PART C. BACKGROUND AND KEY PHYSICAL ACTIVITY CONCEPTS

Table of Contents

HISTORICAL PERSPECTIVE

The field of physical activity and public health has been developing at a rapid pace during the past several decades. During the 1950s and 1960s, two scientific areas – exercise science and epidemiologic

science – converged in an effort to understand and address the heart disease epidemic. In the United States, the percentage of all deaths caused by heart disease had risen from 8 to 10 percent in the early 1900s to slightly less than 40 percent by 1960.[1] By the late 1980s, scientific evidence had clearly shown that regularly performed moderate-to-vigorous physical activity reduced the risk of heart disease.[2] Evidence of other health benefits soon followed.[3] This *2018 Physical Activity Guidelines Advisory Committee Scientific Report* adds to the lengthening list of health benefits of regular physical activity.

Less well recognized has been a third area of influence beyond exercise science and epidemiologic science. In 1974, the Canadian government published a report titled *A New Perspective on the Health of Canadians*.[4] More commonly referred to as "The Lalonde Report," after the Canadian Minister of Health and Welfare, the report made a clear distinction between the clinical health care system and the arena of disease prevention and health promotion. Within disease prevention and health promotion, it called attention to the importance of "lifestyle," including physical activity. The Canadian report was followed by the U.S. report, *Healthy People: The Surgeon General's Report on Health Promotion and Disease Prevention*, which had a similar message.[5] These documents called attention to the important impact of lifestyle behaviors on the risk of disease, an observation that is now well accepted. Also widely recognized is the fact that individual behaviors, including physical activity behaviors, are determined not solely by individual choice but by social and cultural factors as well as environmental impediments or opportunities.

Thus, while exercise science and epidemiologic science remain central to the field of physical activity and public health, the field now includes an array of other scientific disciplines. Behavioral science, clinical science, recreation science, transportation science, city planning, political science, and other disciplines are now recognized to be essential for the proper study and practice of physical activity and public health.

The widening range of scientific fields currently contributing to this topic reflects the recognition that physical activity is embedded and intricately connected to every aspect of daily life. No longer viewed only as distinct and prolonged bouts of "vigorous physical exercise,"[6] physical activity is recognized as encompassing the accumulation of movement occurring throughout the day, regardless of location, type, or purpose. This broader view of physical activity complicates the study, understanding, and discussion of this key health behavior. The purpose of this chapter is to provide a brief discussion of

physical activity-related terminology and issues that may help readers understand the concepts, evidence, and interpretations that are presented elsewhere in this report.

The *Physical Activity Guidelines Advisory Committee Report, 2008*[7] and the *2008 Physical Activity Guidelines for Americans*[8] demonstrated that the importance and value of physical activity and public health had been recognized at the highest level of government. The 2018 Scientific Report is further evidence of the importance of physical activity to the national interest.

PHYSICAL ACTIVITY TERMS AND DIMENSIONS

As the field has matured and the complexity of physical activity has become more apparent, applying clear definitions and descriptions of relevant concepts and issues has become increasingly important. In this document, the Committee has endeavored to use the most appropriate terms for the physical activity behaviors and concepts being discussed.

Core Terms

Physical activity is bodily movement produced by skeletal muscles that results in energy expenditure.[9] The term, physical activity, does not require or imply any specific aspect or quality of movement. The term encompasses all types, intensities, and domains. Although the term "physical activity" has been used often as a short-hand description for moderate-to-vigorous-intensity forms of physical activity, given current interest and discussions about physical activity of intensities less than moderate-intensity (i.e., <3 METs, see description below), the term "physical activity" should be used when discussing the full range of intensities. More specific descriptors such as sedentary behavior, light, moderate, vigorous, or moderate-to-vigorous should be used when talking about a specific range of intensities.

Exercise is physical activity that is planned, structured, repetitive, and designed to improve or maintain physical fitness, physical performance, or health.[9] Exercise, like physical activity, encompasses all intensities. The word exercise, like the term physical activity, has been used often to mean moderate-to-vigorous-intensity physical activity. However, it is preferable to specify the intensity when discussing or describing exercise.

Sedentary behavior is any waking behavior characterized by an energy expenditure 1.5 or fewer METs while sitting, reclining, or lying.[10] Most office work, driving a car, and sitting while watching television are examples of sedentary behaviors.

Non-exercise physical activity is a phrase that encompasses all physical activity that is not exercise. It has been used to mean various types and intensities of physical activity, mostly light intensity physical activity. Given its ambiguity, however, clearer descriptions of the physical activity behavior of interest are preferable.

Types of Physical Activity

Specific Types of Activity

A common way of describing physical activity type is to specify the activity under discussion. Walking, bicycling, tai chi, bocce ball, gardening, and vacuuming are examples of specific activities.

Activity by Predominant Physiologic Effect

Aerobic Physical Activity

Aerobic physical activity includes forms of activity that are intense enough and performed long enough to maintain or improve an individual's cardiorespiratory fitness. Aerobic activities such as walking, basketball, soccer, or dancing, commonly require the use of large muscle groups. The connection between aerobic activities such as these and cardiorespiratory fitness is sufficiently close that the term "aerobic capacity" is considered equivalent to cardiorespiratory fitness. Technically, aerobic physical activity includes any activity that could be maintained using only oxygen-supported metabolic energy pathways and could be continued for more than a few minutes. However, since the publication of *Aerobics* in 1969[11] in both common and scientific usage, "aerobic" activity has come to mean physical activity that would be expected to maintain or improve cardiorespiratory fitness or aerobic capacity.

Anaerobic Physical Activity

Anaerobic physical activity refers to high-intensity activity that exceeds the capacity of the cardiovascular system to provide oxygen to muscle cells for the usual oxygen consuming metabolic pathways. Anaerobic activity can be maintained for only about 2 to 3 minutes. Sprinting and power lifting are examples of anaerobic physical activity.

Muscle-strengthening Activities

Muscle-strengthening activities maintain or improve muscular strength (how much resistance can be overcome), endurance (how many times or for how long resistance can be overcome), or power (how fast can the resistance be overcome). Muscle-strengthening activities include everyday behaviors, such as carrying heavy groceries, shoveling snow, lifting children, or climbing stairs, as well as the use of exercise equipment, such as weight machines, free weights, or elastic bands.

Bone-strengthening Activities

Bone-strengthening activities are movements that create impact and muscle-loading forces on bone. These forces stress the bone, which adapts by modifying its structure (shape) or mass (mineral content), thereby increasing its resistance to fracture. Jumping, hopping, skipping, and dancing are activities that are good for bone strengthening, as are muscle-strengthening activities.

Balance Training

Balance training activities are movements that safely challenge postural control. If practiced regularly, they improve the ability to resist intrinsic or environmental forces that cause falls whether walking, standing, or sitting. Standing on one foot, walking heel-to-toe, the balance walk, and using a wobble board are examples of balance training activities.[12, 13]

Flexibility Training

Flexibility training, also called stretching, improves the range and ease of movement around a joint. Dynamic stretching, such as the movements of tai chi, qigong, and yoga, and static stretching are examples of flexibility training.

Yoga, Tai Chi, and Qigong

These activities, whose origins lie outside of Western culture, typically combine muscle-strengthening, balance training, light-intensity aerobic activity, and flexibility in one package. Some variations of yoga, tai chi, and qigong emphasize relaxation, meditation, or spirituality as well. As a result, are sometimes referred to as “mind-body” activities.

