Christoph GutsMuths and Friedrich Ludwig Jahn. Also, Americans like Catharine Beecher (1856) and Dioclesian Lewis (1883) devised their own extensive systems of calisthenic exercises intended to benefit both women and men. By the 1870s, American physicians and educators frequently discussed exercise and health. For example, physical training in relation to health was a regular topic in the *Boston Medical and Surgical Journal* from the 1880s to the early 1900s.

Testing of physical fitness in physical education began with the extensive anthropometric documentation by Edward Hitchcock in 1861 at Amherst College. By the 1880s, Dudley Sargent at Harvard University was also recording the bodily measurements of college students and promoting strength testing (Leonard and Affleck 1947). During the early 1900s, the focus on measuring body parts shifted to tests of vital working capacity. These tests included measures of blood pressure (McCurdy 1901; McKenzie 1913), pulse rate (Foster 1914), and fatigue (Storey 1903). As early as 1905, C. Ward Crampton, former director of physical training and hygiene in New York City, published the article "A Test of Condition" in *Medical News*. Attempts to assess physical fitness had constituted a significant aspect of the work of turn-of-the-century physical educators, many of whom were physicians.

Allegations that American conscripts during World War I were inadequately fit to serve their country helped shift the emphasis of physical education from health-related exercise to performance outcomes. Public concern stimulated legislation to make physical education a required subject in schools. But the financial austerities of the Great Depression had a negative effect on education in general, including physical education (Rogers 1934). At the same time, the combination of increased leisure time for many Americans and a growing national interest in college and high school sports shifted the emphasis on physical education away from the earlier aim of enhancing performance and health to a new focus on sports-related skills and the worthy use of leisure time.

Physical efficiency was a term widely used in the literature of the 1930s. Another term, physical condition, also found its way into research reports. In 1936, Arthur Steinhaus published one of the earliest articles on "physical fitness" in the *Journal of Health, Physical Education, and Recreation*; in 1938, C. H. McCloy's article "Physical Fitness and Citizenship" appeared in the same journal.

As the United States entered World War II, the federal government showed increasing interest in physical education, especially toward physical fitness testing and preparedness. In October 1940, President Franklin Roosevelt named John Kelly, a former Olympic rower, to the new position of national director of physical training. The following year, Fiorella La Guardia, the Mayor of New York City and the director of civilian defense for the Federal Security Agency, appointed Kelly as assistant in charge of physical fitness; tennis star Alice Marble was also chosen to promote physical fitness among girls and women (Park 1989; Berryman 1995).

In 1943, Arthur Steinhaus chaired a committee appointed by the Board of Directors of the American Medical Association to review the nature and role of exercise in physical fitness (Steinhaus et al. 1943), and C. Ward Crampton chaired a committee on physical fitness under the direction of the Federal Security Agency. Crampton and his 73-member advisory council were charged with developing physical fitness in the civilian population (Crampton 1941; Park 1989).

In 1941, Morris Fishbein, editor of the *Journal of the American Medical Association,* stated that "from the point of view on physical fitness we are a far better nation now than we were in 1917," but he cautioned Americans not to believe "we have attained an optimum in physical fitness" (p. 54). He realized the magnitude of the fitness problem when he noted that the poor results of physical examinations reported by the Selective Service Boards were "a challenge to the medical profession, to the social scientists, the physical educators, the public health officials, and all those concerned in the United States with the physical improvement of our population" (p. 55). The goals most frequently cited for physical education between 1941 and 1945 were resistance to disease, muscular strength and endurance, cardiorespiratory endurance, muscular growth, flexibility, speed, agility, balance, and accuracy (Larson and Yocom 1951).

After World War II concluded, a continuing interest in physical fitness convinced other key members of the medical profession and the American Medical Association to continue studying exercise. Much of this interest can be attributed to the pioneering work of Thomas K. Cureton, Jr., and his Physical Fitness Research Laboratory at the University of Illinois (Shea 1993). Cardiologists, health education specialists, and physicians in preventive medicine were becoming aware of the contributions of exercise to the overall health and efficiency of the heart and circulatory system. In 1946, the American Medical Association's Bureau of Health Education designed and organized the Health and Fitness Program to provide "assistance to local organizations throughout the nation in the development of satisfactory health education programs" (Fishbein 1947, p. 1009). The program became an important link among physical educators, physicians, and physiologists.

The event that attracted the most public attention to physical fitness, including that of President Dwight D. Eisenhower, was the publication of the article "Muscular Fitness and Health" in the December 1953 issue of the *Journal of Health, Physical Education, and Recreation.* The authors, Hans Kraus and Ruth Hirschland of the Institute of Physical Medicine and Rehabilitation at the New York University Bellevue Medical Center, stated that 56.6 percent of the American schoolchildren tested "failed to meet even a minimum standard required for health" (p. 17). When this rate was compared with the 8.3 percent failure rate for European children, a call for reform went out. Kraus and Hirschland labeled the lack of sufficient exercise "a serious deficiency comparable with vitamin deficiency" and declared "an urgent need" for its remedy (pp. 17–19). John Kelly, the former national director of physical fitness during World War II, notified Pennsylvania Senator James Duff of these startling test results. Duff, in turn, brought the research to the attention of President Eisenhower, who invited several athletes and exercise experts to a meeting in 1955 to examine this issue in more depth. A President's Conference on Fitness of American Youth, held in June 1956, was attended by 150 leaders from government, physical education, medical, public health, sports, civic, and recreational organizations. This meeting eventually led to the establishment of the President's Council on Youth Fitness and the President's Citizens Advisory Committee on the Fitness of American Youth (Hackensmith 1966; Van Dalen and Bennett 1971).

When John Kennedy became president in 1961, one of his first actions was to call a conference on physical fitness and young people. In 1963, the President's Council on Youth Fitness was renamed the President's Council on Physical Fitness. In 1968, the word "sports" was added to the name, making it the President's Council on Physical Fitness and Sports (PCPFS). The PCPFS was charged with promoting physical activity, fitness, and sports for Americans of all ages.

During the 1960s, a number of educational and public health organizations published articles and statements on the importance of fitness for children and youths. The American Association for Health, Physical Education, and Recreation (AAHPER) expanded its physical fitness testing program to include college-aged men and women. The association developed new norms from data collected from more than 11,000 boys and girls 10–17 years old. The AAHPER also joined with the President's Council on Physical Fitness to conduct the AAHPER Youth Fitness Test, which had motivational awards. In 1966, President Lyndon Johnson's newly created Presidential Physical Fitness Award was incorporated into the program.

In the mid-1970s, the need to promote the health—rather than exclusively the performance—benefits of exercise and physical fitness began to reappear. In 1975, AAHPER stated it was time to differentiate physical fitness related to health from performance related to athletic ability (Blair, Falls, Pate 1983). Accordingly, AAHPER commissioned the development of the Health Related Physical Fitness Test. This move in youth fitness paralleled the adoption of the aerobic concept, which promoted endurance-type exercise among the public (Cooper 1968).

## Exercise Physiology Research and Health

The study of the physiology of exercise in a modern sense began in Paris, France, when Antoine Lavoisier in 1777 and Lavoisier and Pierre de Laplace in 1780 developed techniques to measure oxygen uptake and carbon dioxide production at rest and during exercise. During the 1800s, European scientists used and advanced these procedures to study the metabolic responses to exercise (Scharling 1843; Smith 1857; Katzenstein 1891; Speck 1889; Allen and Pepys 1809). The first major application of this research to humans—Edward Smith's study of the effects of "assignment to hard labor" by prisoners in London in 1857—was to determine if hard manual labor negatively affected the health and welfare of the prisoners and whether it should be considered cruel and unusual punishment.

William Byford published "On the Physiology of Exercise" in the *American Journal of Medical Sciences* in 1855, and Edward Mussey Hartwell, a leading physical educator, wrote a two-part article, "On the Physiology of Exercise," for the *Boston Medical and Surgical Journal* in 1887. The first important book on the subject, George Kolb's *Beitrage zur Physiologie Maximaler Muskelarbeit Besonders des Modernen Sports*, was published in 1887 (trans. *Physiology of Sport*, 1893) (cited in Langenfeld 1988 and Park 1992). The following year, Fernand Lagrange's *Physiology of Bodily Exercise* was published in France.

From the early 1900s to the early 1920s, several works on exercise physiology began to appear. George Fitz, who had established a physiology of exercise laboratory during the early 1890s, published his *Principles of Physiology and Hygiene* in 1908. R. Tait McKenzie's *Exercise in Education and Medicine* (1909) was followed by such works as Francis Benedict and Edward Cathcart's *Muscular Work, A Metabolic Study with Special Reference to the Efficiency of the Human Body as a Machine* (1913). The next year, a professor of physiology at the University of London, F.A. Bainbridge, published a second edition of *Physiology of Muscular Exercise* (Park 1981).

In 1923, the year Archibald Hill was appointed Joddrell Professor of Physiology at University College, London, the physiology of exercise acquired one of its most respected researchers and staunchest supporters, for Hill had won the Nobel Prize in Medicine and Physiology the year before. Hill's 1925 presidential address on "The Physiological Basis of Athletic Records" to the British Association for the Advancement of Science appeared in *The Lancet* (1925a) and *Scientific Monthly* (1925b), and in 1926 he published his landmark book *Muscular Activity*. The following year, Hill published *Living Machinery*, which was based largely on his lectures before audiences at the Lowell Institute in Boston and the Baker Laboratory of Chemistry in Ithaca, New York.

Several leading physiologists besides Hill were interested in the human body's response to exercise and environmental stressors, especially activities involving endurance, strength, altitude, heat, and cold. Consequently, they studied soldiers, athletes, aviators, and mountain climbers as the best models for acquiring data. In the United States, such research was centered in the Boston area, first at the Carnegie Nutrition Laboratory in the 1910s and later at the Harvard Fatigue Laboratory, which was established under the leadership of Lawrence Henderson in 1927 (Chapman and Mitchell 1965; Dill 1967; Horvath and Horvath 1973). That year, Henderson and colleagues first demonstrated that endurance exercise training improved the efficiency of the cardiovascular system by increasing stroke volume and decreasing heart rate at rest. Two years later, Schneider and Ring (1929) published the results of a 12-week endurance training program on one person, demonstrating a 24-percent increase in "crest load of oxygen" (maximal oxygen uptake). Over the next 15 years, a limited number of exercise training studies were published that evaluated the response of maximal oxygen uptake or endurance performance capacity to exercise training. These included noteworthy reports by Gemmill and colleagues (1931), Robinson and Harmon (1941), and Knehr, Dill, and Neufeld (1942) on endurance training responses by male college students. However, none of those early studies compared the effects of different types, intensities, durations, or frequencies of exercise on performance capacity or health-related outcomes.

Activities surrounding World War II greatly influenced the research in exercise physiology, and several laboratories, including the Harvard Fatigue Laboratory, began directing their efforts toward topics of importance to the military. The other national concern that created much interest among physiologists was the fear (discussed earlier in this chapter), that American children were less fit than their European counterparts. Research was directed toward the concept of fitness in growth and development, ways to measure fitness, and the various components of fitness (Berryman 1995). Major advances were also made in the 1940s and 1950s in developing the components of physical fitness (Cureton 1947) and in determining the effects of endurance and strength training on measures of performance and physiologic function, especially adaptations of the cardiovascular and metabolic systems. Also investigated were the effects of exercise training on health-related outcomes, such as cholesterol metabolism (Taylor, Anderson, Keys 1957; Montoye et al. 1959).

Starting in the late 1950s and continuing through the 1970s, a rapidly increasing number of published studies evaluated or compared different components of endurance-oriented exercise training regimens. For example, Reindell, Roskamm, and Gerschler (1962) in Germany, Christensen (1960) in Denmark, and Yakovlev and colleagues (1961) in Russia compared—and disagreed—about the relative benefits of interval versus continuous exercise training in increasing cardiac stroke volume and endurance capacity. Other investigators began to evaluate the effects of different modes (Sloan and Keen 1959) and durations (Sinasalo and Juurtola 1957) of endurance-type training on physiologic and performance measures.

Karvonen and colleagues' (1957) landmark paper that introduced using "percent maximal heart rate reserve" to calculate or express exercise training intensity was one of the first studies designed to compare the effects of two different exercise intensities on cardiorespiratory responses during exercise. Over the next 20 years, numerous investigators documented the effects of different exercise training regimens on a variety of health-related outcomes among healthy men and women and among persons under medical care (Bouchard, Shephard, Stephens 1994). Many of these studies evaluated the effects of endurance or aerobic exercise training on cardiorespiratory capacity and were initially summarized by Pollock (1973). The American College of Sports Medicine (ACSM) (1975, 1978) and the American Heart Association (AHA) (1975) further refined the results of this research (see the section on "Evolution of Physical Activity Recommendations," later in this chapter).

Over the past two decades, experts from numerous disciplines have determined that exercise training substantially enhances physical performance and have begun to establish the characteristics of the exercise required to produce specific health benefits (Bouchard, Shephard, Stephens 1994). Also, behavioral scientists have begun to evaluate what determines physical activity habits among different segments of the population and are developing strategies to increase physical activity among sedentary persons (Dishman 1988). The results of much of this research are cited in the other chapters of this report and were the focus of the various conferences, reports, and guidelines summarized later in this chapter.

As the literature of exercise science has matured and recommendations have evolved, certain widely agreed-on terms have emerged. Because a number of these occur throughout the rest of this chapter and report, they are presented and briefly defined in the following section.

## Terminology of Physical Activity, Physical Fitness, and Health

This section discusses four broad terms used frequently in this report: physical activity, exercise (or exercise training), physical fitness, and health. Also included is a glossary (Table 2-1) of more specific terms and concepts crucial to understanding the material presented in later parts of this chapter and report.

**Physical activity.** Physical activity is defined as bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above the basal level. Physical activity can be categorized in various ways, including type, intensity, and purpose.

Because muscle contraction has both mechanical and metabolic properties, it can be classified by either property. This situation has caused some confusion. Typically, mechanical classification stresses whether the muscle contraction produces movement of the limb: isometric (same length) or static exercise if there is no movement of the limb, or isotonic (same tension) or dynamic exercise if there is movement of the limb. Metabolic classification involves the availability of oxygen for the contraction process and includes aerobic (oxygen available) or anaerobic (oxygen unavailable) processes. Whether an activity is aerobic or anaerobic depends primarily on its intensity. Most activities involve both static and dynamic contractions and aerobic and anaerobic metabolism. Thus, activities tend to be classified according to their dominant features.

The physical activity of a person or group is frequently categorized by the context in which it occurs. Common categories include occupational, household, leisure time, or transportation. Leisure-time activity can be further subdivided into categories such as competitive sports, recreational activities (e.g., hiking, cycling), and exercise training.

**Exercise (or exercise training).** Exercise and physical activity have been used synonymously in the past, but more recently, exercise has been used to denote a subcategory of physical activity: "physical activity that is planned, structured, repetitive, and purposive in the sense that improvement or maintenance of one or more components of physical fitness is the objective" (Caspersen, Powell, Christensen 1985). Exercise training also has denoted physical activity performed for the sole purpose of enhancing physical fitness.

**Physical fitness.** Physical fitness has been defined in many ways (Park 1989). A generally accepted approach is to define physical fitness as the ability to carry out daily tasks with vigor and alertness, without undue fatigue, and with ample energy to enjoy leisure-time pursuits and to meet unforeseen emergencies. Physical fitness thus includes cardiorespiratory endurance, skeletal muscular endurance, skeletal muscular strength, skeletal muscular power, speed, flexibility, agility, balance, reaction time, and body composition. Because these attributes differ in their importance to athletic performance versus health, a distinction has been made between performance-related fitness and health-related fitness (Pate 1983; Caspersen, Powell, Christensen 1985). Health-related fitness has been

**Table 2-1. Glossary of terms**

**Aerobic training**—Training that improves the efficiency of the aerobic energy-producing systems and that can improve cardiorespiratory endurance.*

**Agility**—A skill-related component of physical fitness that relates to the ability to rapidly change the position of the entire body in space with speed and accuracy.†

**Anaerobic training**—Training that improves the efficiency of the anaerobic energy-producing systems and that can increase muscular strength and tolerance for acid-base imbalances during high-intensity effort.*

**Balance**—A skill-related component of physical fitness that relates to the maintenance of equilibrium while stationary or moving.†

**Body composition**—A health-related component of physical fitness that relates to the relative amounts of muscle, fat, bone, and other vital parts of the body.†

**Calorimetry**—Methods used to calculate the rate and quantity of energy expenditure when the body is at rest and during exercise.*

**Direct calorimetry**—A method that gauges the body's rate and quantity of energy production by direct measurement of the body's heat production; the method uses a calorimeter, which is a chamber that measures the heat expended by the body.*

**Indirect calorimetry**—A method of estimating energy expenditure by measuring respiratory gases. Given that the amount of $O_2$ and $CO_2$ exchanged in the lungs normally equals that used and released by body tissues, caloric expenditure can be measured by $CO_2$ production and $O_2$ consumption.*

**Cardiorespiratory endurance (cardiorespiratory fitness)**—A health-related component of physical fitness that relates to the ability of the circulatory and respiratory systems to supply oxygen during sustained physical activity.†

**Coordination**—A skill-related component of physical fitness that relates to the ability to use the senses, such as sight and hearing, together with body parts in performing motor tasks smoothly and accurately.†

**Detraining**—Changes the body undergoes in response to a reduction or cessation of regular physical training.*

**Endurance training/endurance activities**—Repetitive, aerobic use of large muscles (e.g., walking, bicycling, swimming).‡

**Exercise** (exercise training)—Planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness.

**Flexibility**—A health-related component of physical fitness that relates to the range of motion available at a joint.*

**Kilocalorie (kcal)**—A measurement of energy. 1 kilocalorie = 1 Calorie = 4,184 joules = 4.184 kilojoules.

**Kilojoule (kjoule)**—A measurement of energy. 4.184 kilojoules = 4,184 joules = 1 Calorie = 1 kilocalorie.

**Maximal heart rate reserve**—The difference between maximum heart rate and resting heart rate.*

**Maximal oxygen uptake ($\dot{V}O_2$ max)**—The maximal capacity for oxygen consumption by the body during maximal exertion. It is also known as aerobic power, maximal oxygen consumption, and cardiorespiratory endurance capacity.*

**Maximal heart rate (HR max)**—The highest heart rate value attainable during an all-out effort to the point of exhaustion.*

**Metabolic equivalent (MET)**—A unit used to estimate the metabolic cost (oxygen consumption) of physical activity. One MET equals the resting metabolic rate of approximately 3.5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$.*

**Muscle fiber**—An individual muscle cell.*

**Muscular endurance**—The ability of the muscle to continue to perform without fatigue.*

**Overtraining**—The attempt to do more work than can be physically tolerated.*

**Physical activity**—Bodily movement that is produced by the contraction of skeletal muscle and that substantially increases energy expenditure.

**Physical fitness**—A set of attributes that people have or achieve that relates to the ability to perform physical activity.

**Power**—A skill-related component of physical fitness that relates to the rate at which one can perform work.

**Relative perceived exertion (RPE)**—A person's subjective assessment of how hard he or she is working. The Borg scale is a numerical scale for rating perceived exertion.*

**Reaction time**—A skill-related component of physical fitness that relates to the time elapsed between stimulation and the beginning of the reaction to it.†

**Resistance training**—Training designed to increase strength, power, and muscle endurance.*

**Resting heart rate**—The heart rate at rest, averaging 60 to 80 beats per minute.*

**Retraining**—Recovery of conditioning after a period of inactivity.*

**Speed**—A skill-related component of physical fitness that relates to the ability to perform a movement within a short period of time.†

**Strength**—The ability of the muscle to exert force.*

**Training heart rate (THR)**—A heart rate goal established by using the heart rate equivalent to a selected training level (percentage of $\dot{V}O_2$ max). For example, if a training level of 75 percent $\dot{V}O_2$ max is desired, the $\dot{V}O_2$ at 75 percent is determined and the heart rate corresponding to this $VO_2$ is selected as the THR.*

*From Wilmore JH, Costill DL. *Physiology of sport and exercise*. Champaign, IL: Human Kinetics, 1994.
† From Corbin CB, Lindsey R. *Concepts in physical education with laboratories*. 8th ed. Dubuque, IA: Times Mirror Higher Education Group, 1994.
‡Adapted from Corbin CB, Lindsey R, 1994, and Wilmore JH, Costill DL, 1994.

said to include cardiorespiratory fitness, muscular strength and endurance, body composition, and flexibility. The relative importance of any one attribute depends on the particular performance or health goal.

**Health.** The 1988 International Consensus Conference on Physical Activity, Physical Fitness, and Health (Bouchard et al. 1990) defined health as "a human condition with physical, social, and psychological dimensions, each characterized on a continuum with positive and negative poles. Positive health is associated with a capacity to enjoy life and to withstand challenges; it is not merely the absence of disease. Negative health is associated with morbidity and, in the extreme, with premature mortality." Thus, when considering the role of physical activity in promoting health, one must acknowledge the importance of psychological well-being, as well as physical health.

## Evolution of Physical Activity Recommendations

In the middle of the 20th century, recommendations for physical activity to achieve fitness and health benefits were based on systematic comparisons of effects from different profiles of exercise training (Cureton 1947; Karvonen, Kentala, Mustala 1957; Christensen 1960; Yakolav et al. 1961; Reindell, Roskamm, Gerschler 1962). In the 1960s and 1970s, expert panels and committees, operating under the auspices of health- or fitness-oriented organizations, began to recommend specific physical activity programs or exercise prescriptions for improving physical performance capacity or health (President's Council on Physical Fitness 1965; AHA 1972, 1975; ACSM 1975). These recommendations were based on substantial clinical experience and on scientific data available at that time.

Pollock's 1973 review of what type of exercise was needed to improve aerobic power and body composition subsequently formed the basis for a 1978 position statement by the ACSM titled "The Recommended Quantity and Quality of Exercise for Developing and Maintaining Fitness in Healthy Adults." This statement outlined the exercise that healthy adults would need to develop and maintain cardiorespiratory fitness and healthy body composition. These guidelines recommended a frequency of exercise training of 3–5 days per week, an intensity of training of 60–90 percent of maximal heart rate (equivalent to 50–85 percent of maximal oxygen uptake or heart rate reserve), a duration of 15–60 minutes per training session, and the rhythmical and aerobic use of large muscle groups through such activities as running or jogging, walking or hiking, swimming, skating, bicycling, rowing, cross-country skiing, rope skipping, and various endurance games or sports (Table 2-2).

Between 1978 and 1990, most exercise recommendations made to the general public were based on this 1978 position statement, even though it addressed only cardiorespiratory fitness and body composition. By providing clear recommendations, these guidelines proved invaluable for promoting cardiorespiratory endurance, although many people overinterpreted them as guidelines for promoting overall health. Over time, interest developed in potential health benefits of more moderate forms of physical activity, and attention began to shift to alternative physical activity regimens (Haskell 1984; Blair, Kohl, Gordon 1992; Blair 1993).

In 1990, the ACSM updated its 1978 position statement by adding the development of muscular strength and endurance as a major objective (ACSM 1990). The recommended frequency, intensity, and mode of exercise remained similar, but the duration was slightly increased from 15–60 minutes to 20–60 minutes per session, and moderate-intensity resistance training (one set of 8–12 repetitions of 8–10 different exercises at least 2 times per week) was suggested to develop and maintain muscular strength and endurance (Table 2-2). These 1990 recommendations also recognized that activities of moderate intensity may have health benefits independent of cardiorespiratory fitness:

> *Since the original position statement was published in 1978, an important distinction has been made between physical activity as it relates to health versus fitness. It has been pointed out that the quantity and quality of exercise needed to obtain health-related benefits may differ from what is recommended for fitness benefits. It is now clear that lower levels of physical activity than recommended by this position statement may reduce the risk for certain chronic degenerative diseases*

*and yet may not be of sufficient quantity or quality to improve [maximal oxygen uptake]. ACSM recognizes the potential health benefits of regular exercise performed more frequently and for longer duration, but at lower intensities than prescribed in this position statement.*

In conjunction with a program to certify exercise professionals at various levels of experience and competence, the ACSM has published five editions of *Guidelines for Exercise Testing and Prescription* (ACSM 1975, 1980, 1986, 1991, 1995b) that describe the components of the exercise prescription and explain how to initiate and complete a proper exercise training program (Table 2-2). The ACSM has also published recommendations on the role of exercise for preventing and managing hypertension (1993) and for patients with coronary heart disease (1994) and has published a position stand on osteoporosis (1995a). For the most part, newer recommendations that focus on specific health outcomes are consistent with the ACSM's 1978 and 1990 position statements, but they generally expand the range of recommended activities to include moderate-intensity exercise.

Between the 1960s and 1990s, other U.S. health and fitness organizations published recommendations for physical activity. Because these organizations used the same scientific data as the ACSM, their position statements and guidelines are similar. A notable example is *Healthy People 2000* (USDHHS 1990), the landmark publication of the U.S. Public Health Service that lists various health objectives for the nation. (The objectives for physical activity and fitness, as revised in 1995 [USDHHS 1995], are included as Appendix A of this chapter.) Other recommendations include specific exercise programs developed for men and women by the President's Council on Physical Fitness (1965) and the YMCA (National Council YMCA 1989). The AHA (1972, 1975, 1992, 1993, 1994, 1995) has published for both health professionals and the public a series of physical activity recommendations and position statements directed at CHD prevention and cardiac rehabilitation. In 1992, the AHA published a statement identifying physical inactivity as a fourth major risk factor for CHD, along with smoking, high blood pressure, and high blood cholesterol (Fletcher et al. 1992). The American Association of Cardiovascular and Pulmonary Rehabilitation has also published guidelines for using physical activity for cardiac (1991, 1995) and pulmonary (1993) rehabilitation. Some of these recommendations provide substantial advice to ensure that exercise programs are safe for people at increased risk for heart disease or for patients with established disease.

Between the 1970s and the mid-1990s, exercise training studies conducted on middle-aged and older persons and on patients with lower functional capacity demonstrated that significant cardiorespiratory performance and health-related benefits can be obtained at more moderate levels of activity intensity than previously realized. In addition, population-based epidemiologic studies demonstrated dose-response gradients between physical activity and health outcomes. As a result of these findings, the most recent CDC-ACSM guidelines recommend that all adults perform 30 or more minutes of moderate-intensity physical activity on most, and preferably all, days—either in a single session or "accumulated" in multiple bouts, each lasting at least 8–10 minutes (Pate et al. 1995). This guideline thus significantly differs from the earlier ones on three points: it reduces the minimum starting exercise intensity from 60 percent of maximal oxygen uptake to 50 percent in healthy adults and to 40 percent in patients or persons with very low fitness; it increases the frequency of exercise sessions from 3 days per week to 5–7 days per week, depending on intensity and session duration; and it includes the option of accumulating the minimum of 30 minutes per day in multiple sessions lasting at least 8–10 minutes (Pate et al. 1995). This modification in advice acknowledges that people who are sedentary and who do not enjoy, or are otherwise not able to maintain, a regimen of regular, vigorous activity can still derive substantial benefit from more moderate physical activity as long as it is done regularly.

The NIH Consensus Development Conference Statement on Physical Activity and Cardiovascular Health identifies physical inactivity as a major public health problem in the United States and issues a call to action to increase physical activity levels among persons in all population groups. (See Appendix B for full text of the recommendations.) The core recommendations, similar to those jointly made by the CDC and the ACSM (Pate et al. 1995), call for

**Table 2-2. Selected physical activity recommendations in the United States (1965–1996)**

| Source | Objective | Type/mode |
|---|---|---|
| PCPF (1965) | Physical fitness | General fitness |
| AHA Recommendations (1972) | CHD prevention | Endurance |
| YMCA (1973) | General health and fitness | Endurance, strength, flexibility |
| ACSM Guidelines (1975) | Cardiorespiratory fitness | Endurance, strength, flexibility |
| AHA Recommendations (1975) | Secondary prevention in patients with heart disease | Endurance |
| ACSM Position Statement (1978) | Cardiorespiratory fitness and body composition | Endurance |
| USDHEW–Healthy People (1979) | Disease prevention/ health promotion | Endurance |
| ACSM Guidelines (1980) | Cardiorespiratory fitness | Endurance, strength, flexibility |
| ACSM Guidelines (1986) | Cardiorespiratory fitness | Endurance, strength, flexibility |
| USDHHS–Surgeon General's Report on Nutrition and Health (1988) | Weight control | Endurance |
| USPSTF (1989) | Primary prevention in clinical practice | Not specified, implied endurance |
| ACSM Position Stand (1990) | Cardiorespiratory and muscular fitness | Endurance, strength |
| ACSM Guidelines (1991) | Cardiorespiratory fitness | Endurance, strength, flexibility |
| USHHS/USDA Dietary Guidelines (1990) | Health promotion/disease prevention, weight maintenance | Not specified |
| AACVPR (1991) | Cardiac rehabilitation | Endurance, strength |
| DHHS-Healthy People 2000 (1991)* | Disease prevention/health promotion | Endurance, strength, flexibility |
| AHA Position Statement (1992) | CVD prevention and rehabilitation | Endurance |
| AHA Standards (1992 and 1995) | CHD prevention and rehabilitation | Endurance, strength |
| AACVPR (1993) | Pulmonary rehabilitation | Endurance |
| ACSM Position Statement (1993) | Prevention and treatment of hypertension | Endurance, strength |

| Endurance | | | Resistance training |
|---|---|---|---|
| Intensity | Frequency | Duration | |
| Five levels | 5 x week | Approximately 30 minutes | Selected calisthenics |
| 70–85% MHR | 3–7 x week | 15–20 minutes | Not addressed |
| 80% $\dot{V}O_2$ max | 3 x week | 40–45 minutes | Not specified |
| 60–90% $\dot{V}O_2$ max<br>60–90% HRR | 3 x week | 20–30 minutes | Not specified |
| 70–85% MHR | 3–4 x week | 20–60 minutes | Not addressed |
| 50–85% $\dot{V}O_2$ max<br>50–85% HRR<br>60–90% MHR | 3–5 x week | 15–60 minutes | Not addressed |
| Moderate/hard | 3 x week | 15–30 minutes | Not addressed |
| 50–85% $\dot{V}O_2$ max/HRR<br>60–90% MHR | 3–5 x week | 15–60 minutes | Not specified |
| 50–85% $\dot{V}O_2$ max/HRR<br>60–90% MHR | 3–5 x week | 15–60 minutes | Not specified |
| Not specified | ≥ 3 x week | ≥ 20 minutes | Not addressed |
| At least moderate | Not specified | Not specified | Not addressed |
| 50–85% $\dot{V}O_2$ max<br>50–85% HRR<br>60–90% MHR | 3–5 x week | 20–60 minutes | 1 set, 8–12 repetitions<br>8–10 exercises<br>2 days x week |
| 40–85% $\dot{V}O_2$ max<br>55–90% MHR<br>RPE = 12–16 | 3–5 x week | 15–60 minutes | Not specified |
| Not specified | Not specified | Not specified | Not addressed |
| Exercise following ACSM (1986) and AHA (1983) recommendations | 3–5 x week | 15–60 minutes | 1–3 sets, 12–15 repetitions<br>major muscle groups<br>2–3 days x week |
| Light/moderate/vigorous | 3–5 x week | 20–30 minutes | Not specified |
| > 50% $\dot{V}O_2$ max | 3–4 x week | 30–60 minutes | Not addressed |
| 50–60% $\dot{V}O_2$ max<br>50–60% HR reserve | ≥ 3 x week | ≥ 30 minutes | 1 set, 10–15 repetitions<br>8–10 exercises,<br>2–3 days x week |
| 60% HR reserve | 3 x week | 20–30 minutes | Not addressed |
| 40–70% $\dot{V}O_2$ max | 3–5 x week | 20–60 minutes | Not specified |

**Table 2-2.** *Continued*

| Source | Objective | Type/mode |
|---|---|---|
| AHA Position Statement (1993) | CVD prevention and rehabilitation | Moderate intensity (i.e., brisk walking) integrated into daily routine |
| ACSM Position Stand (1994) | Secondary prevention in patients with coronary heart disease | Endurance, strength |
| AHA Position Statement (1994) | Cardiac rehabilitation | Endurance and strength training of moderate intensity following other guidelines |
| Physical Activity Guidelines for Adolescents (1994)† | Lifetime health promotion for adolescents | Endurance |
| AACVPR (1995) | Cardiac rehabilitation | Endurance, strength |
| ACSM Guidelines (1995) | Cardiorespiratory fitness and muscular fitness | Endurance, strength |
| ACSM Position Stand (1995) | Prevention of osteoporosis | Strength, flexibility, coordination, cardiorespiratory fitness |
| AHCPR (1995) | Cardiac rehabilitation | Endurance, strength |
| AMA Guidelines for Adolescent Preventive Services (GAPS) (1994) | Health promotion/ physical fitness | Endurance |
| CDC/ACSM (1995)‡ | Health promotion | Endurance |
| USHHS/USDA Dietary Guidelines (1995) | Health promotion/disease prevention, weight maintenance | Endurance |
| NHLBI Consensus Conference (1996) | CVD prevention for adults and children and cardiac rehabilitation | Endurance |
| USPSTF (1996) | Primary prevention in clinical practice | Endurance, strength, flexibility |

| Endurance | | | Resistance training |
|---|---|---|---|
| **Intensity** | **Frequency** | **Duration** | |
| Not specified | Not specified | Not specified | Not addressed |
| 40–85% $\dot{V}O_2$ max<br>40–85% HRR<br>55–90% MHR | 3 x week,<br>nonconsecutive days | 20–40 minutes | Not specified |
| Not specified | Not specified | Not specified | Not specified |
| Moderate/vigorous | 3 x week, vigorous<br>daily, moderate | ≥ 20 minutes, vigorous<br>not specified, moderate | Not addressed |
| > 50% $\dot{V}O_2$ max<br>RPE 12–14 | 3–5 x week | 30–45 minutes, 200–300 kcal per session or 1,000–1,500 kcal per week | 1 set, 10–15 repetitions, major muscle groups<br>2–3 days x week |
| 40–85% $\dot{V}O_2$ max/HRR<br>RPE 12–16 | 3-5 x week | 12–15 minutes initially:<br>20–30 minutes for conditioning and maintaining | 1 set, 8–12 repetitions<br>8–10 exercises<br>2 days x week |
| Not specified | Not specified | Not specified | Not specified |
| 70–85% MHR | 3 x week | 20–40 minutes | Not specified |
| Moderate | ≥ 3 x week | 20–30 minutes | Not addressed |
| Moderate/hard | All or most days | ≥ 30 minutes per day<br>in bouts of at least 8–10 minutes | Not specified |
| Moderate | All or most days | ≥ 30 minutes per day | Not addressed |
| Moderate/hard | All or most days | ≥ 30 minutes per day | Not addressed |
| Moderate | Most days | 30 minutes | Not specified |

*See Appendix B for listing of objectives. †See Sallis and Patrick, 1994. ‡See Pate et al., 1995.