Domains of Physical Activity

As noted above, physical activity occurs throughout the day, for a variety of purposes, and in many types of settings. Occupational forms of physical activity were the focus of most of the initial epidemiologic studies on physical activity and health.[14, 15] As occupations requiring high levels of physical activity

declined, the research focus shifted to leisure-time or recreational physical activity.[16, 17] Most of the research findings summarized for this report are based on studies of leisure-time physical activities. For many individuals, physical activity during leisure-time is more easily modified than during other domains and includes the majority of moderate-to-vigorous intensity activities.

Nevertheless, physical activity can and does occur throughout all portions of the day, and, with few exceptions, the health-enhancing value of physical activity is independent of the purpose for performing it. As a result, non-leisure forms of physical activity, such as transport-related physical activities like cycling to work, are now recognized as options for physical activity promotion. There are many ways of grouping physical activity. One popular method categorizes physical activity into four domains, as follows:

- **Occupational physical activity** is performed while one is working. Stocking shelves in a store, delivering packages in an office, preparing or serving food in restaurant, or carrying tools in a garage are examples of occupational physical activity.
- **Transportation physical activity** is performed in order to get from one place to another. Walking or bicycling to and from work, school, transportation hubs, or a shopping center are examples.
- **Household physical activity** is done in or around one's home. It includes household tasks such as cooking, cleaning, home repair, yardwork, or gardening.
- **Leisure-time physical activity** is performed at one's discretion when one is not working, transporting to a different location, and not doing household chores. Sports or exercise, going for a walk, and playing games (hopscotch, basketball) are examples of leisure-time physical activity.

Body Position

The rising interest and recognized importance of low energy expenditure activities call attention to body position during physical activity. Physical activity occurs in any body position. Some positions, notably, lying, reclining, and sitting, facilitate less bodily movement and energy expenditure than do standing or ambulating. Recently developed motion sensors can measure low levels of physical activity more accurately than previously possible and have enabled research in this area. Given the large amount of awake time that is spent sitting, much of the research has focused upon sitting. To promote standard terminology and improve communication, researchers have collaborated in the development of a proposed set of definitions for research in this area.[10] The definition of sedentary behavior, "any waking

behavior characterized by an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture," is used throughout this report.

Absolute and Relative Intensity

Absolute Intensity

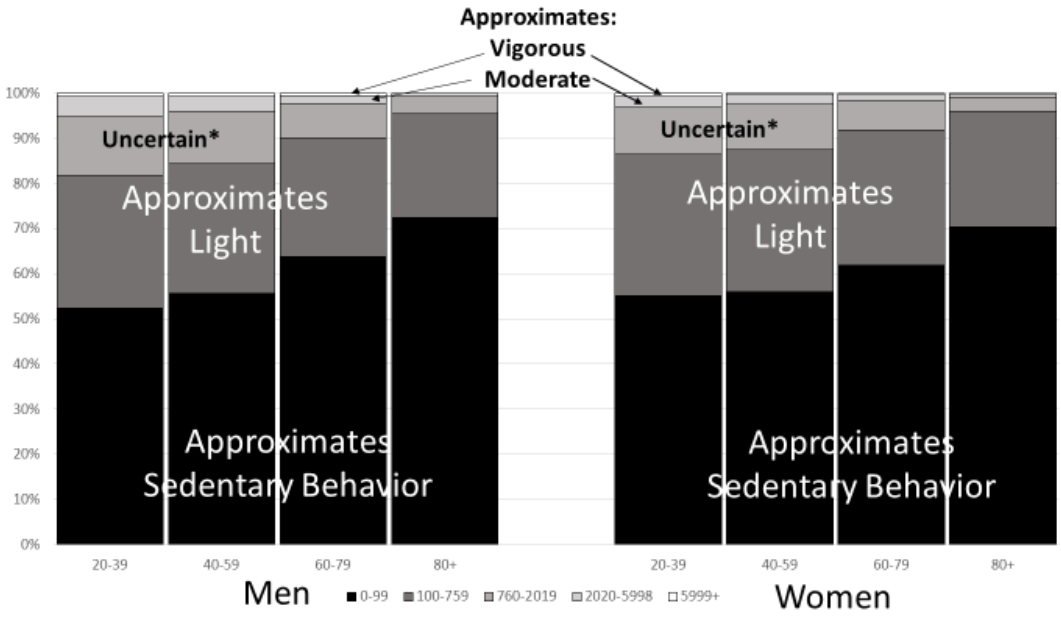
Absolute intensity is the rate of energy expenditure required to perform any physical activity. It can be measured in METs, kilocalories, joules, or oxygen consumption. The most commonly mentioned unit in this report is the MET. One MET is the rate of energy expenditure while sitting at rest, which, for most people approximates an oxygen uptake of 3.5 milliliters per kilogram per minute. The energy expenditure of other activities is expressed in multiples of METs. For example, for the average adult, sitting and reading requires about 1.3 METs. Strolling or walking slowly requires about 2.0 METs. Walking at about 3.0 miles per hour requires about 3.3 METs, and running at 5 miles per hour requires about 8.3 METs. The average rate of energy expenditure for a substantial number of activities has been documented for the general adult population[18] and for children and youth ages 6 to 18.[19]

Absolute rates of energy expenditure commonly have been divided into 4 categories.

- **Vigorous-intensity activity** requires 6.0 or greater METs; examples include walking very fast (4.5 to 5 mph), running, carrying heavy groceries or other loads upstairs, shoveling snow by hand, mowing grass with a hand-push mower, or participating in an aerobics class. Adults generally spend less than 1 percent of waking time in vigorous activity (Figure C-1).[20]
- **Moderate-intensity activity** requires 3.0 to less than 6.0 METs; examples include walking briskly or with purpose (3 to 4 mph), mopping or vacuuming, or raking a yard.
- **Light-intensity activity** requires 1.6 to less than 3.0 METs; examples include walking at a slow or leisurely pace (2 mph or less), cooking activities, or standing while scanning groceries as a cashier.
- Physical activity requiring 1.0 to 1.5 METs have, in the past, been referred to as "sedentary activity." Almost all these physical activities are included in the term "sedentary behavior," defined earlier to be any waking behavior characterized by an energy expenditure 1.5 or fewer METs while sitting, reclining, or lying.[10] The one common activity with an energy expenditure of 1.5 METs not included within sedentary behavior is standing quietly. Continued use of the term "sedentary activity" is sure to be confusing, especially because standing is the only behavior within it not covered by "sedentary behavior." In this report, the Committee has simply used the

word standing whenever necessary. These low-intensity physical activity behaviors are very common. Accelerometer-based estimates indicate that adults in the United States spend more than 50 percent of their waking time in physical activities requiring an estimated 1.0 to 1.5 METs (Figure C-1).[21]

Figure C-1. Proportion of Time-awake at Different Categories of Accelerometer Counts for U.S. Adults, by Sex and Age Group, 2003-2004



Note: *=Some researchers categorize counts in this range as light-intensity, others as moderate-intensity.
Source: Adapted from data found in Matthew, 2005,[22] and Troiano et al., 2008.[20]

Relative Intensity

For the general young to middle-aged adult population, the terms used to describe the rate of energy expenditure – light, moderate, vigorous – adequately represent the perceived level of effort to perform an activity. Older individuals, those with certain physical impairments, or individuals who have been very inactive may have a lower aerobic capacity and, as a result, may perceive the activity to be relatively more difficult to perform,[23] thereby creating a mismatch between the word used to describe the absolute rate of energy expenditure and the individual's perceived level of effort.