Key to associations: AACVPR = American Association for Cardiovascular and Pulmonary Rehabilitation; ACSM = American College of Sports Medicine; AHA = American Heart Association; AHCPR = Agency for Health Care Policy and Research; CDC = Centers for Disease Control and Prevention; NHLBI = National Heart, Lung, and Blood Institute; PCPF = President's Council on Physical Fitness; USDA = United States Department of Agriculture; USDHEW = United States Department of Health, Education, and Welfare; USDHHS = United States Department of Health and Human Services; USPSTF = United States Preventive Services Task Force; YMCA = Young Men's Christian Association.

Key to abbreviations: CHD = coronary heart disease; CVD = cardiovascular disease; HRR = heart rate reserve; MHR = maximal heart rate; RPE = rating of perceived exertion; $\dot{V}O_2$ max = maximal oxygen uptake.

Not addressed = not included in recommendations. Not specified = recommended but not quantified.

all children and adults to accumulate at least 30 minutes per day of moderate-intensity physical activity. The recommendations also acknowledge that persons already achieving this minimum could experience greater benefits by increasing either the duration or the intensity of activity. In addition, the statement recommends more widespread use of cardiac rehabilitation programs that include physical activity.

The consensus statement from the 1993 International Consensus Conference on Physical Activity Guidelines for Adolescents (Sallis and Patrick 1994) emphasizes that adolescents should be physically active every day as part of general lifestyle activities and that they should engage in 3 or more 20-minute sessions of moderate to vigorous exercise each week. The American Academy of Pediatrics has issued several statements encouraging active play in preschool children, assessment of children's activity levels, and evaluation of physical fitness (1992, 1994). Both the consensus statement and the American Academy of Pediatrics' statements emphasize active play, parental involvement, and generally active lifestyles rather than specific vigorous exercise training. They also acknowledge the need for appropriate school physical education curricula.

Recognizing the important interrelationship of nutrition and physical activity in achieving a balance between energy consumed and energy expended, the 1988 Surgeon General's Report on Nutrition and Health (USDHHS 1988) recommended physical activities such as walking, jogging, and bicycling for at least 20 minutes, 3 times per week. The 1995 *Dietary Guidelines for Americans* greatly expanded physical activity guidance to maintain and improve weight. The bulletin recommends that all Americans engage in 30 minutes of moderate-intensity physical activity on all, or most, days of the week (USDA/USDHHS 1995).

The U.S. Preventive Services Task Force (USPSTF) has recommended that health care providers counsel all patients on the importance of incorporating physical activities into their daily routines to prevent coronary heart disease, hypertension, obesity, and diabetes (Harris et al. 1989; USPSTF 1989, 1996). Similarly, the American Medical Association's *Guidelines for Adolescent Preventive Services (GAPS)* (AMA 1994) recommends that physicians provide annual physical activity counseling to all adolescents.

## Summary of Recent Physical Activity Recommendations

Sedentary persons can increase their physical activity in many ways. The traditional, structured approach originally described by the ACSM and others involved rather specific recommendations regarding type, frequency, intensity, and duration of activity. Recommended activities typically included fast walking, running, cycling, swimming, or aerobics classes. More recently, physical activity recommendations have adopted a lifestyle approach to increasing activity (Pate et al. 1995). This method involves common activities, such as brisk walking, climbing stairs (rather than taking the elevator), doing more house and yard work, and engaging in active recreational pursuits. Recent physical activity recommendations thus acknowledge both the structured and lifestyle approaches to increasing physical activity. Either approach can be beneficial for a sedentary person, and individual interests and opportunities should determine which is used. The most recent recommendations cited agree on several points:

- All people over the age of 2 years should accumulate at least 30 minutes of endurance-type physical activity, of at least moderate intensity, on most—preferably all—days of the week.
- Additional health and functional benefits of physical activity can be achieved by adding more time in moderate-intensity activity, or by substituting more vigorous activity.
- Persons with symptomatic CVD, diabetes, or other chronic health problems who would like to increase their physical activity should be evaluated by a physician and provided an exercise program appropriate for their clinical status.

- Previously inactive men over age 40, women over age 50, and people at high risk for CVD should first consult a physician before embarking on a program of vigorous physical activity to which they are unaccustomed.
- Strength-developing activities (resistance training) should be performed at least twice per week. At least 8–10 strength-developing exercises that use the major muscle groups of the legs, trunk, arms, and shoulders should be performed at each session, with one or two sets of 8–12 repetitions of each exercise.

## Measurement of Physical Activity, Fitness, and Intensity

The ability to relate physical activity to health depends on accurate, precise, and reproducible measures (Wilson et al. 1986; National Center for Health Statistics 1989). Measurement techniques have evolved considerably over the years (Park 1989), creating a shifting pattern of strength and weakness in the evidence supporting the assertion that physical activity improves health (Ainsworth et al. 1994). The complexity is heightened by the different health implications of measuring activity, gauging intensity, and assessing fitness. The tools currently in use (Table 2-3) must be evaluated not only for their efficacy in measuring an individual's status, but also for their applicability as instruments in larger-scale epidemiologic research. These tools vary considerably in the age groups to which they can be applied, as well as in their cost, in their likelihood of affecting the behavior they try to measure, and in their acceptability. For example, many of the tools that are appropriate for young and middle-aged persons are less so for the elderly and may have no relevance at all for children. A brief review of these approaches provides some insight into the current constellation of strengths and weaknesses on which epidemiologic conclusions rest.

### Measuring Physical Activity

#### *Measures Based on Self-Report*

Physical activity is a complex set of behaviors most commonly assessed in epidemiologic studies by asking people to classify their level of physical activity (LaPorte, Montoye, Caspersen 1985; Caspersen 1989). Techniques used to gather this self-reported information include diaries, logs, recall surveys, retrospective quantitative histories, and global self-reports (Kannel, Wilson, Blair 1985; Wilson et al. 1986; Powell et al. 1987; Caspersen 1989). Surveys are practical for assessing physical activity in large populations because they are not costly, are relatively easy to administer, and are generally acceptable to study participants (Montoye and Taylor 1984; LaPorte, Montoye, Caspersen 1985; Caspersen 1989). Information obtained from self-report instruments has often been converted into estimates of energy expenditure (i.e., kilocalories or kilojoules; metabolic equivalents [METs]) or some other summary measure that can be used to categorize or rank persons by their physical activity level. This technique has also been used to convert job classifications into summary measures.

*Diaries* can detail virtually all physical activity performed during a specified (usually short) period. A summary index can be derived from a diary by 1) summing the total duration of time spent in a given activity multiplied by an estimated rate of energy expenditure for that activity, or 2) listing accumulated time across all activities or time accrued within specific classes of activities. Comparisons with indirect calorimetry or with caloric intake have shown that diaries are accurate indices of daily energy expenditure (Acheson et al. 1980). Because diaries are commonly limited to spans of 1–3 days, they may not represent long-term physical activity patterns (LaPorte, Montoye, Caspersen 1985). Diaries require intensive effort by the participant, and their use may itself produce changes in the physical activities the participant does during the monitoring period (LaPorte, Montoye, Caspersen 1985; Caspersen 1989).

*Logs* are similar to diaries but provide a record of participation in specific types of physical activity rather than in all activites (King et al. 1991). The time that activity was started and stopped may be recorded, either soon after participation or at the end of the day. Logs can be useful for recording participation in an exercise training program. But as with diaries, they can be inconvenient for the participant, and their use may itself influence the participant's behavior.

**Table 2-3. Assessment procedures and their potential use in epidemiologic research**

| Measurement tool | Applicable age groups | Use in large scale studies | Low $ cost | Low time cost | Low subject time cost | Low subject effort cost | Likely to influence behavior | Accep-table to persons | Socially accep-table | Activity specific |
|---|---|---|---|---|---|---|---|---|---|---|
| **Surveying** | | | | | | | | | | |
| Task specific diary | adult, elderly | yes | yes | yes | no | no | yes | ? | yes | yes |
| Recall questionnaire | adult, elderly | yes | yes | yes | yes | yes | no | yes | yes | yes |
| Quantitative history | adult, elderly | yes | yes | no | no | no | no | yes | yes | yes |
| Global self-report | adult, elderly | yes | yes | yes | yes | yes | no | yes | yes | no |
| **Monitoring** | | | | | | | | | | |
| Behavioral observation | adult, elderly | no | no | no | no | yes | yes | ? | ? | yes |
| Job classification | adult | yes | yes | yes | yes | yes | no | yes | yes | yes |
| Heart rate monitor | all | no | no | no | yes | yes | no | yes | yes | no |
| Heart rate and motion sensor | all | no | no | no | yes | yes | no | yes | yes | no |
| Electronic motion sensor | adult, elderly | yes | no | yes | yes | yes | no | yes | yes | no |
| Pedometer | adult, elderly | yes | yes | yes | yes | yes | no | yes | yes | no |
| Gait assessment | child, adult, elderly | no | no | yes | yes | yes | no | yes | yes | no |
| Accelerometers | all | yes | yes | yes | yes | yes | no | yes | yes | no |
| Horizontal time monitor | child, adult, elderly | no | no | yes | yes | yes | no | yes | yes | no |
| Stabilometers | infant | no | no | yes | yes | yes | no | yes | yes | no |
| Direct calorimetry | all | no | no | no | no | no | yes | no | no | yes |
| Indirect calorimetry | adult, elderly | no | no | no | no | no | yes | no | no | yes |
| Doubly labeled water | child, adult, elderly | yes | no | no | yes | yes | no | yes | yes | no |

Modified from LaPorte, Montoye, Caspersen. *Public Health Reports*, 1985.

Note that most tests that are applicable for adults can be used in adolescents as well. Few tests can be applied to the pediatric age groups; among infants, only direct calorimetry, accelerometers, heart rate monitoring, and stabilometers can be used with accuracy.

*Recall surveys* are less likely to influence behavior and generally require less effort by the respondent than either diaries or logs, although some participants have trouble remembering details of past participation in physical activity (Baranowski 1985). Recall surveys of physical activity generally have been used for time frames of from 1 week to a lifetime (Kriska et al. 1988; Blair et al. 1991). They can ascertain either precise details about physical activity or more general estimates of usual or typical participation. The recall survey is the method used for the national and state-based information systems providing data for Chapter 5 of this report.

The *retrospective quantitative history*—the most comprehensive form of physical activity recall survey —generally requires specific detail for time frames of up to 1 year (LaPorte, Montoye, Caspersen 1985). If the time frame is long enough, the quantitative history can adequately represent year-round physical activity. For example, the Minnesota Leisure-Time Physical Activity Questionnaire and the Tecumseh questionnaire obtained information on the average frequency and duration of participation for a specific list of physical activities performed over the previous year (Montoye and Taylor 1984; Taylor et al. 1978). Unfortunately, obtaining this abundance of data is a heavy demand on the respondent's memory, and the complexity of the survey generates additional expense (LaPorte, Montoye, Caspersen 1985).

*Global self-reports*, another type of recall survey, ask individuals to rate their physical activity relative to other people's in general or to that of a similar age and sex group. This easy-to-use approach, which was employed for the National Health Interview Survey (NCHS, Bloom 1982), tends to best represent participation in vigorous physical activity (Washburn, Adams, Haile 1987; Caspersen and Pollard 1988; Jacobs et al. 1993). A weakness of this approach is that persons reporting the same rating may have different actual physical activity profiles (Washburn, Adams, Haile 1987; Caspersen and Pollard 1988).

Although survey approaches generally apply to adults, adolescents, and the elderly, survey instruments must often be tailored to the specific demographic requirements of the group under study. Recently, some researchers have suggested developing special survey instruments for older persons (Voorrips et al. 1991; Dipietro et al. 1993; Washburn et al. 1993) and adolescents or children (Noland et al. 1990; Sallis et al. 1993).

### Measures Based on Direct Monitoring

The major alternative to surveys is to directly measure physical activity through behavioral observation, mechanical or electronic devices, or physiologic measurements (Table 2-3). Such approaches eliminate the problems of poor memory and biased self-reporting but are themselves limited by high cost and the burden on participants and staff. Consequently, these measures have been used primarily in small-scale studies, though they have been used recently in some large-scale studies (Lakka, Nyyssonen, Salonen 1994).

Behavioral observation is the straightforward process of watching and recording what a person does. Using general guidelines for caloric expenditure associated with specific activities, a summary estimate of caloric output can be obtained from such observation. An important subtype of this approach is the classification of work based on the amount of physical activity it requires. These approaches can be labor-intensive (hence prohibitively expensive for large-scale studies) but are usually well accepted by study participants.

In the category of mechanical or electronic measurement, various instruments have been used to monitor heart rate and thus provide a continuous recording of a physiologic process that reflects both the duration and intensity of physical activity. Heart rate is typically used to estimate daily energy expenditure (i.e., oxygen uptake) on physical activity; the underlying assumption is that a linear relationship exists between heart rate and oxygen uptake. A major disadvantage of heart rate monitoring is the need to calibrate the heart rate–energy expenditure curve for each individual. Another limitation is that the relationship between heart rate and energy expenditure is variable for low-intensity physical activities. Most monitors have to be worn for extended periods by the participant, and they pose some discomfort and inconvenience.

Other approaches for using heart rate to measure physical activity include using the percentage of time spent during daily activities in various ranges of heart rate (Gilliam et al. 1981), using the difference between mean daily heart rate and resting heart rate (Sallis et al. 1990), and using the integration of the area under a heart rate versus time curve adjusted for resting heart rate (Freedson 1989). Heart rate alone may not be a suitable surrogate for determining the level of physical activity, given that other factors, such as psychological stress or changes in body temperature, can significantly influence heart rate throughout the day.

A variety of sensors have been developed to measure physical activity by detecting motion. Pedometers, perhaps the earliest motion sensors, were designed to count steps and thus measure the distance walked or run. However, not all pedometers are reliable enough for estimating physical activity in either laboratory or field research (Kashiwazaki et al. 1986; Washburn, Janney, Fenster 1990). Electronic motion sensors tend to perform better than their mechanical counterparts (Wong et al. 1981; Taylor et al. 1982; LaPorte et al. 1983). Their output has been significantly correlated with energy expenditure assessed with indirect calorimetry in controlled laboratory conditions using graded treadmill exercise (Balogun, Amusa, Onyewadume 1988; Haskell et al. 1993; Montoye et al. 1996), under short-term controlled activity (e.g., walking or cycling over a measured course) for heart rate during laboratory and daily activities, and for observed behavior in a controlled setting (Klesges and Klesges 1987; Rogers et al. 1987; Freedson 1989; Sallis et al. 1990; Washburn, Janney, Fenster 1990). Direct validation has shown reasonable correlation with physical activity records completed over a year (Richardson et al. 1995). Recording simultaneously both the heart rate and the motion from sensors on several parts of the body and then calibrating each individual's heart rate and motion sensor output versus oxygen uptake for various activities can accurately estimate the energy expended from physical activity (Haskell et al. 1993). Several other devices (e.g., accelerometers, stabilometers) are of lesser value for large-scale studies, and their use is limited to small physiologic investigations.

Methods for physiologically monitoring energy expenditure include direct calorimetry (requiring the participant to remain in a metabolic chamber) and indirect calorimetry (requiring the participant to wear a mask and to carry equipment for analyzing expired air). Both methods are too expensive and complicated for use in large-scale studies. Another physiologic measurement, the use of doubly labeled water, offers researchers special opportunities to assess energy expenditure. By using two stable isotopes ($^{2}H_2O$ and $H_2{}^{18}O$) measured every few days or weeks in the urine, researchers can calculate the rate of carbon dioxide production—a reflection of the rate of energy production in humans over time. According to their body weight, study participants drink a specified amount of these isotopes. A mass spectrometer is used to track the amount of unmetabolized isotope in the urine. Although this technique obtains objective data with little effort on the part of participants, two disadvantages are its relatively high cost and its inability to distinguish between types of activities performed. The technique has been proven accurate when compared with indirect calorimetry (Klein et al. 1984; Westerterp et al. 1988; Edwards et al. 1990).