Relative intensity refers to the ease or difficulty with which an individual performs any given physical activity. It has a physiologic basis and can be described using physiologic parameters, such as percent of

aerobic capacity (VO_2max) or percent of maximal heart rate. Relative intensity can also be measured with tools that assess an individual's perception about how difficult it is to perform an activity. A variety of tools have been developed to help individuals self-regulate the relative intensity of their aerobic physical activity. For ease of use in non-clinical settings, the sing-talk test is the simplest. During light-intensity activities most people are able to sing, during moderate-intensity they can talk but not sing, and during vigorous activities, even talking is difficult.[24] Also simple to use is a 10-point scale, originally designed as a communication tool, where 0 is sitting and 10 is the greatest effort possible.[8] Moderate-intensity physical activity is about half way (five or six points), with vigorous higher (seven or eight). In general, an individual's subjective assessment of how hard he or she is working corresponds well with laboratory-based assessments of capacity.

The contrast between absolute and relative intensities can be highlighted by noting that the focus of absolute intensity is the activity, whereas the focus of relative intensity is the individual's level of effort during the activity. Observational population-based studies typically determine what an individual has done and estimate the energy required to do it, so the measurement is absolute. Experimental studies typically use relative intensity in prescribing a program of physical activity to ensure the desired level of effort is appropriate for the individual.

Dose, Volume, and Dose-response for Aerobic Activities

Dose

Dose of aerobic physical activity is the type and amount of reported or prescribed physical activity. Physical activity may be prescribed for improving health, rehabilitation, training, or research. As devices to measure physical activity become more common and functional in both research and popular use, modifications in the components and summary descriptors of dose are likely.

The components of dose for aerobic physical activity are the frequency, duration, and intensity of the physical activity:

- **Frequency** is usually counted as sessions or bouts of moderate-to-vigorous physical activity per day or per week.
- **Duration** is the length of time for each session or bout.
- **Intensity** is the rate of energy expended during the physical activity session or bout, usually in METs.

Dose is commonly calculated for a specific period of time, such as per day or per week, and, for aerobic activity, has been limited to moderate-to-vigorous physical activity because those are the intensities known to provide benefits. Increasingly, the acronym FITT, standing for frequency, intensity, time (duration), and type of activity (e.g., aerobic, muscle-strengthening) has been used to describe physical activity dose.[25]

Volume

Volume is the quantification of the dose of activity accumulated over a specified length of time. Volume is usually expressed in MET-minutes or MET-hours per day or week. It is calculated by multiplying the physical activity frequency and duration by the MET values corresponding to that physical activity. For activities, such as walking or running, where a rate of energy expenditure at any given speed is a fixed amount, volume is sometimes simplified to minutes or hours of the activity, such as minutes per week of walking. Kilocalories per day or per week is used is used less frequently.

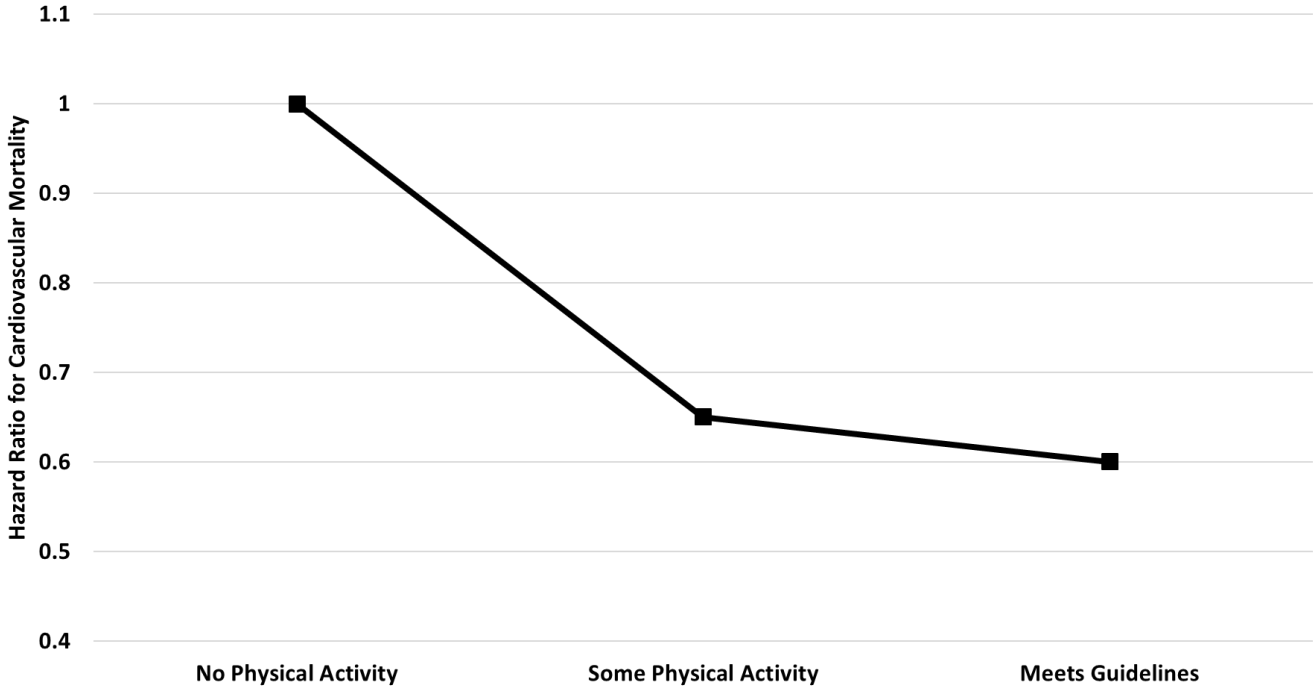
As the use of personal devices (see Devices, below) to measure physical activity has increased, volume is sometimes expressed as activity counts or step counts during a set period of time. Steps are easily counted. Step counts are easily understood by individuals and the media. They are a useful prescription tool for health care providers and trainers. Step counts blend well with public health messages encouraging the use of stairs rather than elevators, walking in airports rather than taking the train or shuttle, or parking at a distance from the final destination. Step counts include light- as well as moderate- and vigorous-intensity physical activity. As a result, the number of steps that would be equivalent to 150 to 300 minutes per week of moderate-to-vigorous physical activity varies from individual to individual and it may be less than the commonly suggested 10,000 steps.[26, 27] Regardless, step counts are simple to use, can be tailored to meet individual needs, and appear to be useful for monitoring progress toward personal goals.[8]

Dose-response

Dose-response is the relationship between the dose or volume of physical activity and the magnitude of change, if any, in the health outcome or physiologic change. A graduated response—small dose with small response, large dose with large response—is evidence of the truth of the relationship. For ordinal data, a dose-response relationship requires at least three levels of exposure, in this case three volumes of physical activity (Figure C-2). For data collected as a continuous variable, differing shapes of the relationship can be examined. The shape of a dose response curve adds importantly to the

understanding of the relationship. For example, in Figure C-2, the shape indicates that the majority of the reduction in mortality risk among individuals with type 2 diabetes is achieved by moving from "no activity" to "some activity", and that meeting the Guidelines confers additional benefits.

Figure C-2. Risk of Cardiovascular Mortality Among People with Type 2 Diabetes by Dose of Physical Activity



Source: Adapted from data found in Sadarangani et al., 2014.[28]

MEASURING PHYSICAL ACTIVITY

Measuring physical activity with reasonable accuracy and acceptable cost is vital to the understanding of the relationship between physical activity and health. Because of the complexity of physical activity, measuring it may be the most difficult aspect of the study and promotion of physical activity.