### *Measuring Intensity of Physical Activity*

Common terms used to characterize the intensity of physical activity include light or low, moderate or mild, hard or vigorous, and very hard or strenuous (Table 2-4). A frequent approach to classifying intensity has been to express it relatively—that is, in relation to a person's capacity for a specific type of activity. For example, the intensity prescribed for aerobic exercise training usually is expressed in relation to the person's measured cardiorespiratory fitness (ACSM 1990). Because heart rate during aerobic exercise is highly associated with the increase in oxygen uptake, the percentage of maximal heart rate is often used as a surrogate for estimating the percentage of maximal oxygen uptake (ACSM 1990). Exercise intensity can also be expressed in absolute terms, such as a specific type of activity with an assigned intensity (for example, walking at 4 miles per hour or jogging at 6 miles per hour). Such quanta of work can also be described in absolute terms as METs, where one MET is about 3.5 ml $O_2 \bullet kg^{-1} \bullet min^{-1}$, corresponding to the body at rest. The workloads in the just-quoted example are equivalent to 4 and 10 METs, respectively. The number of METs associated with a wide range of specific activities can be estimated from aggregated laboratory and field measurements (Ainsworth, Montoye, Leon 1994).

The process of aging illustrates an important relationship between absolute and specific measures. As people age, their maximal oxygen uptake decreases. Activity of a given MET value (an absolute intensity) therefore requires a greater percentage of their maximal oxygen uptake (a relative intensity). The aforementioned walk at 4 miles per hour (4 METs) may be light exercise for a 20-year-old, moderate for a 60-year-old, and vigorous for an 80-year-old.

Most exercise training studies have used relative intensity to evaluate specific exercise training regimens. On the other hand, observational studies relating physical activity to morbidity or mortality usually report absolute intensity or total amount of physical activity estimated from composite measures that include intensity, frequency, and duration. It is thus difficult to compare the intensity of activity that improves physiologic markers with the intensity of activity that may reduce morbidity and mortality.

**Table 2-4. Classification of physical activity intensity, based on physical activity lasting up to 60 minutes**

| | Endurance-type activity | | | | | | | | Strength-type exercise |
|---|---|---|---|---|---|---|---|---|---|
| | Relative intensity | | | Absolute intensity (METs) in healthy adults (age in years) | | | | | Relative intensity* |
| Intensity | $\dot{V}O_2$ max (%) heart rate reserve (%) | Maximal heart rate (%) | RPE† | Young (20–39) | Middle-aged (40–64) | Old (65–79) | Very old (80+) | RPE | Maximal voluntary contraction (%) |
| Very light | <25 | <30 | <9 | <3.0 | <2.5 | <2.0 | ≤1.25 | <10 | <30 |
| Light | 25–44 | 30–49 | 9–10 | 3.0–4.7 | 2.5–4.4 | 2.0–3.5 | 1.26–2.2 | 10–11 | 30–49 |
| Moderate | 45–59 | 50–69 | 11–12 | 4.8–7.1 | 4.5–5.9 | 3.6–4.7 | 2.3–2.95 | 12–13 | 50–69 |
| Hard | 60–84 | 70–89 | 13–16 | 7.2–10.1 | 6.0–8.4 | 4.8–6.7 | 3.0–4.25 | 14–16 | 70–84 |
| Very hard | ≥85 | ≥90 | >16 | ≥10.2 | ≥8.5 | ≥6.8 | ≥4.25 | 17–19 | >85 |
| Maximal‡ | 100 | 100 | 20 | 12.0 | 10.0 | 8.0 | 5.0 | 20 | 100 |

Table 2-4 provided courtesy of Haskell and Pollock.

*Based on 8–12 repetitions for persons under age 50 years and 10–15 repetitions for persons aged 50 years and older.

†Borg rating of Relative Perceived Exertion 6–20 scale (Borg 1982).

‡Maximal values are mean values achieved during maximal exercise by healthy adults. Absolute intensity (METs) values are approximate mean values for men. Mean values for women are approximately 1–2 METs lower than those for men.

Recent public health guidelines and research reports have used absolute intensity to define appropriate levels of physical activity, but the term “absolute” may convey a misplaced sense of precision. For example, the CDC-ACSM guidelines (Pate et al. 1995) use absolute intensity to classify brisk walking as moderate physical activity. In contrast, *Healthy People 2000* objective 1.3 defines brisk walking as “light to moderate” intensity and takes into account the age- and sex-related variability in maximal capacity (USDHHS 1990). One solution to this inconsistency in terminology is to create consistent categories that equate a variety of measures to the same adjective (Table 2-4). Using such a rubric, the observations of Spelman and colleagues (1993) that brisk walking for healthy adults aged 22–58 years demands 40–60 percent of their aerobic power suggests a correspondence with 3–5 METs and a classification of moderate intensity. Those prescribing an exercise pattern for adults can use the rating of perceived exertion (RPE) scale (ACSM 1991). An RPE of 10–11 corresponds to light intensity, 12–13 to moderate intensity, and 14–16 to hard intensity (Table 2-4), and the approximate physiologic equivalents can be estimated. This type of subjective scale furnishes a convenient way to monitor performance.

### *Measuring Physical Fitness*

Perhaps the most highly developed measurement area is the assessment of physical fitness, since it rests on physiologic measurements that have good to excellent accuracy and reliability. The major foci of fitness measurements are endurance (or cardiorespiratory fitness), muscular fitness, and body composition.

#### *Endurance*

Cardiorespiratory fitness, also referred to as cardiorespiratory capacity, aerobic power, or endurance fitness, is largely determined by habitual physical activity. However, other factors influence cardiorespiratory fitness, including age, sex, heredity, and medical status (Bouchard, Shepard, Stevens 1994).

The best criterion of cardiorespiratory fitness is maximal oxygen uptake or aerobic power ($\dot{V}O_2$ max). Measured in healthy persons during large muscle, dynamic activity (e.g., walking, running, or cycling), $\dot{V}O_2$ max is primarily limited by the oxygen transport capacity of the cardiovascular system (Mitchell and Blomqvist 1971). $\dot{V}O_2$ max is most accurately determined by measuring expired air composition and respiratory volume during maximal exertion. This procedure requires relatively expensive equipment, highly trained technicians, and time and cooperation from the participant, all of which usually limit its use in large epidemiologic studies (Montoye et al. 1970; King et al. 1991).

Because the individual variation in mechanical and metabolic efficiency is for activities that do not require much skill—such as walking or running on a motor-driven treadmill, cycling on a stationary bicycle ergometer, or climbing steps—oxygen uptake can be quite accurately estimated from the rate of work (Siconolfi et al. 1982). Thus, $\dot{V}O_2$ max can be estimated from the peak exercise workload during a maximal exercise test without measuring respiratory gases. Such procedures require an accurately calibrated exercise device, careful adherence to a specific protocol, and good cooperation by the participant. They have been used in numerous exercise training studies for evaluating the effects of exercise on cardiovascular risk factors and performance, in secondary prevention trials for patients after hospitalization for myocardial infarction, and in some large-scale observational studies (Blair et al. 1989; Sidney et al. 1992).

Any maximal test to assess cardiorespiratory fitness imposes a burden on both the participant and the examiner. To reduce this burden, several submaximal exercise testing protocols have been developed. With these protocols, the heart rate response to a specified workload is used to predict the $\dot{V}O_2$ max. The underlying assumption (besides the linear relationship between heart rate and oxygen uptake) is that the participant's maximal heart rate can be estimated accurately. Both assumptions are adequately met when a standardized protocol is used to test a large sample of healthy adults. In some cases, no extrapolation to maximal values is performed, and an individual's cardiorespiratory fitness is expressed as the heart rate at a set workload (e.g., heart rate at 5 kilometers/hour or at 100 watts) or at the workload required to reach a specific submaximal heart rate (workload at a heart rate of 120 beats/minute).

In another approach to assessing cardiorespiratory fitness, participants usually walk, jog, or run a specified time or distance, and their performance is converted to an estimate of $\dot{V}O_2$ max (Cooper 1968). These procedures have been frequently used to test the cardiorespiratory fitness of children, of young adults, or of groups that have occupation-related physical fitness requirements, such as military and emergency service personnel. In many cases, these tests require maximal or near-maximal effort by the participant and thus have not been used for older persons or those at increased risk for CVD. The advantage is that large numbers of participants can be tested rapidly at low cost. However, to obtain an accurate evaluation, participants must be willing to exert themselves and know how to set a proper pace.

### *Muscular Fitness*

Common measures of muscular fitness are muscular strength, muscular endurance, flexibility, and balance, agility, and coordination. Muscular strength can be measured during performance of either static or dynamic muscle contraction (NCHS, Wilmore 1989). Because muscular strength is specific to the muscle group, the testing of one group does not provide accurate information about the strength of other muscle groups (Clarke 1973). Thus, for a comprehensive assessment, strength testing must involve at least several major muscle groups, including the upper body, trunk, and lower body. Standard tests have included the bench press, leg extension, and biceps curl using free weights. The heaviest weight a person can lift only one time through the full range of motion for a particular muscle group is considered the person's maximum strength for that specific muscle group.

Muscular endurance is specific to each muscle group. Most tests for use in the general population do not distinguish between muscular endurance and muscular strength. Tests of muscular endurance and strength, which include sit-ups, push-ups, bent-arm hangs, and pull-ups, must be properly administered and may not discriminate well in some populations (e.g., pull-ups are not a good test for many populations because a high percentage of those tested will have 0 scores). Few laboratory tests of muscular endurance have been developed, and such tests usually involve having the participant perform a series of contractions at a set percentage of maximal strength and at a constant rate until the person can no longer continue at that rate. The total work performed or the test duration is used as a measure of muscular endurance.

Flexibility is difficult to measure accurately and reliably. Because it is specific to the joint being tested, no one measure provides a satisfactory index of an individual's overall flexibility (Harris 1969). Field testing of flexibility frequently has been limited to the sit-and-reach test, which is considered to be a measure of lower back and hamstring flexibility. The criterion method for measuring flexibility in the laboratory is goniometry, which is used to measure the angle of the joint at both extremes in the range of motion (NCHS, Wilmore 1989).

Balance, agility, and coordination are especially important among older persons, who are more prone to fall and, as a result, suffer fractures due to reduced bone mineral density. Field methods for measuring balance, agility, and coordination have included various balance stands (e.g., one-foot stand with eyes open and with eyes closed; standing on a narrow block) and balance walks on a narrow line or rail (Tse and Bailey 1992). In the laboratory, computer-based technology is now being used to evaluate balance measured on an electronic force platform or to analyze a videotape recording of the participant walking (Lehmann et al. 1990). Agility or coordination are measured most frequently by using a field test, such as an agility walk or run (Cureton 1947). In the laboratory, coordination or reaction/movement time are determined by using electronic signaling and timing devices (Spirduso 1975). More development is needed to establish norms using standardized tests for measuring balance, agility, and coordination, especially of older persons.

### *Body Composition*

In most population-based studies that have provided information on the relationship between physical activity and morbidity or mortality, body composition has been estimated by measuring body height and weight and calculating body mass index (weight/height$^2$). The preferred method for determining amount of body fat and lean body mass in exercise training studies has been hydrostatic or underwater weighing (NCHS, Wilmore 1989); however, this method lacks accuracy in some populations, including older persons and children (Lohman 1986). Anthropometric measurements (i.e., girths, diameters, and skinfolds) used to calculate the percentage of body fat have varying degrees of accuracy and reliability (Wilmore and Behnke 1970).

Data now suggest that the distribution of body fat, especially accumulation in the abdominal area, and total body fat are significant risk factors for CVD and diabetes (Bierman and Brunzell 1992; Blumberg and Alexander 1992). Researchers have determined the magnitude of this abdominal or central obesity by calculating the waist-to-hip circumference ratio or by using new electronic methods that can image regional fat tissue. New technologies that measure body composition include total body electrical conductivity (Segal et al. 1985), bioelectrical impedance (Lukaski et al. 1986), magnetic resonance imaging (Lohman 1984), and dual-energy x-ray absorptiometry (DEXA) (Mazess et al. 1990). These new procedures have substantial potential to provide new information on how changes in physical activity affect body composition and fat distribution.

### *Validity of Measurements*

Health behaviors are difficult to measure, and this is certainly true for the behavior of physical activity. Of particular concern is how well self-reported physical activity accurately represents a person's habitual activity status. Factors that interfere with obtaining accurate assessments include incomplete recall, exaggeration of amount of activity, and nonrepresentative sampling of time intervals during which activity is assessed.

One of the principal difficulties in establishing the validity of a physical activity measure is the lack of a suitable "gold-standard" criterion measure for comparison. In the absence of a true criterion measure, cardiorespiratory fitness has often been used as a validation standard for physical activity surveys. Although habitual physical activity is a major determinant of cardiorespiratory fitness, other factors, such as genetic inheritance, also play a role. Therefore, a perfect correlation between physical activity reporting and cardiorespiratory fitness would not be expected. Nonetheless, correlations of reported physical activity with measured cardiorespiratory fitness have been examined. Table 2-5 shows results from studies

**Table 2-5. Correlation of two survey instruments with physiologic measures of caloric exchange**

| Study | Sample | Physiologic test | Correlation coefficient |
|---|---|---|---|
| | | ***Minnesota Leisure-Time Physical Activity Questionnaire*** | |
| Taylor et al. (1978) | 175 men | Treadmill endurance | 0.45 |
| Skinner et al. (1966) | 54 men | Submaximal treadmill text | 0.13 NS |
| Leon et al. (1981) | 175 men | Treadmill | 0.41 |
| | | Submaximal heart rate | 0.59 |
| DeBacker et al. (1981) | 1,513 men | Submaximal treadmill test | 0.10 |
| Jacobs et al. (1993) | 64 men | $\dot{V}O_2$ max | 0.43 |
| | & women | Submaximal heart rate | 0.45 |
| Richardson et al. (1995) | 78 men | $\dot{V}O_2$ max | 0.47 |
| | & women | | |
| Albanes et al. (1990) | 21 men | Resting caloric intake | 0.17 NS |
| Montoye et al. (1996) | 28 men | Doubly labeled water | 0.26 NS |
| | | ***College Alumni Study Survey*** | |
| Siconolfi et al. (1985) | 36 men | $\dot{V}O_2$ max | 0.29 |
| | 32 women | $\dot{V}O_2$ max | 0.46 |
| Jacobs et al. (1993) | 64 men | | |
| | & women | $\dot{V}O_2$ max | 0.52 |
| | | Submaximal heart rate | 0.52 |
| Albanes et al. (1990) | 21 men | Resting caloric intake | 0.32 NS |
| Montoye et al. (1996) | 28 men | Doubly labeled water | 0.39 |
| | | Energy intake, 7 days | 0.44 |

NS = nonsignificant correlation coefficient; all others were statistically significant.

in which questionnaire data from the Minnesota Leisure-Time Physical Activity Questionnaire (Taylor et al. 1978) and the College Alumni Study survey (Paffenbarger et al. 1993) are compared with physiological measures, in most cases cardiorespiratory fitness. Although most correlation coefficients (e.g., Pearson's *r*) are statistically significant, they exhibit considerable variability (range 0.10 to 0.59), and the overall central tendency (median, 0.41) suggests only moderate external validity. However, in a study of predictors of cardiorespiratory fitness among adults (Blair et al. 1989), in all age and sex subgroups, self-reported physical activity was the principal contributor to the predictive models that also included weight, resting heart rate, and current smoking. Thus, self-reported physical activity may not be perfectly correlated with cardiorespiratory fitness, but it may be the predominant predictive factor.

Because misclassification of physical activity, as could occur by using an invalid measure, would tend to bias studies towards finding no association, the consistently found associations between physical activity and lower risk of several diseases (as is discussed in Chapter 4) suggest that the measure has at least some validity. Moreover, they suggest that a more precise measure of physical activity would likely yield even stronger associations with health. Thus, although measurement of physical activity by currently available methods may be far from ideal, it has provided a means to investigate and demonstrate important health benefits of physical activity.

## Chapter Summary

The assertion that frequent participation in physical activity contributes to better health has been a recurring theme in medicine and education throughout much of Western history. Early empirical observations and case studies suggesting that a sedentary life was not healthy have been supported by rigorous scientific investigation that has evolved over the past century. In recent decades, a number of experimental and clinical specialties have contributed substantially to an emerging field that may accurately be described as exercise science. This field includes disciplines ranging from exercise physiology and biomechanics to physical activity epidemiology, exercise psychology, clinical sports medicine, and preventive medicine. Research findings from these specialties provide the basis for this first Surgeon General's report on physical activity and health. Numerous expert panels, committees, and conferences have been convened over the years to evaluate the evidence relating physical activity and health. These gatherings have laid a solid foundation for the current consensus that for optimal health, people of all ages should be physically active on most days. Specific exercise recommendations have emphasized only vigorous activity for cardiorespiratory fitness until recently, when the benefits of moderate-intensity physical activity have been recognized and promoted as well.

## Conclusions

1. Physical activity for better health and well-being has been an important theme throughout much of western history.

2. Public health recommendations have evolved from emphasizing vigorous activity for cardiorespiratory fitness to including the option of moderate levels of activity for numerous health benefits.

3. Recommendations from experts agree that for better health, physical activity should be performed regularly. The most recent recommendations advise people of all ages to include a minimum of 30 minutes of physical activity of moderate intensity (such as brisk walking) on most, if not all, days of the week. It is also acknowledged that for most people, greater health benefits can be obtained by engaging in physical activity of more vigorous intensity or of longer duration.

4. Experts advise previously sedentary people embarking on a physical activity program to start with short durations of moderate-intensity activity and gradually increase the duration or intensity until the goal is reached.

5. Experts advise consulting with a physician before beginning a new physical activity program for people with chronic diseases, such as CVD and diabetes mellitus, or for those who are at high risk for these diseases. Experts also advise men over age 40 and women over age 50 to consult a physician before they begin a vigorous activity program.

6. Recent recommendations from experts also suggest that cardiorespiratory endurance activity should be supplemented with strength-developing exercises at least twice per week for adults, in order to improve musculoskeletal health, maintain independence in performing the activities of daily life, and reduce the risk of falling.

# Appendix A: *Healthy People 2000* Objectives

The nation's public health goals for the 1990s and beyond, as presented in *Healthy People 2000* (USDHHS 1990), aim to increase the span of healthy life for all Americans, to reduce health disparities among Americans, and to achieve access to preventive services for all Americans. Reproduced here are the *Healthy People 2000* objectives for physical activity and fitness as revised in 1995 (USDHHS 1995).

Duplicate objectives that appear in two or more priority areas are marked with an asterisk alongside the objective number.

## Physical Activity and Fitness

### *Health Status Objectives*

1.1* Reduce coronary heart disease deaths to no more than 100 per 100,000 people.

*Special Population Target*

| *Coronary Deaths (per 100,000)* | | *2000 Target* |
|---|---|---|
| 1.1a | Blacks | 115 |

1.2* Reduce overweight to a prevalence of no more than 20 percent among people aged 20 and older and no more than 15 percent among adolescents aged 12–19.

*Special Population Target*

| *Overweight Prevalence* | | *2000 Target* |
|---|---|---|
| 1.2a | Low-income women aged 20 and older | 25% |
| 1.2b | Black women aged 20 and older | 30% |
| 1.2c | Hispanic women aged 20 and older | 25% |
| 1.2d | American Indians/Alaska Natives | 30% |
| 1.2e | People with disabilities | 25% |
| 1.2f | Women with high blood pressure | 41% |
| 1.2g | Men with high blood pressure | 35% |
| 1.2h | Mexican-American men | 25% |

*Note: For people aged 20 and older, overweight is defined as body mass index (BMI) equal to or greater than 27.8 for men and 27.3 for women. For adolescents, overweight is defined as BMI equal to or greater than 23.0 for males aged 12–14, 24.3 for males aged 15–17, 25.8 for males aged 18–19, 23.4 for females aged 12–14, 24.8 for females aged 15–17, and 25.7 for females aged 18–19. The values for adults are the gender-specific 85th percentile values of the 1976–80 National Health and Nutrition Examination Survey (NHANES II), reference population 20–29 years of age. For adolescents, overweight was defined using BMI cutoffs based on modified age- and gender-specific 85th percentile values of the NHANES II. BMI is calculated by dividing weight in kilograms by the square of height in meters. The cut points used to define overweight approximate the 120 percent of desirable body weight definition used in the 1990 objectives.*

### *Risk Reduction Objectives*

1.3* Increase to at least 30 percent the proportion of people aged 6 and older who engage regularly, preferably daily, in light to moderate physical activity for at least 30 minutes per day.

*Special Population Targets*

| *Moderate Physical Activity* | | *2000 Target* |
|---|---|---|
| 1.3a | Hispanics aged 18 and older<br>5 or more times per week | 25 % |

*Note: Light to moderate physical activity requires sustained, rhythmic muscular movements, is at least equivalent to sustained walking, and is performed at less than 60 percent of maximum heart rate for age. Maximum heart rate equals roughly 220 beats per minute minus age. Examples may include walking, swimming, cycling, dancing, gardening and yardwork, various domestic and occupational activities, and games and other childhood pursuits.*

1.4 Increase to at least 20 percent the proportion of people aged 18 and older and to at least 75 percent the proportion of children and adolescents aged 6–17 who engage in vigorous physical activity that promotes the development and maintenance of cardiorespiratory fitness 3 or more days per week for 20 or more minutes per occasion.

*Special Population Targets*

| *Vigorous Physical Activity* | | *2000 Target* |
|---|---|---|
| 1.4a | Lower-income people aged 18 and older (annual family income <$20,000) | 12% |
| 1.4b | Blacks aged 18 years and older | 17% |
| 1.4c | Hispanics aged 18 years and older | 17% |

*Note: Vigorous physical activities are rhythmic, repetitive physical activities that use large muscle groups at 60 percent or more of maximum heart rate for age. An exercise rate of 60 percent of maximum heart rate for age is about 50 percent of maximal cardiorespiratory capacity and is sufficient for cardiorespiratory conditioning. Maximum heart rate equals roughly 220 beats per minute minus age.*

1.5 Reduce to no more than 15 percent the proportion of people aged 6 and older who engage in no leisure-time physical activity.

*Special Population Targets*

| *No Leisure-Time Physical Activity* | | *2000 Target* |
|---|---|---|
| 1.5a | People aged 65 and older | 22% |
| 1.5b | People with disabilities | 20% |
| 1.5c | Lower-income people (annual family income <$20,000) | 17% |
| 1.5d | Blacks aged 18 and older | 20% |
| 1.5e | Hispanics aged 18 and older | 25% |
| 1.5f | American Indians/Alaska Natives aged 18 and older | 21% |

*Note: For this objective, people with disabilities are people who report any limitation in activity due to chronic conditions.*

1.6 Increase to at least 40 percent the proportion of people aged 6 and older who regularly perform physical activities that enhance and maintain muscular strength, muscular endurance, and flexibility.

1.7* Increase to at least 50 percent the proportion of overweight people aged 12 and older who have adopted sound dietary practices combined with regular physical activity to attain an appropriate body weight.

*Special Population Targets*

| *Adoption of Weight-Loss Practices* | | *2000 Target* |
|---|---|---|
| 1.7a | Overweight Hispanic males aged 18 and older | 24% |
| 1.7b | Overweight Hispanic females aged 18 and older | 22% |

***Services and Protection Objectives***

1.8 Increase to at least 50 percent the proportion of children and adolescents in 1st–12th grade who participate in daily school physical education.

1.9 Increase to at least 50 percent the proportion of school physical education class time that students spend being physically active, preferably engaged in lifetime physical activities.

## Physical Activity and Health

*Note: Lifetime activities are activities that may be readily carried into adulthood because they generally need only one or two people. Examples include swimming, bicycling, jogging, and racquet sports. Also counted as lifetime activities are vigorous social activities such as dancing. Competitive group sports and activities typically played only by young children such as group games are excluded.*

1.10 Increase the proportion of worksites offering employer-sponsored physical activity and fitness programs as follows:

| *Worksite Size* | *2000 Target* |
|---|---|
| 50–99 employees | 20% |
| 100–249 employees | 35% |
| 250–749 employees | 50% |
| ≥750 employees | 80% |

1.11 Increase community availability and accessibility of physical activity and fitness facilities as follows:

| *Facility* | *2000 Target* |
|---|---|
| Hiking, biking, and fitness trail miles | 1 per 10,000 people |
| Public swimming pools | 1 per 25,000 people |
| Acres of park and recreation open space | 4 per 1,000 people (250 people per managed acre) |

1.12 Increase to at least 50 percent the proportion of primary care providers who routinely assess and counsel their patients regarding the frequency, duration, type, and intensity of each patient's physical activity practices.

***Health Status Objective***

1.13* Reduce to no more than 90 per 1,000 people the proportion of all people aged 65 and older who have difficulty in performing two or more personal care activities thereby preserving independence.

*Special Population Targets*

| *Difficulty Performing Self Care (per 1,000)* | *2000 Target* |
|---|---|
| 1.13a People aged 85 and older | 325 |
| 1.13b Blacks aged 65 and older | 98 |

*Note: Personal care activities are bathing, dressing, using the toilet, getting in and out of bed or chair, and eating.*

## Appendix B: NIH Consensus Conference Statement

In Press (3/18/96)

National Institutes of Health
Consensus Development Conference Statement

Physical Activity and Cardiovascular Health
December 18–20, 1995

NIH Consensus Statements are prepared by a nonadvocate, non-Federal panel of experts, based on (1) presentations by investigators working in areas relevant to the consensus questions during a 2-day public session; (2) questions and statements from conference attendees during open discussion periods that are part of the public session; and (3) closed deliberations by the panel during the remainder of the second day and morning of the third. This statement is an independent report of the panel and is not a policy statement of the NIH or the Federal Government.

### Abstract

*Objective.* To provide physicians and the general public with a responsible assessment of the relationship between physical activity and cardiovascular health.

*Participants.* A non-Federal, nonadvocate, 13-member panel representing the fields of cardiology, psychology, exercise physiology, nutrition, pediatrics, public health, and epidemiology. In addition, 27 experts in cardiology, psychology, epidemiology, exercise physiology, geriatrics, nutrition, pediatrics, public health, and sports medicine presented data to the panel and a conference audience of 600.

*Evidence.* The literature was searched through Medline and an extensive bibliography of references was provided to the panel and the conference audience. Experts prepared abstracts with relevant citations from the literature. Scientific evidence was given precedence over clinical anecdotal experience.

*Consensus Process.* The panel, answering predefined questions, developed their conclusions based on the scientific evidence presented in open forum and the scientific literature. The panel composed a draft statement that was read in its entirety and circulated to the experts and the audience for comment. Thereafter, the panel resolved conflicting recommendations and released a revised statement at the end of the conference. The panel finalized the revisions within a few weeks after the conference.

*Conclusions.* All Americans should engage in regular physical activity at a level appropriate to their capacity, needs, and interest. Children and adults alike should set a goal of accumulating at least 30 minutes of moderate-intensity physical activity on most, and preferably, all days of the week. Most Americans have little or no physical activity in their daily lives, and accumulating evidence indicates that physical inactivity is a major risk factor for cardiovascular disease. However, moderate levels of physical activity confer significant health benefits. Even those who currently meet these daily standards may derive additional health and fitness benefits by becoming more physically active or including more vigorous activity. For those with known cardiovascular disease, cardiac rehabilitation programs that combine physical activity with reduction in other risk factors should be more widely used.

### Introduction

Over the past 25 years, the United States has experienced a steady decline in the age- adjusted death toll from cardiovascular disease (CVD), primarily in mortality caused by coronary heart disease and stroke. Despite this decline, coronary heart disease remains the leading cause of death and stroke the third leading cause of death. Lifestyle improvements by the American public and better control of the risk factors for heart disease and stroke have been major factors in this decline.

Coronary heart disease and stroke have many causes. Modifiable risk factors include smoking, high blood pressure, blood lipid levels, obesity, diabetes, and physical inactivity. In contrast to the positive national trends observed with cigarette smoking, high blood pressure, and high blood cholesterol, obesity and physical inactivity in the United States have not improved. Indeed automation and other technologies have contributed greatly to lessening physical activity at work and home.

The purpose of this conference was to examine the accumulating evidence on the role of physical activity in the prevention and treatment of CVD and its risk factors.

Physical activity in this statement is defined as "bodily movement produced by skeletal muscles that requires energy expenditure" and produces healthy benefits. Exercise, a type of physical activity, is defined as "a planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness." Physical inactivity denotes a level of activity less than that needed to maintain good health.

Physical inactivity characterizes most Americans. Exertion has been systematically engineered out of most occupations and lifestyles. In 1991, 54 percent of adults reported little or no regular leisure physical activity. Data from the 1990 Youth Risk Behavior Survey show that most teenagers in grades 9-12 are not performing regular vigorous activity. About 50 percent of high school students reported they are not enrolled in physical education classes.

Physical activity protects against the development of CVD and also favorably modifies other CVD risk factors, including high blood pressure, blood lipid levels, insulin resistance, and obesity. The type, frequency, and intensity of physical activity that are needed to accomplish these goals remain poorly defined and controversial.

Physical activity is also important in the treatment of patients with CVD or those who are at increased risk for developing CVD, including patients who have hypertension, stable angina, or peripheral vascular disease, or who have had a prior myocardial infarction or heart failure. Physical activity is an important component of cardiac rehabilitation, and people with CVD can benefit from participation. However, some questions remain regarding benefits, risks, and costs associated with becoming physically active.

Many factors influence adopting and maintaining a physically active lifestyle, such as socioeconomic status, cultural influences, age, and health status. Understanding is needed on how such variables influence the adoption of this behavior at the individual level. Intervention strategies for encouraging individuals from different backgrounds to adopt and adhere to a physically active lifestyle need to be developed and tested. Different environments such as schools, worksites, health care settings, and the home can play a role in promoting physical activity. These community-level factors also need to be better understood.

To address these and related issues, the NIH's National Heart, Lung, and Blood Institute and Office of Medical Applications of Research convened a Consensus Development Conference on Physical Activity and Cardiovascular Health. The conference was cosponsored by the NIH's National Institute of Child Health and Human Development, National Institute on Aging, National Institute of Arthritis and Musculoskeletal and Skin Diseases, National Institute of Diabetes and Digestive and Kidney Diseases, National Institute of Nursing Research, Office of Research on Women's Health, and Office of Disease Prevention, as well as the Centers for Disease Control and Prevention and the President's Council on Physical Fitness and Sports.

The conference brought together specialists in medicine, exercise physiology, health behavior, epidemiology, nutrition, physical therapy, and nursing as well as representatives from the public. After a day and a half of presentations and audience discussion, an independent, non-Federal consensus panel weighed the scientific evidence and developed a draft statement that addressed the following five questions.

- What is the health burden of a sedentary lifetyle on the population?
- What type, what intensity, and what quantity of physical activity are important to prevent cardiovascular disease?
- What are the benefits and risks of different types of physical activity for people with cardiovascular disease?
- What are the successful approaches to adopting and maintaining a physically active lifestyle?
- What are the important questions for future research?

## 1. What Is the Health Burden of a Sedentary Lifestyle on the Population?

Physical inactivity among the U.S. population is now widespread. National surveillance programs have documented that about one in four adults (more women than men) currently have sedentary lifestyles with no leisure time physical activity. An additional one-third of adults are insufficiently active to achieve health benefits. The prevalence of inactivity varies by gender, age, ethnicity, health status, and geographic region but is common to all demographic groups. Change in physical exertion associated with occupation has declined markedly in this century.

Girls become less active than do boys as they grow older. Children become far less active as they move through adolescence. Obesity is increasing among children, at least in part related to physical inactivity. Data indicate that obese children and adolescents have a high risk of becoming obese adults, and obesity in adulthood is related to coronary artery disease, hypertension, and diabetes. Thus, the prevention of childhood obesity has the potential of preventing CVD in adults. At age 12, 70 percent of children report participation in vigorous physical activity; by age 21 this activity falls to 42 percent for men and 30 percent for women. Furthermore, as adults age, their physical activity levels continue to decline.

Although knowledge about physical inactivity as a risk factor for CVD has come mainly from investigations of middle-aged, white men, more limited evidence from studies in women minority groups and the elderly suggests that the findings are similar in these groups. On the basis of current knowledge, we must note that physical inactivity occurs disproportionately among Americans who are not well educated and who are socially or economically disadvantaged.

Physical activity is directly related to physical fitness. Although the means of measuring physical activity have varied between studies (i.e., there is no standardization of measures), evidence indicates that physical inactivity and lack of physical fitness are directly associated with increased mortality from CVD. The increase in mortality is not entirely explained by the association with elevated blood pressure, smoking, and blood lipid levels.

There is an inverse relationship between measures of physical activity and indices of obesity in most U.S. population studies. Only a few studies have examined the relationship between physical activity and body fat distribution, and these suggest an inverse relationship between levels of physical activity and visceral fat. There is evidence that increased physical activity facilitates weight loss and that the addition of physical activity to dietary energy restriction can increase and help to maintain loss of body weight and body fat mass.

Middle-aged and older men and women who engage in regular physical activity have significantly higher high-density lipoprotein (HDL) cholesterol levels than do those who are sedentary. When exercise training has extended to at least 12 weeks, beneficial HDL cholesterol level changes have been reported.

Most studies of endurance exercise training of individuals with normal blood pressure and those with hypertension have shown decreases in systolic and diastolic blood pressure. Insulin sensitivity is also improved with endurance exercise.

A number of factors that affect thrombotic function—including hematocrit, fibrinogen, platelet function, and fibrinolysis—are related to the risk of CVD. Regular endurance exercise lowers the risk related to these factors.

The burden of CVD rests most heavily on the least active. In addition to its powerful impact on the cardiovascular system, physical inactivity is also associated with other adverse health effects, including osteoporosis, diabetes, and some cancers.