Over time, the preferred method of measuring physical activity behavior has changed. Early epidemiologic studies commonly relied upon job categories to categorize workers into higher or lower levels of physical activity. As mechanization reduced the number of jobs requiring substantial amounts of physical activity, questionnaires to assess primarily leisure-time physical activity became the predominant method. Recently, technological advances have made possible the development of devices

to assess bodily movement. The accuracy of devices has improved and the cost has declined such that devices are now the preferred measurement tool in many epidemiologic studies.

Occupational Categories

Estimates of the energy requirements for various job categories provided an inexpensive and simple method of dividing individuals into higher and lower physical activity categories. Only employed individuals, mostly men, were included and the method assumes all workers in the same category expend about the same energy on the job. The decline in physically demanding jobs has made job categories a less useful measurement tool than they were 60 to 70 years ago. Nevertheless, the method provided persuasive evidence that individuals who were more physically active had lower rates of cardiovascular disease than did their co-workers who had less physically demanding jobs.

Questionnaires

Information for questionnaires usually comes from individuals reporting on their own physical activity behavior. It may also come from proxy reporters, such as parents of young children, or observers watching the physical activity of others. Several general categories of questionnaires have been developed, as have large numbers of specific questionnaires within each category. Global questionnaires strive to place individuals into physical activity categories using one or more questions. Quantitative history questionnaires use more questions to inquire about participation in specific activities or activities of specific intensity, almost always moderate-to-vigorous intensity. Physical activity diaries are another form of questionnaire. Many recent questionnaires have begun to inquire about sedentary or sitting behaviors but, for the most part, questionnaires have focused upon moderate-to-vigorous physical activity because those activities are most easily remembered. Questionnaires generally do an adequate job of ranking individuals from high to low physical activity volumes. They are less accurate determining the actual volume of moderate-to-vigorous physical activity performed. Questionnaires are capable of determining the specific activities performed and the domains for those activities. Individuals can also report the relative intensity of their activities. The use of the Internet to administer questionnaires and to collate the responses has reduced the burden on both respondents and researchers.

Devices

The types and accuracy of devices to measure physical movement have been improving rapidly and their cost has steadily declined. Formerly, devices were one of two general types: pedometers, devices that

counted steps, and accelerometers, devices that measured truncal or limb movement. With current technology, accelerometers are now available as smart phone apps and components of wrist watches. They have become more accurate at assessing upper body as well as lower body movements and some are waterproof, enabling the assessment of water activities. Many of these systems use a variety of sensors and technologies and are referred to as "multi-sensor systems." They measure steps, often are paired with global positioning systems providing estimates of speed and distance, and some include heart rate monitors, making estimates of relative as well as absolute energy expenditure possible. The advances in measurement of bodily movement, especially light-intensity physical activities, will continue to improve knowledge and understanding of the relationship between physical activity and health.

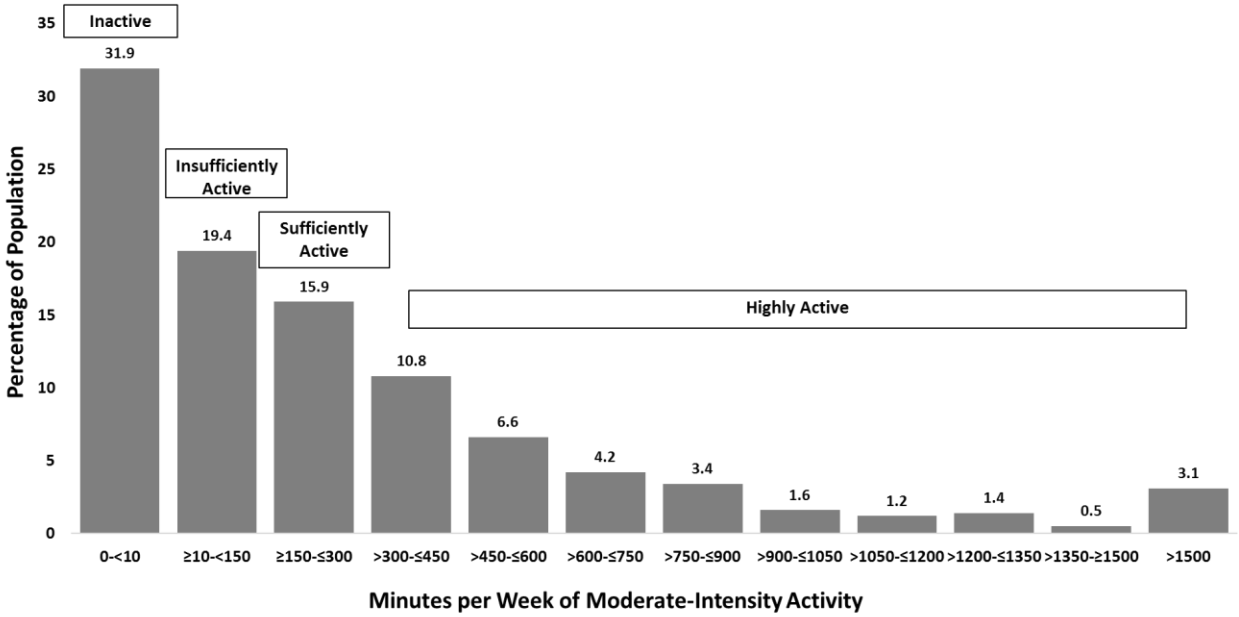
MONITORING PHYSICAL ACTIVITY

Monitoring the status of selected health indicators is a vital function of public health agencies and a critical factor in the allocation of public health resources. Public health agencies now monitor, in addition to causes of death, disease incidence and prevalence, and the prevalence of important health-related behaviors, such as physical activity. They now also recognize the importance of monitoring factors that facilitate or impede physical activity, such as policies and environments. As indicated in the previous section, physical activity is difficult to measure and monitor precisely. Until recently, public health monitoring systems used only self-report instruments. Device-measured physical activity monitoring systems are becoming more available, and already provide useful supplements to existing national systems. The increasing use and capacity of devices that measure physical activity is likely to both enable and require flexibility and change in public health physical activity monitoring systems in the near future.

This section provides examples of useful information provided by public health monitoring systems. One simple and important use of monitoring data is to describe the proportion of individuals performing different amounts of physical activity (Figure C-3). About half of the U.S. adult population reports that they accumulate less than the target range of 150 to 300 minutes of leisure-time moderate-intensity equivalent physical activity each week. Nearly one-third are classified as "inactive," meaning that they report doing less than 10 minutes of moderate-to-vigorous physical activity. Because the benefits for several important health outcomes, such as cardiovascular disease, type 2 diabetes, and all-cause mortality, accrue rapidly at the lower end of the physical activity range, facilitating more physical activity

among the individuals who are inactive would be expected to produce substantial reductions in morbidity and mortality.