## 2. What Type, What Intensity, and What Quantity of Physical Activity Are Important to Prevent Cardiovascular Disease?

Activity that reduces CVD risk factors and confers many other health benefits does not require a structured or vigorous exercise program. The majority of benefits of physical activity can be gained by performing moderate-intensity activities. The amount or type of physical activity needed for health benefits or optimal health is a concern due to limited time and competing activities for most Americans. The amount and types of physical activity that are needed to prevent disease and promote health must, therefore, be clearly communicated, and effective strategies must be developed to promote physical activity to the public.

The quantitative relationship between level of activity or fitness and magnitude of cardiovascular benefit may extend across the full range of activity. A moderate level of physical activity confers health benefits. However, physical activity must be performed regularly to maintain these effects.

Moderate=intensity activity performed by previously sedentary individuals results in significant improvement in many health-related outcomes. These moderate intensity activities are more likely to be continued than are high-intensity activities.

We recommend that all people in the United States increase their regular physical activity to a level appropriate to their capacities, needs, and interest. We recommend that all children and adults should set a long-term goal to accumulate at least 30 minutes or more of moderate-intensity physical activity on most, or preferably all, days of the week. Intermittent or shorter bouts of activity (at least 10 minutes), including occupational, nonoccupational, or tasks of daily living, also have similar cardiovascular and health benefits if performed at a level of moderate intensity (such as brisk walking, cycling, swimming, home repair, and yardwork) with an accumulated duration of at least 30 minutes per day. People who currently meet the recommended minimal standards may derive additional health and fitness benefits from becoming more physically active or including more vigorous activity.

Some evidence suggests lowered mortality with more vigorous activity, but further research is needed to more specifically define safe and effective levels. The most active individuals have lower cardiovascular morbidity and mortality rates than do those who are least active; however, much of the benefit appears to be accounted for by comparing the least active individuals to those who are moderately active. Further increases in the intensity or amount of activity produce further benefits in some, but not all, parameters of risk. High-intensity activity is also associated with an increased risk of injury, discontinuation of activity, or acute cardiac events during the activity. Current low rates of regular activity in Americans may be partially due to the mis-perception of many that vigorous, continuous exercise is necessary to reap health benefits. Many people, for example, fail to appreciate walking as "exercise" or to recognize the substantial benefits of short bouts (at least 10 minutes) of moderate-level activity.

The frequency, intensity, and duration of activity are interrelated. The number of episodes of activity recommended for health depends on the intensity and/or duration of the activity: higher intensity or longer duration activity could be performed approximately three times weekly and achieve cardiovascular benefits, but low-intensity or shorter duration activities should be performed more often to achieve cardiovascular benefits.

The appropriate type of activity is best determined by the individual's preferences and what will be sustained. Exercise, or a structured program of activity, is a subset of activity that may encourage interest and allow for more vigorous activity. People who perform more formal exercise (i.e., structured or planned exercise programs) can accumulate this daily total through a variety of recreational or sports activities. People who are currently sedentary or minimally active should gradually build up to the recommended goal of 30 minutes of moderate activity daily by adding a few minutes each day until reaching their personal goal to reduce the risk associated with suddenly increasing the amount or intensity of exercise. (The defined levels of effort depend on individual characteristics such as baseline fitness and health status.)

Developing muscular strength and joint flexibility is also important for an overall activity program to improve one's ability to perform tasks and to reduce the potential for injury. Upper extremity and resistance (or strength) training can improve muscular function, and evidence suggests that there may be cardiovascular benefits, especially in older patients or those with underlying CVD, but further research and guidelines are needed. Older people or those who have been deconditioned from recent inactivity or illness may particularly benefit from resistance training due to improved ability in accomplishing tasks of daily living. Resistance training may contribute to better balance, coordination, and agility that may help prevent falls in the elderly.

Physical activity carries risks as well as benefits. The most common adverse effects of activity relate to musculoskeletal injury and are usually mild and self-limited. The risk of injury increases with increased intensity, frequency, and duration of activity and also depends on the type of activity. Exercise-related injuries can be reduced by moderating these parameters. A more serious but rare complication of activity is myocardial infarction or sudden cardiac death. Although persons who engage in vigorous physical activity have a slight increase in risk of sudden cardiac death during activity, the health benefits outweigh this risk because of the large overall risk reduction.

In children and young adults, exertion-related deaths are uncommon and are generally related to congenital heart defects (e.g., hypertrophic cardiomyopathy, Marfan's syndrome, severe aortic valve stenosis, prolonged QT syndromes, cardiac conduction abnormalities) or to acquired myocarditis. It is recommended that patients with those conditions remain active but not participate in vigorous or competitive athletics.

Because the risks of physical activity are very low compared with the health benefits, most adults do not need medical consultation or pretesting before starting a moderate-intensity physical activity program. However, those with known CVD and men over age 40 and women over age 50 with multiple cardiovascular risk factors who contemplate a program of vigorous activity should have a medical evaluation prior to initiating such a program.

## 3. What Are the Benefits and Risks of Different Types of Physical Activity for People with Cardiovascular Disease?

More than 10 million Americans are afflicted with clinically significant CVD, including myocardial infarction, angina pectoris, peripheral vascular disease, and congestive heart failure. In addition, more than 300,000 patients per year are currently subjected to coronary artery bypass surgery and a similar number to percutaneous transluminal coronary angioplasty. Increased physical activity appears to benefit each of these groups. Benefits include reduction in cardiovascular mortality, reduction of symptoms, improvement in exercise tolerance and functional capacity, and improvement in psychological well-being and quality of life.

Several studies have shown that exercise training programs significantly reduce overall mortality, as well as death caused by myocardial infarction. The reported reductions in mortality have been highest—approximately 25 percent—in cardiac rehabilitation programs that have included control of other cardiovascular risk factors. Rehabilitation programs using both moderate and vigorous physical activity have been associated with reductions in fatal cardiac events, although the minimal or optimal level and duration of exercise required to achieve beneficial effects remains uncertain. Data are inadequate to determine whether stroke incidence is affected by physical activity or exercise training.

The risk of death during medically supervised cardiac exercise training programs is very low. However, those who exercise infrequently and have poor functional capacity at baseline may be at somewhat higher risk during exercise training. All patients with CVD should have a medical evaluation prior to participation in a vigorous exercise program.

Appropriately prescribed and conducted exercise training programs improve exercise tolerance and physical fitness in patients with coronary heart disease. Moderate as well as vigorous exercise training regimens are of value. Patients with low basal levels of exercise capacity experience the most functional benefits, even at relatively modest levels of physical activity. Patients with angina pectoris typically experience improvement in angina in association with a reduction in effort-induced myocardial ischemia, presumably as a result of decreased myocardial oxygen demand and increased work capacity.

Patients with congestive heart failure also appear to show improvement in symptoms, exercise capacity, and functional well-being in response to exercise training, even though left ventricular systolic function appears to be unaffected. The exercise program should be tailored to the needs of these patients and supervised closely in view of the marked predisposition of these patients to ischemic events and arrhythmias.

Cardiac rehabilitation exercise training often improves skeletal muscle strength and oxidative capacity and, when combined with appropriate nutritional changes, may result in weight loss. In addition, such training generally results in improvement in measures of psychological status, social adjustment, and functional capacity. However, cardiac rehabilitation exercise training has less influence on rates of return to work than many nonexercise variables, including employer attitudes, prior employment status, and economic incentives. Multifactorial intervention programs, including nutritional changes and medication plus exercise, are needed to improve health status and reduce cardiovascular disease risk.

Cardiac rehabilitation programs have traditionally been institutional-based and group-centered (e.g., hospitals, clinics, community centers). Referral and enrollment rates have been relatively low, generally ranging from 10 to 25 percent of patients with CHD. Referral rates are lower for women than for men and lower for non-whites than for whites. Home-based programs have the potential to provide rehabilitative services to a wider population. Home-based programs incorporating limited hospital visits with regular mail or telephone followup by a nurse case manager have demonstrated significant increases in functional capacity, smoking cessation, and improvement in blood lipid levels. A range of options exists in cardiac rehabilitation including site, number of visits, monitoring, and other services.

There are clear medical and economic reasons for carrying out cardiac rehabilitation programs. Optimal outcomes are achieved when exercise training is combined with educational messages and feedback about changing lifestyle. Patients who participate in cardiac rehabilitation programs show a lower incidence of rehospitalization and lower charges per hospitalization. Cardiac rehabilitation is a cost-efficient therapeutic modality that should be used more frequently.

## 4. What Are the Successful Approaches to Adopting and Maintaining a Physically Active Lifestyle?

The cardiovascular benefits from and physiological reactions to physical activity appear to be similar among diverse population subgroups defined by age, sex, income, region of residence, ethnic background, and health status. However, the behavioral and attitudinal factors that influence the motivation for and ability to sustain physical activity are strongly determined by social experiences, cultural background, and physical disability and health status. For example, perceptions of appropriate physical activity differ by gender, age, weight, marital status, family roles and responsibilities, disability, and social class. Thus, the following general guidelines will need to be further refined when one is planning with or prescribing for specific individuals and population groups, but generally physical activity is more likely to be initiated and maintained if the individual

- Perceives a net benefit.
- Chooses an enjoyable activity.
- Feels competent doing the activity.
- Feels safe doing the activity.
- Can easily access the activity on a regular basis.
- Can fit the activity into the daily schedule.
- Feels that the activity does not generate financial or social costs that he or she is unwilling to bear.
- Experiences a minimum of negative consequences such as injury, loss of time, negative peer pressure, and problems with self-identity.
- Is able to successfully address issues of competing time demands.
- Recognizes the need to balance the use of labor-saving devices (e.g., power lawn mowers, golf carts, automobiles) and sedentary activities (e.g., watching television, use of computers) with activities that involve a higher level of physical exertion.

Other people in the individual's social environment can influence the adoption and maintenance of physical activity. Health care providers have a key role in promoting smoking cessation and other risk-reduction behaviors. Preliminary evidence suggests that this also applies to physical activity. It is highly probable that people will be more likely to increase their physical activity if their health care provider counsels them to do so. Providers can do this effectively by learning to recognize stages of behavior change, to communicate the need for increased activity, to assist the patient in initiating activity, and by following up appropriately.

Family and friends can also be important sources of support for behavior change. For example, spouses or friends can serve as "buddies," joining in the physical activity; or a spouse could offer to take on a household task, giving his or her mate time to engage in physical activity. Parents can support their children's activity by providing transportation, praise, and encouragement, and by participating in activities with their children.

Worksites have the potential to encourage increased physical activity by offering opportunities, reminders, and rewards for doing so. For example, an appropriate indoor area can be set aside to enable walking during lunch hours. Signs placed near elevators can encourage the use of the stairs instead. Discounts on parking fees can be offered to employees who elect to park in remote lots and walk.

Schools are a major community resource for increasing physical activity, particularly given the urgent need to develop strategies that affect children and adolescents. As noted previously, there is now clear evidence that U.S. children and adolescents have become more obese. There is also evidence that obese children and adolescents exercise less than their leaner peers. All schools should provide opportunities for physical activities that

- Are appropriate and enjoyable for children of all skill levels and are not limited to competitive sports or physical education classes.
- Appeal to girls as well as to boys, and to children from diverse backgrounds.
- Can serve as a foundation for activities throughout life.
- Are offered on a daily basis.

Successful approaches may involve mass education strategies or changes in institutional policies or community variables. In some environments (e.g., schools, worksites, community centers), policy-level interventions may be necessary to enable people to achieve and maintain an adequate level of activity. Policy changes that increase opportunities for physical activity can facilitate activity maintenance for motivated individuals and increase readiness to change among the less motivated. As in other areas of health promotion, mass communication strategies should be used to promote physical activity. These strategies should include a variety of mainstream channels and techniques to reach diverse audiences that acquire information through different media (e.g., TV, newspaper, radio, Internet).

### 5. What Are the Important Considerations for Future Research?

While much has been learned about the role of physical activity in cardiovascular health, there are many unanswered questions.

- Maintain surveillance of physical activity levels in the U.S. population by age, sex, geographic, and socioeconomic measures.
- Develop better methods for analysis and quantification of activity. These methods should be applicable to both work and leisure time measurements and provide direct quantitative estimates of activity.
- Conduct physiologic, biochemical, and genetic research necessary to define the mechanisms by which activity affects CVD including changes in metabolism as well as cardiac and vascular effects. This will provide new insights into cardiovascular biology that may have broader implications than for other clinical outcomes.
- Examine the effects of physical activity and cardiac rehabilitation programs on morbidity and mortality in elderly individuals.
- Conduct research on the social and psychological factors that influence adoption of a more active lifestyle and the maintenance of that behavior change throughout life.
- Carry out controlled randomized clinical trials among children and adolescents to test the effects of increased physical activity on CVD risk factor levels including obesity. The effects of intensity, frequency, and duration of increased physical activity should be examined in such studies.

## Conclusions

Accumulating scientific evidence indicates that physical inactivity is a major risk factor for CVD. Moderate levels of regular physical activity confer significant health benefits. Unfortunately, most Americans have little or no physical activity in their daily lives.

All Americans should engage in regular physical activity at a level appropriate to their capacities, needs, and interests. All children and adults should set and reach a goal of accumulating at least 30 minutes of moderate-intensity physical activity on most, and preferably all, days of the week. Those who currently meet these standards may derive additional health and fitness benefits by becoming more physically active or including more vigorous activity.

Cardiac rehabilitation programs that combine physical activity with reduction in other risk factors should be more widely applied to those with known CVD. Well-designed rehabilitation programs have benefits that are lost because of these programs' limited use.

Individuals with CVD and men over 40 or women over 50 years of age with multiple cardiovascular risk factors should have a medical evaluation prior to embarking on a vigorous exercise program.

Recognizing the importance of individual and societal factors in initiating and sustaining regular physical activity, the panel recommends the following:

- Development of programs for health care providers to communicate to patients the importance of regular physical activity.
- Community support of regular physical activity with environmental and policy changes at schools, worksites, community centers, and other sites.
- Initiation of a coordinated national campaign involving a consortium of collaborating health organizations to encourage regular physical activity.
- The implementation of the recommendations in this statement has considerable potential to improve the health and well-being of American citizens.

## About the NIH Consensus Development Program

NIH Consensus Development Conferences are convened to evaluate available scientific information and resolve safety and efficacy issues related to a biomedical technology. The resultant NIH Consensus Statements are intended to advance understanding of the technology or issue in question and to be useful to health professionals and the public.

## References


Acheson KJ, Campbell IT, Edholm OG, Miller DS, Stock MJ. The measurement of daily energy expenditure: an evaluation of some techniques. *American Journal of Clinical Nutrition* 1980;33:1155–1164.

Ainsworth BE, Montoye HJ, Leon AS. Methods of assessing physical activity during leisure and work. In: Bouchard C, Shephard RJ, Stephens T, editors. *Physical activity, fitness, and health: international proceedings and consensus statement*. Champaign, IL: Human Kinetics, 1994:146–159.

Albanes D, Conway JM, Taylor PR, Moe PW, Judd J. Validation and comparison of eight physical activity questionnaires. *Epidemiology* 1990;1:65–71.

Allen W, Pepys WH. On respiration. *Philosophical Transactions of the Royal Society of London* 1809(Pt 2):404–429.

American Academy of Pediatrics, Committee on Sports Medicine and Fitness. Assessing physical activity and fitness in the office setting. *Pediatrics* 1994;93:686–689.

American Academy of Pediatrics, Committee on Sports Medicine and Fitness. Fitness, activity, and sports participation in the preschool child. *Pediatrics* 1992;90:1002–1004.

American Association of Cardiovascular and Pulmonary Rehabilitation. *Guidelines for cardiac rehabilitation programs*. Champaign, IL: Human Kinetics, 1991.

American Association of Cardiovascular and Pulmonary Rehabilitation. *Guidelines for pulmonary rehabilitation programs*. Champaign, IL: Human Kinetics, 1993.

American Association of Cardiovascular and Pulmonary Rehabilitation. *Guidelines for cardiac rehabilitation programs*. 2nd ed. Champaign, IL: Human Kinetics, 1995.

American College of Sports Medicine. ACSM position stand on osteoporosis and exercise. *Medicine and Science in Sports and Exercise* 1995a;27:i–vii.

American College of Sports Medicine. *ACSM's guidelines for exercise testing and prescription*. 5th ed. Baltimore: Williams and Wilkins, 1995b.

American College of Sports Medicine. *Guidelines for exercise testing and prescription*. 3rd ed. Philadelphia: Lea and Febiger, 1986.

American College of Sports Medicine. *Guidelines for exercise testing and prescription*. 4th ed. Philadelphia: Lea and Febiger, 1991.

American College of Sports Medicine. *Guidelines for graded exercise testing and exercise prescription*. Philadelphia: Lea and Febiger, 1975.

American College of Sports Medicine. *Guidelines for graded exercise testing and exercise prescription*. 2nd ed. Philadelphia: Lea and Febiger, 1980.

American College of Sports Medicine. Physical activity, physical fitness, and hypertension. *Medicine and Science in Sports and Exercise* 1993;25:i–x.