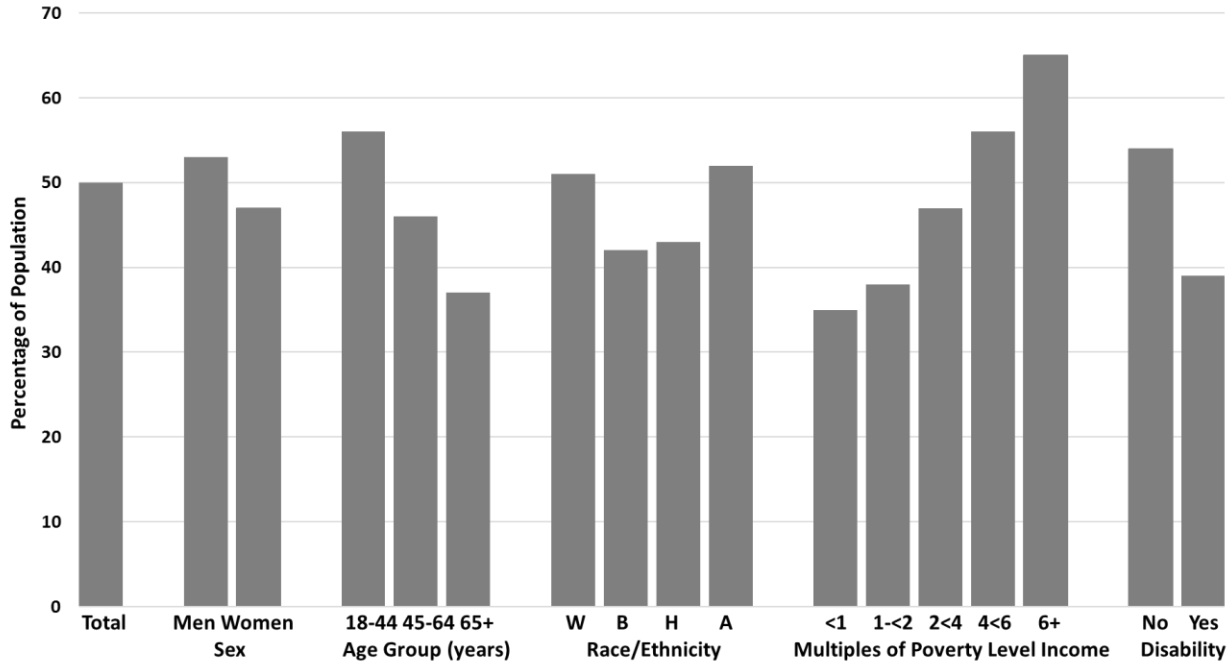
Figure C-3. Distribution of Self-Reported Volume of Moderate-to-Vigorous Physical Activity, 150 Minutes per Week Increments, U.S. Adults, 2015



Source: Adapted from data found in the National Health Interview Survey, 2015.[29]

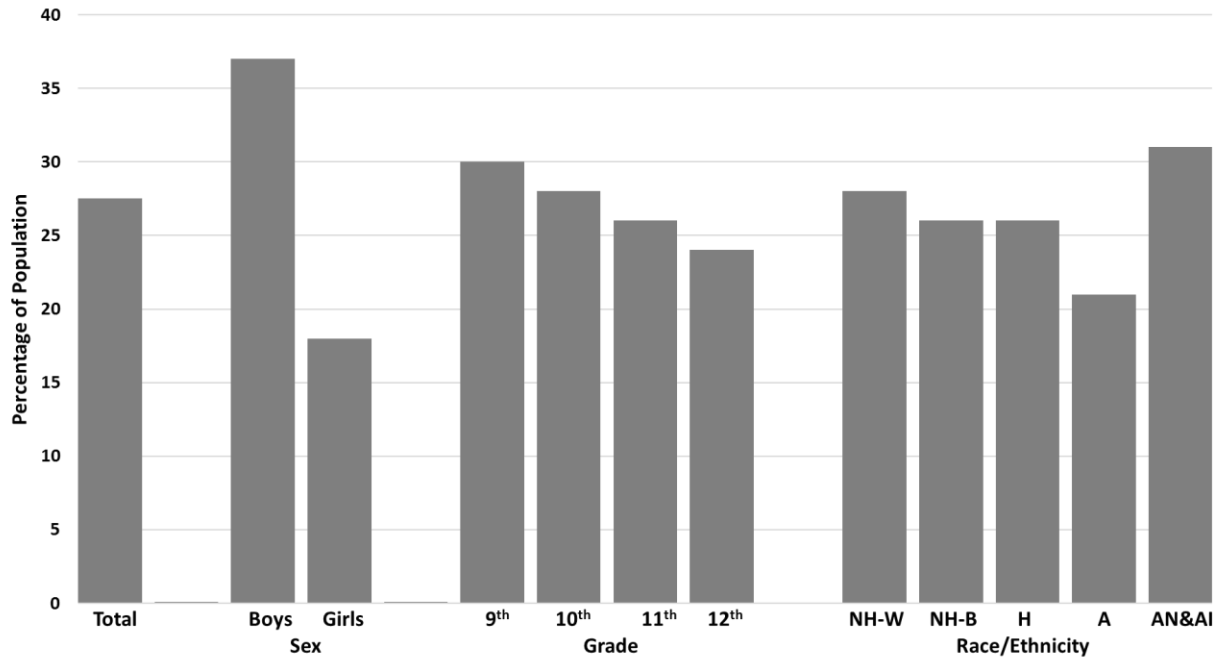
Another important use of monitoring data is to identify population subgroups who stand to benefit the most from increasing their physical activity level (Figure C-4). The proportion of adults in or above the target range differ substantially and systematically across age groups, income groups, and by disability status. Similar information is available for high school students (Figure C-5).

Figure C-4. Percentage Adults within or above Target Range for Moderate-to-Vigorous Physical Activity by Population Subgroup, 2015



Legend: W=White, B=Black, H=Hispanic, A=Asian.
Note: Estimates are age-adjusted using the year 2000 standard population.
Source: Adapted from data found in the National Health Interview Survey, 2015.[29]

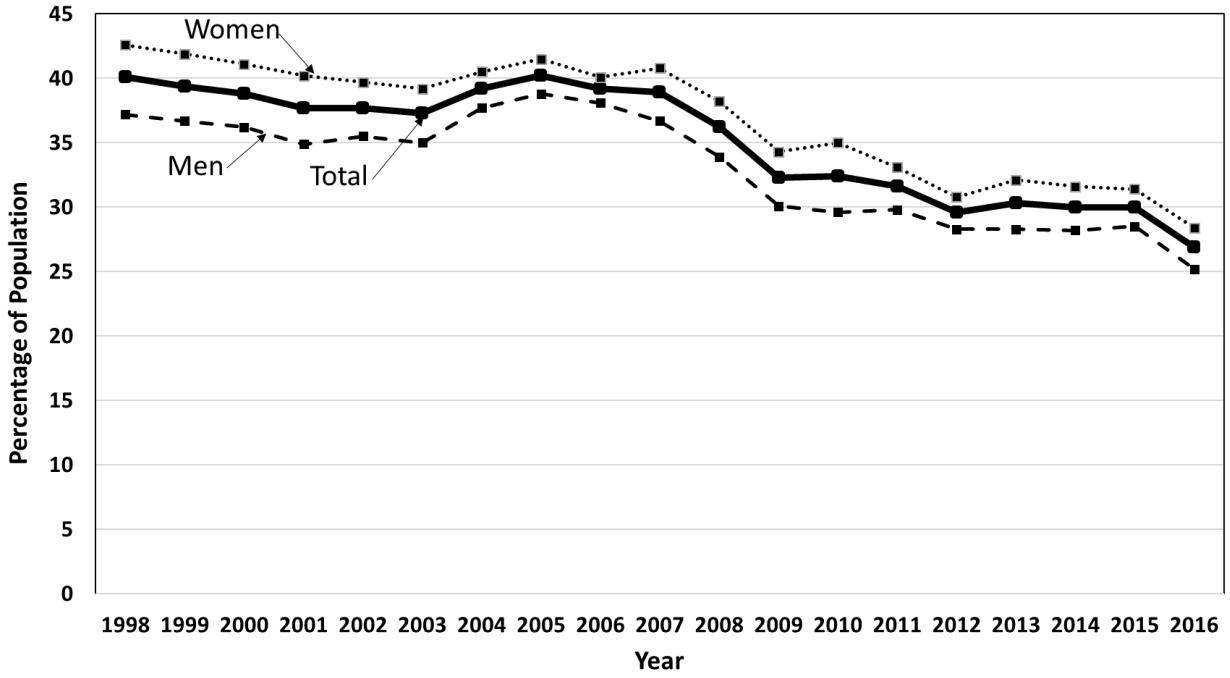
Figure C-5. Percentage of High School Students Meeting Aerobic Target Range, 2013



Legend: NH-W=Non-Hispanic White, NH-B=Non-Hispanic Black, H=Hispanic, A=Asian, AN&AI=Alaska Native and American Indian.
Source: Adapted from data found in the Youth Risk Behavior Survey, 2013.[30]

In addition to information about the current prevalence of physical activity behaviors overall and among subgroups, public health monitoring systems also provide information about changes, if any, over time (Figure C-6). National estimates of changes in prevalence over time provide information about the overall impact of the multiple factors that influence physical activity behaviors. Data from the National Health Interview Survey suggest that from 1998 through 2015 the prevalence of individuals who report doing no leisure-time moderate-to-vigorous physical activity has declined from about 40 percent to 30 percent.[29] The decline has occurred for both women and men.[29]

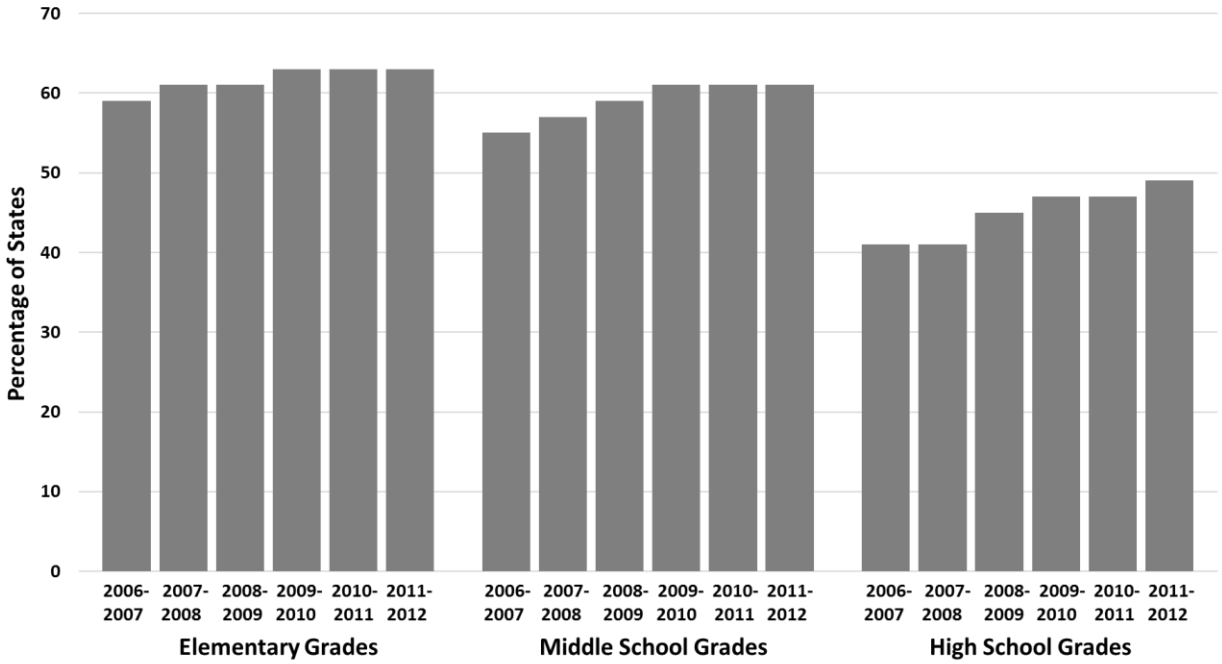
Figure C-6. Prevalence of Adults Who Engage in No Leisure-time Moderate-to-Vigorous Physical Activity, by Sex and Year, 1998 to 2015



Note: Estimates are age-adjusted using the year 2000 standard population.
Source: Adapted from data found in the National Health Interview Survey, 1998-2015.[29]

In addition to monitoring the prevalence of physical activity among population subgroups and over time, current surveillance systems are beginning to monitor the prevalence of policies and environmental characteristics that facilitate regular physical activity participation. For example, the number of states with clear physical education curriculum policies in elementary, middle, and high schools has slowly risen between 2006 and 2012 (Figure C-7).[31]

Figure C-7. Percentage of States with a Clear Physical Education Policy, by Level of School, School Years 2006-2007 to 2011-2012



Source: Adapted from data found in Institute of Medicine, 2013.[31]

PHYSICAL FITNESS

Physical fitness is a physiologic attribute determining a person's ability to perform muscle-powered work. A fundamental manifestation of this attribute is the ability to move—for example, to walk, run, climb stairs, and lift heavy objects. As a result, physical fitness is an important factor in the ability of individuals to perform routine daily activities and an important issue from a public health perspective. Physical fitness has been defined 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 respond to emergencies."[32]

The concept of physical fitness typically has been operationalized as a multicomponent construct including cardiorespiratory endurance (aerobic power), musculoskeletal fitness, flexibility, balance, and speed of movement (see Table C-1). For the purposes of this report, to the term "fitness" refers to this general sense.

Table C-1. Components of Physical Fitness

Cardiorespiratory Endurance	The ability to perform large-muscle, whole-body exercise at moderate to high intensities for extended periods of time.
Musculoskeletal Fitness	The integrated function of muscle strength, muscle endurance, and muscle power to enable performance of work.
Flexibility	The range of motion available at a joint or group of joints.
Balance	The ability to maintain equilibrium while moving or while stationary.
Speed	The ability to move the body quickly.