American College of Sports Medicine. Position stand: exercise for patients with coronary artery disease. *Medicine and Science in Sports and Exercise* 1994;26:i–v.

American College of Sports Medicine. Position stand: the recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. *Medicine and Science in Sports and Exercise* 1990;22:265–274.

American College of Sports Medicine. The recommended quantity and quality of exercise for developing and maintaining fitness in healthy adults. *Medicine and Science in Sports* 1978;10:vii–x.

American Heart Association. Cardiac rehabilitation programs: a statement for healthcare professionals from the American Heart Association. *Circulation* 1994;90:1602–1610.

American Heart Association. Exercise standards: a statement for healthcare professionals from the American Heart Association. *Circulation* 1995;91:580–615.

American Heart Association. *Exercise testing and training of apparently healthy individuals: a handbook for physicians*. Dallas: American Heart Association, 1972.

American Heart Association. *Exercise testing and training of individuals with heart disease or at high risk for its development: a handbook for physicians*. Dallas: American Heart Association, 1975.

American Heart Association. Statement on exercise: benefits and recommendations for physical activity programs for all Americans: a statement for health professionals by the Committee on Exercise and Cardiac Rehabilitation of the Council on Clinical Cardiology, American Heart Association. *Circulation* 1992;86:340–344.

American Heart Association, Blair SN, Powell KE, Bazzarre TL, Early JL, Epstein LH, et al. AHA prevention conference. III. Behavior change and compliance: key to improving cardiovascular health. Physical inactivity: workshop V. *Circulation* 1993;88:1402–1405.

American Medical Association, Elster AB, Kuznets NJ. *AMA guidelines for adolescent preventive services (GAPS): recommendations and rationale*. Chicago, IL: Williams and Wilkins, 1994.

Balogun JA, Amusa LO, Onyewadume IU. Factors affecting Caltrac® and Calcount® accelerometer output. *Physical Therapy* 1988;68:1500–1504.

Baranowski T. Methodologic issues in self-report of health behavior. *Journal of School Health* 1985;55:179–182.

Beecher CE. *Physiology and calisthenics for schools and families*. New York: Harper and Brothers, 1856.

Benedict FG, Cathcart EP. *Muscular work: a metabolic study with special reference to the efficiency of the human body as a machine*. Washington, DC: Carnegie Institution of Washington, 1913.

Berryman JW. Exercise and the medical tradition from Hippocrates through antebellum America: a review essay. In: Berryman JW, Park RJ, editors. *Sport and exercise science: essays in the history of sports medicine*. Urbana, IL: University of Illinois Press, 1992:1–56.

Berryman JW. *Out of many, one: a history of the American College of Sports Medicine*. Champaign, IL: Human Kinetics, 1995.

Bierman EL, Brunzell JD. Obesity and atherosclerosis. In: Björntorp P, Brodoff BN, editors. *Obesity*. Philadelphia: J.B. Lippincott Company, 1992:512–516.

Blair SN. 1993 C.H. McCloy research lecture: physical activity, physical fitness, and health. *Research Quarterly for Exercise and Sport* 1993;64:365–376.

Blair SN, Dowda M, Pate RR, Kronenfeld J, Howe HG Jr, Parker G, et al. Reliability of long-term recall of participation in physical activity by middle-aged men and women. *American Journal of Epidemiology* 1991;133:266–275.

Blair SN, Falls HB, Pate RR. A new physical fitness test. *Physician and Sportsmedicine* 1983;11:87–95.

Blair SN, Kannel WB, Kohl HW, Goodyear N, Wilson PWF. Surrogate measures of physical activity and physical fitness: evidence for sedentary traits of resting tachycardia, obesity, and low vital capacity. *American Journal of Epidemiology* 1989;129:1145–1156.

Blair SN, Kohl HW, Gordon NF. How much physical activity is good for health? *Annual Reviews of Public Health* 1992;13:99–126.

Blair SN, Kohl HW III, Paffenbarger RS Jr, Clark DG, Cooper KH, Gibbons LW. Physical fitness and all-cause mortality: a prospective study of healthy men and women. *Journal of the American Medical Association* 1989;262:2395–2401.

Blumberg VS, Alexander J. Obesity and the heart. In: Björntorp P, Brodoff BN, editors. *Obesity*. Philadelphia: J.B. Lippincott Company, 1992:517–531.

Borg GA. Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise* 1982;14:377-381.

Bouchard C, Shephard RJ, Stephens T, editors. *Physical activity, fitness, and health: international proceedings and consensus statement*. Champaign, IL: Human Kinetics, 1994.

Bouchard C, Shephard RJ, Stephens T, Sutton JR, McPherson BD. Exercise, fitness, and health: the consensus statement. In: Bouchard C, Shephard RJ, Stephens T, Sutton JR, McPherson BD, editors. *Exercise, fitness, and health*. Champaign, IL: Human Kinetics, 1990:4–28.

Brown RG, Davidson LAG, McKeown T, Whitfield AGW. Coronary-artery disease—influences affecting its incidence in males in the seventh decade. *Lancet* 1957;2:1073–1077.

Buchan W. *Domestic medicine: or, a treatise on the prevention and cure of diseases, by regimen and simple medicines* [1769]. Reprint, Boston: Joseph Bumstead, 1813.

Burns CR. The nonnaturals: a paradox in the western concept of health. *Journal of Medicine and Philosophy* 1976;1:202–211.

Byford WH. On the physiology of exercise. *American Journal of Medical Sciences* 1855;30:32–42.

Bylebyl JJ. The school of Padua: humanistic medicine in the sixteenth century. In: Webster C, editor. *Health, medicine, and mortality in the sixteenth century*. Cambridge, MA: Cambridge University Press, 1979:335–370.

Caldwell C. *Thoughts on physical education: being a discourse delivered to a convention of teachers in Lexington, Kentucky, on the 6th and 7th of November 1833*. Boston: Marsh, Capen, and Lyon, 1834.

Caspersen CJ. Physical activity epidemiology: concepts, methods, and applications to exercise science. *Exercise and Sport Sciences Reviews* 1989;17:423–473.

Caspersen CJ, Pollard RA. Validity of global self-reports of physical activity in epidemiology. *CVD Epidemiology Newsletter* 1988;43:15.

Caspersen CJ, Powell KE, Christensen GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Reports* 1985;100:126–131.

Cassedy JH. Why self-help? Americans alone with their diseases, 1800–1850. In: Risse GB, Numbers RL, Leavitt JW, editors. *Medicine without doctors: home health care in American history*. New York: Science History Publications, 1977:31–48.

Chapman CB, Mitchell JH. The physiology of exercise. *Scientific America* 1965;212:88–96.

Cheyne G. *An essay of health and long life* [1724]. Reprint, London: George Strahan, 1734.

Christensen EH. Intervallarbeit und intervalltraining. *Arbeitsphysiologie* 1960;18:345–356.

Clarke HH, editor. Toward a better understanding of muscular strength. *Physical Fitness Research Digest* 1973;3:1–20.

Cogan T. *The haven of health* [1584]. Reprint, London: Bonham Norton, 1596.

Cooper KH. A means of assessing maximal oxygen intake: correlation between field and treadmill testing. *Journal of the American Medical Association* 1968;203:135–138.

Corbin CB, Lindsey R. *Concepts in physical education with laboratories.* 8th ed. Dubuque, IA: Times Mirror Higher Education Group, 1994.

Cornaro L. *The art of living long* [1558]. Reprint, Milwaukee: William F. Butler, 1905.

Crampton CW. A test of condition: preliminary report. *Medical News* 1905;87:529–535.

Crampton CW. *Start today: your guide to physical fitness.* New York: A.S. Barnes, 1941.

Cureton TK. *Physical fitness workbook: a manual of conditioning exercises and standards, tests, and rating scales for evaluating physical fitness.* 3rd ed. St. Louis: C.V. Mosby Company, 1947.

Cyriax RJ. A short history of mechano-therapeutics in Europe until the time of Ling. *Janus* 1914;19:178–240.

DeBacker G, Kornitzer M, Sobolski J, Dramaix M, Degre S, de Marneffe M. Physical activity and physical fitness levels of Belgian males aged 40–55 years. *Cardiology* 1981;67:110–128.

Dill DB. The Harvard Fatigue Laboratory: its development, contributions, and demise. In: Chapman CB, editor. *Physiology of muscular exercise.* New York: American Heart Association, 1967.

DiPietro L, Caspersen CJ, Ostfeld AM, Nadel ER. A survey for assessing physical activity among older adults. *Medicine and Science in Sports and Exercise* 1993;25:628–642.

Dishman RK, editor. *Exercise adherence: its impact on public health.* Champaign, IL: Human Kinetics, 1988.

Dublin L. Longevity of college athletes. *Statistical Bulletin of the Metropolitan Insurance Company* 1932;13:5–7.

Eaton SB, Shostak M, Konner M. *The paleolithic prescription: a program of diet and exercise and a design for living.* New York: Harper and Row, 1988.

Edwards JE, Stager JM, Updyke W, Elizondo R. Validity of the doubly labeled water method of measuring energy expenditure with rest and exercise in non-human primates. *Medicine and Science in Sports and Exercise* 1990;22:550–557.

Fitz GW. *Principles of physiology and hygiene.* New York: H. Holt and Company, 1908.

Fishbein M. *A history of the American Medical Association, 1847 to 1947.* Philadelphia: W.B. Saunders, 1947.

Fishbein M. Health of young men under selective service. *Journal of the American Medical Association* 1941;116:54–55.

Fletcher GF, Blair SN, Blumenthal J, Caspersen C, Chaitman B, Epstein S, et al. Statement on exercise: benefits and recommendations for physical activity programs for all Americans: a statement for health professionals by the Committee on Exercise and Cardiac Rehabilitation of the Council on Clinical Cardiology, American Heart Association. *Circulation* 1992;86:340–344.

Foster WL. A test of physical efficiency. *American Physical Education Review* 1914;19:632–636.

Freedson PS. Field monitoring of physical activity in children. *Pediatric Exercise Science* 1989;1:8–18.

Gemmill C, Booth W, Detrick J, Schiebel H. Muscular training. II. The effects of training on the recovery period following severe muscular exercise. *American Journal of Physiology* 1931;96:265–277.

Gilliam TB, Freedson PS, Geenen DL, Shahraray B. Physical activity patterns determined by heart rate monitoring in 6–7 year-old children. *Medicine and Science in Sports and Exercise* 1981;13:65–67.

Green RM. *A translation of Galen's hygiene (De sanitate tuenda).* Springfield, IL: Charles C. Thomas, 1951.

Gruman GJ. The rise and fall of prolongevity hygiene, 1558–1873. *Bulletin of the History of Medicine* 1961; 35:221–229.

Gunn JC. *Gunn's domestic medicine, or poor man's friend* [1830]. Reprint, with an introduction by Charles E. Rosenberg. Knoxville, TN: University of Tennessee Press, 1986.

Hackensmith CW. *History of physical education.* New York: Harper and Row, 1966.

Harris ML. A factor analytic study of flexibility. *Research Quarterly* 1969;40:62–70.

Harris SS, Caspersen CJ, DeFriese GH, Estes EH Jr. Physical activity counseling for healthy adults as a primary preventive intervention in the clinical setting: report for the U.S. Preventive Services Task Force. *Journal of the American Medical Association* 1989;261:3588–3598.

Hartwell EM. On the physiology of exercise. *Boston Medical and Surgical Journal* 1887;116:13:297–302.

Haskell WL. Physical activity and health: the need to define the required stimulus. *American Journal of Cardiology* 1984;55:4D–9D.

Haskell WL, Yee MC, Evans A, Irby PJ. Simultaneous measurement of heart rate and body motion to quantitate physical activity. *Medicine and Science in Sports and Exercise* 1993;25:109–115.

Hill AV. *Living machinery: eight lectures delivered at the Lowell Institute, Boston, March 1927*. New York: Harcourt, Brace, and Company, 1927.

Hill AV. *Muscular activity*. Baltimore: Williams and Wilkins, 1926.

Hill AV. The physiological basis of athletic records. *Lancet* 1925a;2:481–486.

Hill AV. The physiological basis of athletic records. *Scientific Monthly* 1925b;21:409–428.

Hippocrates. *Regimen I*. Translated by W.H.S. Jones. Cambridge, MA: Harvard University Press, 1953.

Hitchcock E. *Elementary anatomy and physiology*. Rev. ed. New York: Ivison, Phinney, 1861.

Horvath SM, Horvath EC. *The Harvard Fatigue Laboratory: its history and contributions*. Englewood Cliffs, NJ: Prentice-Hall, 1973.

Huang Ti. *Nei Ching Su Wen: the Yellow Emperor's classic of internal medicine*. Translated by Ilza Veith. Baltimore: Williams and Wilkins, 1949.

Huard P, Wong M. *Chinese medicine*. Translated by Bernard Fielding. London: Weidenfeld and Nicolson, 1968.

Jacobs DR, Ainsworth BE, Hartman TJ, Leon AS. A simultaneous evaluation of 10 commonly used physical activity questionnaires. *Medicine and Science in Sports and Exercise* 1993;25:81–91.

Jaeger W. *Paideia: the ideals of Greek culture*. Translated by Gilbert Highet. *Vol. 1. Archaic Greece—the mind of Athens*. 2nd ed. New York: Oxford University Press, 1965.

Kannel WB, Wilson P, Blair SN. Epidemiological assessment of the role of physical activity and fitness in development of cardiovascular disease. *American Heart Journal* 1985;109:876–885.

Karvonen MJ, Kentala E, Mustala O. The effects of training on heart rate. *Acta Medica Exp Fenn* 1957;35:308–315.

Kashiwazaki H, Inaoka T, Suzuki T, Kondo Y. Correlations of pedometer readings with energy expenditure in workers during free-living daily activities. *European Journal of Applied Physiology* 1986;54:585–590.

Katzenstein G. Ueber die Einwirkung der Muskelthätigkeit auf den Stoffverbrauch des Menschen. Pflüger EFW. *Archiv für die gesammte Physiologie des Menschen und der Thiere*. Bonn: M. Hager, 1891:49:330–404.

King AC, Haskell WL, Taylor CB, Kraemer HC, DeBusk RF. Group- vs home-based exercise training in healthy older men and women: a community-based clinical trial. *Journal of the American Medical Association* 1991;266:1535–1542.

Klein PD, James WPT, Wong WW, Irving CS, Murgatroyd PR, Cabrera M, et al. Calorimetric validation of the doubly labelled water method for determination of energy expenditure in man. *Human Nutrition, Clinical Nutrition* 1984;38C:95–106.

Klesges LM, Klesges RC. The assessment of children's physical activity: a comparison of methods. *Medicine and Science in Sports and Exercise* 1987;19:511–517.

Knehr CA, Dill DB, Neufeld W. Training and its effects on man at rest and at work. *American Journal of Physiology* 1942;136:148–156.

Kraus H, Hirschland RP. Muscular fitness and health. *Journal for Health, Physical Education, and Recreation* 1953;24:17–19.

Kriska AM, Sandler RB, Cauley JA, LaPorte RE, Hom DL, Pambianco G. The assessment of historical physical activity and its relation to adult bone parameters. *American Journal of Epidemiology* 1988;127:1053–1063.

Lagrange F. *Physiology of bodily exercise* [188]. Reprint, New York: D. Appleton, 1890.

Lakka TA, Nyyssonen K, Salonen JT. Higher levels of conditioning leisure-time physical activity are associated with reduced levels of stored iron in Finnish men. *American Journal of Epidemiology* 1994;140:148–160.

Langenfeld H. Auf dem wege zur sportwissenschaft: mediziner und leibesübungen im 19. jahrhundert. *Stadion* 1988;14:125–148.

LaPorte RE, Black-Sandler R, Cauley JA, Link M, Bayles C, Marks B. The assessment of physical activity in older women: analysis of the interrelationship and reliability of activity monitoring, activity surveys, and caloric intake. *Journal of Gerontology* 1983;38:394–397.

LaPorte RE, Montoye HJ, Caspersen CJ. Assessment of physical activity in epidemiologic research: problems and prospects. *Public Health Reports* 1985;100:131–146.

Larson LA, Yocom RD. *Measurement and evaluation in physical, health, and recreation education*. St. Louis: C.V. Mosby, 1951.

Lavoisier AL. Expériences sur la respiration des animaux, et sur les changemens qui arrivent à l'air en passant par leur poumon. *Histoire de l'Académie Royale des Sciences*. Paris: Académie des Sciences, 1777:185–194.

Lavoisier AL, de LaPlace PS. Mémoire sur la chaleur. *Histoire de l'Académie Royale des Sciences*. Paris: Académie des Sciences, 1780:355–408.

Lehmann JF, Boswell S, Price R, Burleigh A, de Lateur BJ, Jaffe KM, et al. Quantitative evaluation of sway as an indicator of functional balance in post-traumatic brain injury. *Archives of Physical Medicine and Rehabilitation* 1990;71:955–962.

Leon AS, Jacobs DR Jr, DeBacker G, Taylor HL. Relationship of physical characteristics and life habits to treadmill exercise capacity. *American Journal of Epidemiology* 1981;113:653–660.