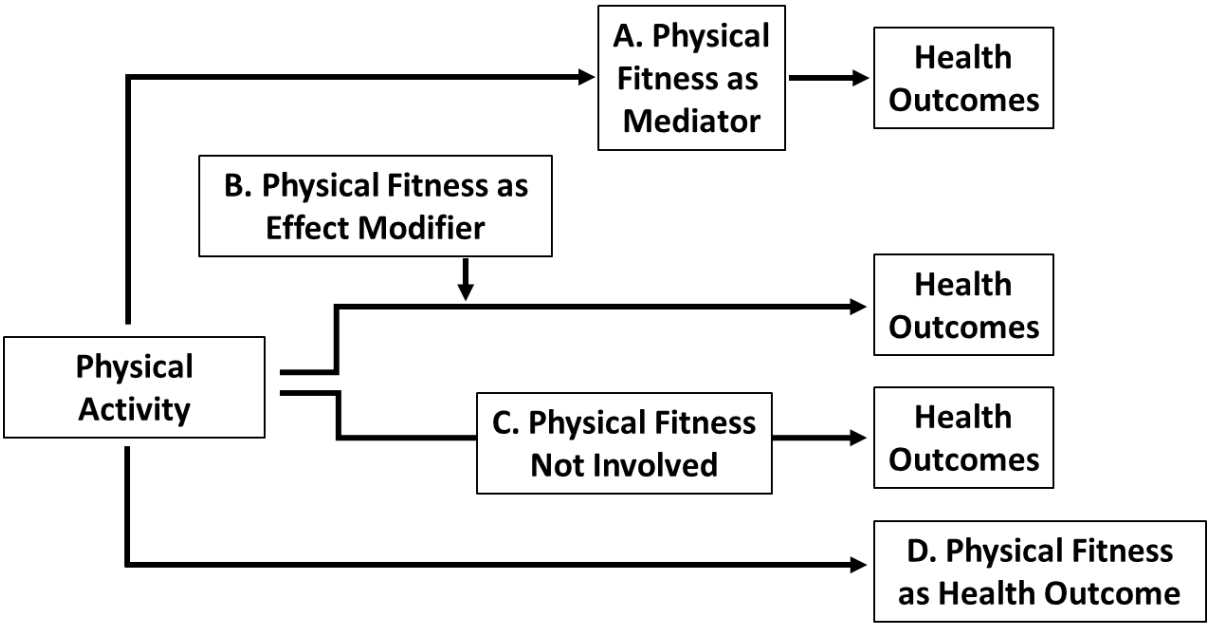
A large volume of research has focused on the relationship between physical activity and health. The findings of that research, summarized elsewhere throughout this report, identify multiple health benefits associated with maintaining greater amounts of physical activity. In addition, a substantial body of research has examined the relationship between physical fitness—cardiorespiratory fitness and, in some cases, musculoskeletal fitness—and health outcomes. The findings show that greater physical fitness is associated with reduced all-cause mortality, cardiovascular disease mortality, and risk of developing a wide range of non-communicable diseases.[33] To date, the majority of this information has been acquired in men, but some data now indicate that these relationships also exist in women.[33]

Thus, compelling scientific evidence indicates that both physical activity and physical fitness provide important health benefits. In addition, it is clear that physical activity and physical fitness are positively correlated,[34] and it is well documented that increases in the amounts and intensities of physical activity typically produce increases in physical fitness, particularly in those who are less physically active at baseline.[35] Accordingly, it is reasonable to question the independence of the relationships between physical activity and physical fitness with health outcomes. In some epidemiological studies it has been possible to examine, independently, the associations of both physical activity and fitness on the incidence of disease outcomes.[36] This research shows that physical activity behavior accounts for only a portion of the impact of physical fitness on health.[37] Similarly, the impact of physical activity on health is partially explained by its effect on physical fitness.[37]

The available evidence suggests that physical activity and physical fitness interact in their effects on a variety of health outcomes. Given that both physical activity and physical fitness are complex

multicomponent concepts, it is likely that they interact in a variety of ways to influence health. Figure C-8 is a simple conceptual framework for observational studies. Figure C-9 is a simple conceptual framework for intervention studies.[38, 39] Both are intended to stimulate thought, discussion, and research into the mechanisms of greatest importance to the field of physical activity and public health. The models will be improved by future investigations.

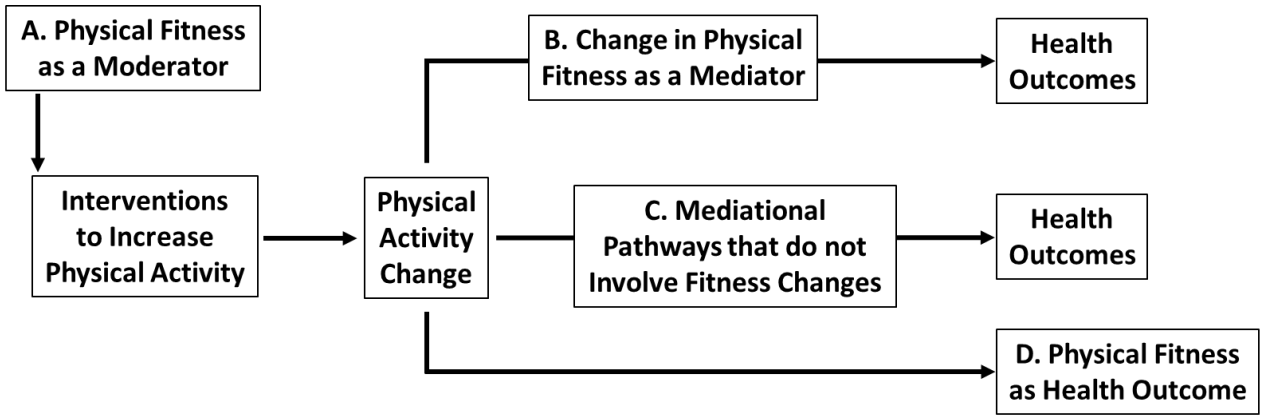
Figure C-8. The Role of Physical Fitness along Various Pathways between Physical Activity and Health Outcomes, Observational Studies



- **Pathway A:** Physical fitness may serve as an intermediate variable along the pathway between physical activity and health outcomes. Synonyms for intermediate variable include contingent variable, intervening (causal) variable, and mediator variable.[40] Intermediate variables lie along the pathway between the exposure and outcome of interest. In this case, physical activity induces changes in physical fitness and physical fitness causes changes in the health outcome.
- **Pathway B:** Physical fitness may serve as an effect modifier. Synonyms for effect modifier include moderator variable or antecedent moderator.[40] Effect modifiers operate outside of the causal chain to influence the effect of the exposure variable on the outcome. If, in an observational study, the participants are stratified according a component of physical fitness and the beneficial effect of a greater volume of physical activity compared to a lower volume differs between strata of physical fitness, then physical fitness is an effect modifier.

- **Pathway C:** Physical activity may be associated with health outcomes through pathways that do not involve physical fitness.
- **Pathway D:** Physical fitness may be considered as an outcome itself. Individuals who are more physically fit are better able "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"—in other words, the definition of fitness suggested above.

Figure C-9. The Role of Physical Fitness along Various Pathways between Physical Activity and Health Outcomes, Intervention Studies



- **Pathway A:** This pathway represents the potential moderating influence of initial physical fitness on interventions to increase physical activity. Baseline physical fitness can exert an important influence on responses to interventions aimed at increasing physical activity. For example, individuals with low baseline fitness may not respond behaviorally as well as individuals with high baseline fitness to interventions emphasizing vigorous physical activity,[41] or may require a more gradual increase in intensity to achieve comparable effects.
- **Pathway B:** This pathway represents the potential mediating influence of changes in physical fitness on the health effects derived from physical activity increases. With an increase in physical activity, a change in physical fitness can mediate some of the resultant health effects, such that the health effects accrue directly in relation to the increases in fitness. In theory, for some health outcomes, an increase in physical activity may produce change in a health outcome only if physical fitness is increased.
- **Pathway C:** Physical activity may be associated with health outcomes through pathways that do not involve changes in physical fitness.

- **Pathway D:** An increase in physical fitness represents an important health outcome in its own right.