Leonard FE, Affleck GB. *A guide to the history of physical education*. 3rd ed. Philadelphia: Lea and Febiger, 1947.

Lewis D. *The new gymnastics for men, women, and children*. New York: Clarke Brothers, 1883.

Licht S. History [of therapeutic exercise]. In: Basmajian JV, editor. *Therapeutic exercise*. 4th ed. Baltimore: Williams and Wilkins, 1984:1–44.

Lohman TG. Applicability of body composition techniques and constants for children and youths. *Exercise and Sport Sciences Reviews* 1986;14:325–357.

Lohman TG. Research progress in validation of laboratory methods of assessing body composition. *Medicine and Science in Sports and Exercise* 1984;16:596–603.

Lukaski HC, Bolonchuk WW, Hall CB, Siders WA. Validation of tetrapolar bioelectric impedance method to assess human body composition. *Journal of Applied Physiology* 1986;60:1327–1332.

Mazess RB, Barden HS, Bisek JP, Hanson J. Dual-energy x-ray absorptiometry for total-body and regional bone-mineral and soft-tissue composition. *American Journal of Clinical Nutrition* 1990;51:1106–1112.

McCloy CH. Physical fitness and citizenship. *Journal of Health and Physical Education* 1938;9:298.

McCurdy JH. The effect of maximum muscular effort on blood pressure. *American Journal of Physiology* 1901; 5:95–103.

McKenzie RT. *Exercise in education and medicine*. Philadelphia: W.B. Saunders, 1909.

McKenzie RT. The influence of exercise on the heart. *American Journal of the Medical Sciences* 1913;145: 69–74.

Mendez C. *Book of bodily exercise* [1553]. translated by F. Guerra. New Haven, CT: Elizabeth Licht, 1960.

Mercurialis H. *De arte gymnastica* [1569]. 2nd ed. Paris: Du Puys, 1577.

Mitchell JH, Blomqvist G. Maximal oxygen uptake. *New England Journal of Medicine* 1971;284:1018–1022.

Montoye HJ. The Raymond Pearl memorial lecture, 1991: health, exercise, and athletics: a millennium of observations—a century of research. *American Journal of Human Biology* 1992;4:69–82.

Montoye HJ, Cunningham DA, Welch HG, Epstein FH. Laboratory methods of assessing metabolic capacity in a large epidemiologic study. *American Journal of Epidemiology* 1970;91:38–47.

Montoye HJ, Kemper HCG, Saris WHM, Washburn RA. *Measuring physical activity and energy expenditure*. Champaign, IL: Human Kinetics, 1996.

Montoye HJ, Taylor HL. Measurement of physical activity in population studies: a review. *Human Biology* 1984;56:195–216.

Montoye HJ, Van Huss WD, Brewer WD, Jones EM, Ohlson MA, MaLoney E, et al. The effects of exercise on blood cholesterol of middle-aged men. *American Journal of Clinical Nutrition* 1959;7:139–145.

Morantz RM. Making women modern: middle-class women and health reform in 19th-century America. In: Leavitt JW, editor. *Women and health in America: historical readings*. Madison, WI: University of Wisconsin Press, 1984:346–358.

Morris JN, Heady JA, Raffle PAB, Roberts CG, Parks JW. Coronary heart disease and physical activity of work. *Lancet* 1953;2:1053–1057, 1111–1120.

Nabokov P. *Indian running: Native American history and tradition*. Santa Barbara, CA: Capra Press, 1981.

National Center for Health Statistics, Bloom B. *Current estimates from the National Health Interview Survey, United States, 1981*. Vital and Health Statistics: Series 10, No. 141. Hyattsville, MD: U.S. Department of Health and Human Services, Public Health Service, National Center for Health Statistics, 1982. DHHS Publication No. (PHS)82-1569.

National Center for Health Statistics, Wilmore JH. Design issues and alternatives in assessing physical fitness among apparently healthy adults in a health examination survey of the general population. In: *Assessing physical fitness and physical activity in population-based surveys*. Hyattsville, MD: U.S. Department of Health and Human Services, Public Health Service, National Center for Health Statistics, 1989:107–153. DHHS Publication No. (PHS)89-1253.

National Council of Young Men's Christian Associations of the United States. *Y's way to physical fitness: the complete guide to fitness testing and instruction*. Champaign, IL: Human Kinetics, 1989.

National Institutes of Health. Consensus development conference statement on physical activity and cardiovascular health, December 20, 1995, Bethesda, MD (draft statement).

Noland M, Danner F, DeWalt K, McFadden M, Kotchen JM. The measurement of physical activity in young children. *Research Quarterly for Exercise and Sport* 1990;61:146–153.

Numbers RL. Do-it-yourself the sectarian way. In: Risse GB, Numbers RL, Leavitt JW, editors. *Medicine without doctors: home health care in American history*. New York: Science History Publications, 1977:49–72.

Olivova V. Scientific and professional gymnastics. In: Olivova V, editor. *Sports and games in the ancient world.* New York: St. Martin's Press, 1985:135–145.

Paffenbarger RS Jr, Hyde RT, Wing AL, Lee IM, Jung DL, Kampert JB. The association of changes in physical activity level and other lifestyle characteristics with mortality among men. *New England Journal of Medicine* 1993;328:538–545.

Park RJ. Athletes and their training in Britain and America, 1800–1914. In: Berryman JW, Park RJ, editors. *Sport and exercise science: essays in the history of sports medicine.* Urbana, IL: University of Illinois Press, 1992:57–107.

Park RJ. *Measurement of physical fitness: a historical perspective.* Office of Disease Prevention and Health Promotion Monograph Series. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, 1989:1–35.

Park RJ. The emergence of the academic discipline of physical education in the United States. In: Brooks GA, editor. *Perspectives on the academic discipline of physical education*. Champaign, IL: Human Kinetics, 1981:20–45.

Pate RR. A new definition of youth fitness. *Physician and Sportsmedicine* 1983;11:77–83.

Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C, et al. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *Journal of the American Medical Association* 1995;273:402–407.

Pollock ML. The quantification of endurance training programs. *Exercise and Sport Sciences Reviews* 1973;1:155–188.

Pomeroy WC, White PD. Coronary heart disease in former football players. *Journal of the American Medical Association* 1958;167:711–714.

Powell KE, Thompson PD, Caspersen CJ, Kendrick JS. Physical activity and the incidence of coronary heart disease. *Annual Review of Public Health* 1987;8:253–287.

Precope J. *Hippocrates on diet and hygiene*. London: Williams, Lea, and Company, 1952.

President's Council on Physical Fitness. *Adult physical fitness: a program for men and women.* Washington, DC: U.S. Government Printing Office, 1965.

Progress of physical education. *American Journal of Education* 1826;1:19–23.

Ramazzini B. *Diseases of workers* [1713]. Translated by W.C. Wright. New York: Hafner, 1964.

Reindell H, Roskamm H, Gerschler W. *Das intervalltraining: physiologische Grundlagen, praktische Anwendungen und Schädigungsmöglichkeiten.* München: Bath, 1962.

Reiser SJ. Responsibility for personal health: a historical perspective. *Journal of Medicine and Philosophy* 1985;10:7–17.

Richardson MT, Leon AS, Jacobs DR, Ainsworth BE, Serfass R. Ability of the Caltrac® accelerometer to assess daily physical activity levels. *Journal of Cardiopulmonary Rehabilitation* 1995;15:107–113.

Ricketson S. *Means of preserving health and preventing diseases.* New York: Collins, Perkins, and Company, 1806.

Robinson S, Harmon PM. The lactic acid mechanism and certain properties of the blood in relation to training. *American Journal of Physiology* 1941;132:757–769.

Rogers F, Juneau M, Taylor CB, Haskell WL, Kraemer HC, Ahn DK, et al. Assessment by a microprocessor of adherence to home-based moderate-intensity exercise training in healthy, sedentary middle-aged men and women. *American Journal of Cardiology* 1987;60:71–75.

Rogers FB. Shadrach Ricketson (1768–1839): Quaker hygienist. *Journal of the History of Medicine* 1965;20:140–150.

Rogers JE. How has the depression in education affected physical education? *Journal of Health and Physical Education 1*934;5:12–3, 57–58.

Rook A. An investigation into the longevity of Cambridge sportsmen. *British Medical Journal* 1954;4:773–777.

Sallis JF, Buono MJ, Roby JJ, Carlson D, Nelson JA. The Caltrac® accelerometer as a physical activity monitor for school-age children. *Medicine and Science in Sports and Exercise* 1990;22:698–703.

Sallis JF, Condon SA, Goggin KJ, Roby JJ, Kolody B, Alcaraz JE. The development of self-administered physical activity surveys for 4th grade students. *Research Quarterly for Exercise and Sport* 1993;64:25–31.

Sallis JF, Patrick K. Physical activity guidelines for adolescents: consensus statement. *Pediatric Exercise Science* 1994;6:302–314.

Scharling EA. Versuche über die Quantität der, von einem Menschen in 24 Stunden ausgeathmeten, Kohlensäure. *Annalen der Chemie und Pharmacie* 1843;45:214–242.

Schneider EC, Ring GC. The influence of a moderate amount of physical training on the respiratory exchange and breathing during physical exercise. *American Journal of Physiology* 1929;91:103–114.

Segal KR, Gutin B, Presta E, Wang J, Van Itallie TB. Estimation of human body composition by electrical impedance methods: a comparative study. *Journal of Applied Physiology* 1985;58:1565–1571.

Shampo MA, Kyle RA. Nei Ching—oldest known medical book. *Mayo Clinic Proceedings* 1989;64:134.

Shea EJ. In memoriam: Thomas K. Cureton, Jr. *Journal of Physical Education, Recreation, and Dance* 1993;64:15.

Siconolfi SF, Cullinane EM, Carleton RA, Thompson PD. Assessin $\dot{V}O_2$ max in epidemiologic studies: modification of the Åstrand-Ryhming test. *Medicine and Science in Sports and Exercise* 1982;14:335–338.

Siconolfi SF, Lasater TM, Snow RC, Carleton RA. Self-reported physical activity compared with maximal oxygen uptake. *American Journal of Epidemiology* 1985;122:101–105.

Sidney S, Haskell WL, Crow R, Sternfeld B, Oberman A, Armstrong MA, et al. Symptom-limited graded treadmill exercise testing in young adults in the CARDIA study. *Medicine and Science in Sports and Exercise* 1992;24:177–183.

Sinasalo UV, Juurtola T. Comparative study of the physiological effects of two ski-training methods. *Research Quarterly* 1957;28:288–294.

Skinner JS, Benson H, McDonough JR, Hames CG. Social status, physical activity, and coronary proneness. *Journal of Chronic Diseases* 1966;19:773–783.

Sloan AW, Keen EN. Physical fitness of oarsmen and rugby players before and after training. *Journal of Applied Physiology* 1959;14:635–636.

Smith E. The influence of the labour of the tread-wheel over respiration and pulsation, and its relation to the waste of the system, and the dietary of the prisoners. *Medical Times and Gazette* 1857;14:601–603.

Smith G. Prescribing the rules of health: self-help and advice in the late eighteenth century. In: Porter R, editor. *Patients and practitioners: lay perceptions of medicine in pre-industrial society*. Cambridge: Cambridge University Press, 1985:249–282.

Snook GA. The history of sports medicine. Part 1. *American Journal of Sports Medicine* 1984;12:252–254.

Speck K. Ueber den Einfluss der Muskelthätigkeit auf dem Athemprocess. *Deutsche Archiv fur Klinische Medicin* 1889;45:461–528.

Spelman CC, Pate RR, Macera CA, Ward DS. Self-selected exercise intensity of habitual walkers. *Medicine and Science in Sports and Exercise* 1993;25:1174–1179.

Spirduso WW. Reaction and movement time as a function of age and physical activity level. *Journal of Gerontology* 1975;30:435–440.

Steinhaus AH. Health and physical fitness from the standpoint of the physiologist. *Journal of Health, Physical Education, and Recreation* 1936;7:224–227, 286–289.

Steinhaus AH, Bauer WW, Hellerbrandt FA, Kranz L, Miller A. The role of exercise in physical fitness. *Journal of Health, Physical Education, and Recreation* 1943;14:299–300, 345.

Storey TA. The influence of fatigue upon the speed of voluntary contraction of human muscle. *American Journal of Physiology* 1903;8:355–375.

Taylor CB, Kraemer HC, Bragg DA, Miles LE, Rule B, Savin WM, et al. A new system for long-term recording and processing of heart rate and physical activity in outpatients. *Computers and Biomedical Research* 1982;15:7–17.

Taylor HL, Anderson JT, Keys A. Physical activity, serum cholesterol and other lipids in man. *Proceedings of the Society for Experimental Biology and Medicine* 1957;95:383–388.

Taylor HL, Jacobs DR, Schucker B, Knudsen J, Leon AS, Debacker G. A questionnaire for the assessment of leisure-time physical activities. *Journal of Chronic Diseases* 1978;31:741–755.

Tse SK, Bailey DM. T'ai chi and postural control in the well elderly. *American Journal of Occupational Therapy* 1992;46:295–300.

U.S. Department of Agriculture, U.S. Department of Health and Human Services. *Nutrition and your health: dietary guidelines for Americans*. 4th ed. Washington, DC: U.S. Department of Agriculture, 1995. Home and Garden Bulletin No. 232.

U.S. Department of Health and Human Services. *Healthy people 2000: midcourse review and 1995 revisions*. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, 1995.

U.S. Department of Health and Human Services. *Healthy people 2000: national health promotion and disease prevention objectives, full report, with commentary*. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, 1990. DHHS Publication No. (PHS)91–50212.

U.S. Department of Health and Human Services. *The Surgeon General's report on nutrition and health*. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, 1988. DHHS Publication No. (PHS)88–50210.

U.S. Preventive Services Task Force. *Guide to clinical preventive services*. Baltimore: Williams and Wilkins, 1989.

U.S. Preventive Services Task Force. *Guide to clinical preventive services*. 2nd ed. Baltimore: Williams and Wilkins, 1996.

Van Dalen DB, Bennett BL. *A world history of physical education: cultural, philosophical, comparative*. Englewood Cliffs, NJ: Prentice-Hall, 1971.

Verbrugge MH. Healthy animals and civic life: Sylvester Graham's physiology of subsistence. *Reviews in American History* 1981;9:359–364.

Voorrips LE, Ravelli AC, Dongelmans PCA, Deurenberg P, Van Staveren WA. A physical activity questionnaire for the elderly. *Medicine and Science in Sports and Exercise* 1991;23:974–979.

Warner JH. *The therapeutic perspective: medical practice, knowledge, and identity in America, 1820–1885*. Cambridge, MA: Harvard University Press, 1986.

Washburn RA, Adams LL, Haile GT. Physical activity assessment for epidemiologic research: the utility of two simplified approaches. *Preventive Medicine* 1987;16:636–646.

Washburn RA, Janney CA, Fenster JR. The validity of objective physical activity monitoring in older individuals. *Research Quarterly for Exercise and Sport* 1990;61:114–117.

Washburn RA, Smith KW, Jette AM, Janney CA. The Physical Activity Scale for the Elderly (PASE): development and evaluation. *Journal of Clinical Epidemiology* 1993;46:153–162.

Wesley J. *Primitive physic: or, an easy and natural method of curing most diseases* [1747]. Reprint, Philadelphia: Parry Hall, 1793.

Westerterp KR, Brouns F, Saris WHM, ten Hoor F. Comparison of doubly labeled water with respirometry at low- and high-activity levels. *Journal of Applied Physiology* 1988;65:53–56.

Whorton JC. *Crusaders for fitness: the history of American health reformers*. Princeton, NJ: Princeton University Press, 1982.

Willich AFM. *Lectures on diet and regimen*. New York: T. and J. Swords, 1801.

Wilmore JH, Behnke AR. An anthropometric estimation of body density and lean body weight in young women. *American Journal of Clinical Nutrition* 1970;23:267–274.

Wilmore JH, Costill DL. *Physiology of sport and exercise*. Champaign, IL: Human Kinetics, 1994.

Wilson PWF, Paffenbarger RS, Morris JN, Havlik RJ. Assessment methods for physical activity and physical fitness in population studies: a report of an NHLBI Workshop. *American Heart Journal* 1986;111:1177–1192.

Wong TC, Webster JG, Montoye HJ, Washburn R. Portable accelerometer device for measuring human energy expenditure. *IEEE Transactions on Biomedical Engineering* 1981;28:467–471.

Yakovlev NN, Kaledin SV, Krasnova AF, Leshkevich LG, Popova NK, Rogozkin VA, et al. Physiological and chemical adaptation to muscular activity in relation to length of rest periods between exertions during training. *Sechenov-Physiological Journal of the USSR* 1961;47:56–59.

Zukel WJ, Lewis RH, Enterline PE, Painter RC, Ralston LS, Fawcett RM, et al. A short-term community study of the epidemiology of coronary heart disease: a preliminary report on the North Dakota study. *American Journal of Public Health* 1959;49:1630–1639.