Although physical activity is the primary exposure of public health concern, physical fitness is an appropriate addition to the list of outcomes important to public health. For many years, physical fitness has been used as an appropriate public health outcome for children and youth, and physical function has been recognized as an important health outcome for older adults. Missing has been the recognition that improved physical fitness is important in the everyday lives of young and middle-aged adults, as well. Depending upon the physical activity regimen and population, physical fitness can change relatively quickly in response to an increase in physical activity.[42] As such changes are typically readily detected by individuals who have increased their physical activity, physical fitness can serve as an important source of positive reinforcement for individuals who have adopted a higher level of activity. It is important to note that, like many other physiologic characteristics, an individual's physical fitness is affected by both genetic factors and behavior. Accordingly, it is to be expected that the extent to which physical fitness is enhanced by an increase in physical activity varies from individual to individual.

PHYSICAL ACTIVITY ACROSS THE LIFE COURSE

Physical activity capacity, preferences, and needs vary substantially across the life course. This creates a tension between the need for public health guidelines to be simple and the need to properly account for the variation among age groups. Current practice is to divide the population into three primary age-groups—youth, adults, and older adults—with several subcategories for the youth group (Table C-2). The break between youth and adults represents the transition from secondary school to higher education or full-time work; the break between adults and older adults is less clear-cut but generally centers on retirement. These breaks represent significant changes in social and environmental factors that influence physical activity participation and are, therefore, important in understanding and designing successful physical activity promotion strategies. These breaks also represent changes in the health outcomes associated with physical activity. Specifically, the youth guidelines are designed to ensure healthy growth and development, the adult guidelines primarily address disease prevention, and the older adult guidelines center on slowing the loss of function due to aging. The differences in these three paradigms (growth and development, disease prevention, maintenance of function) are reflected

in the differences in recommended volumes and types of health-related physical activity across the life course.

Table C-2. Age Groups in National Physical Activity Guidelines or Recommendations from Five Developed Nations

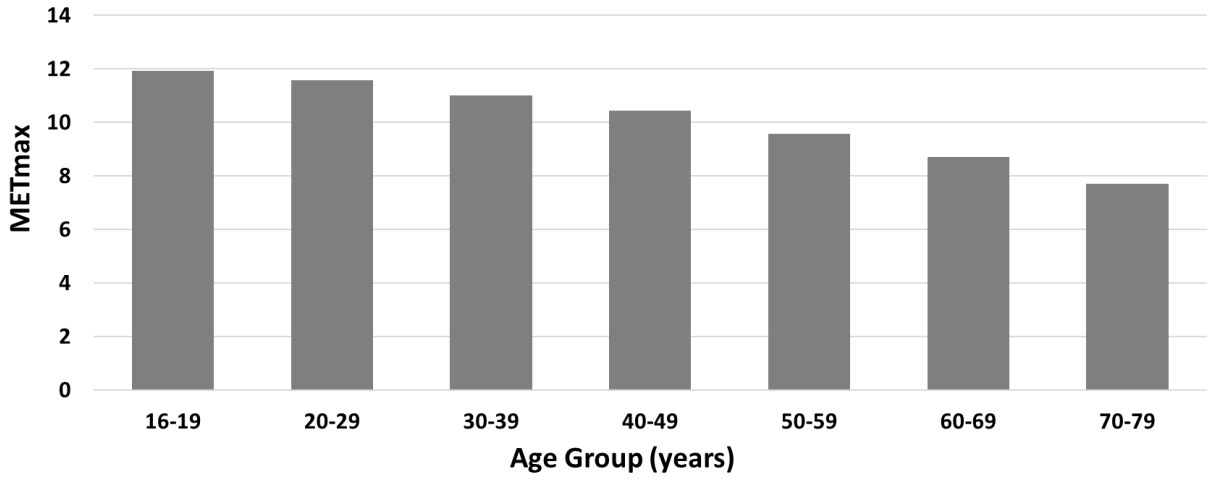
Age Group	Australia (2014)[43]	Canada (2011 and 2017)[44, 45]	Germany (2016)[46]	United Kingdom (2011)[47]	United States (2008)[8]
Children and adolescents	0-5 years 5-12 years 13-17 years	0-4 years 5-11 years 12-17 years	0-3 years 4-6 years 6-11 years 12-18 years	<5 years not walking <5 years walking 5-18 years	6-17 years
Adults	18-64 years	18-64 years	18-65 years	19-64 years	18-64 years
Older adults	Older Australians	65+ years	65+ years	65+ years	65+ years

Legend: <=less than, +=more than.

The normal decline in maximal aerobic capacity across the life course (Figure C-10) suggests that guidelines set for the "average" adult my not be challenging enough for the youngest adults and too challenging for many older adults. The *2008 Physical Guidelines for Americans* acknowledged this problem for older adults and modified the older adult guidelines to emphasize relative rather than absolute intensity to guide the level of effort.[8] The 2018 Advisory Committee recognized that similar adjustments might be appropriate for younger adults, namely that intensity for younger adults should be relative to their aerobic capacity. This would mean a higher absolute intensity and perhaps a higher accumulated volume than for middle-aged and older-adults. In addition, the Committee recognized that the health outcomes influenced by physical activity during young adulthood shared features with the growth and development needs of younger individuals and the disease prevention needs of middle-aged and older adults. As examples, the brain is not fully developed and the skeleton not fully mineralized until well into the third decade, and maintenance of normal blood pressure and body weight is important for younger as well as older adults. After discussion and preliminary research examining physical activity and health outcomes during young adulthood, the Committee felt the issue to be important but set it aside because the available literature did not appear to be strong enough to either confirm or support a change to the current approach. For the present, the age groups used by the

Committee are the same as in the *2008 Physical Activity Guidelines for Americans*,[8] the guidelines from other countries (Table C-2), as well as Healthy People data.[48]

Figure C-10. Maximal Oxygen Uptake in METs, by Age Group



Legend: METmax=maximal oxygen uptake.
Source: Adapted from data in Pate et al., 2006[49] for ages 16 to 19 and American College of Sports Medicine (ACSM)[50] for all other age groups.

SAFETY DURING PHYSICAL ACTIVITY

At the start of their deliberations, the Committee recognized the importance of physical activity-related adverse events. Although the benefits of regular physical activity outweigh the inherent risk of adverse events, adverse events can happen and, though usually not severe, they are an impediment to continued and more widespread participation in regular physical activity. The Committee judged the basic principles and messages of the chapter on adverse events in the *Physical Activity Guidelines Advisory Committee Report, 2008*[7] to still apply in 2018. Rather than prepare a chapter that would duplicate the material in the prior report, each subcommittee looked for information about adverse events uncovered by their searches and, when appropriate, included the information in their chapters. (See, for example, *Part F. Chapter 9. Older Adults*). Included here is a brief summary of the material about adverse events from the 2008 Advisory Report.[7]

The 2008 Advisory Report[7] concluded that the benefits of physical activity outweigh the risks. It acknowledged a wide range of types of physical activity-associated adverse events, including musculoskeletal injuries, cardiac events, heat injuries, and infectious diseases. All types were addressed but the focus was on the prevention of musculoskeletal injuries. The 2008 Scientific Report[7] noted that

physical activity-related musculoskeletal injuries are directly related to the type of activity, the volume of physical activity performed, and the rate of progression or change in volume of physical activity.

Type of activity is important because the risk of musculoskeletal injury is directly related to the force and frequency of contact or collisions with other people, the ground, or other objects. Activities are commonly divided into four categories: Collision (e.g., football, ice hockey), contact (e.g., basketball, soccer), limited-contact (e.g., baseball, ultimate frisbee), and non-contact (e.g., running, swimming). "Activities with fewer and less forceful contact with other people or objects have appreciably lower injury rates than do collision or contact sports. Walking for exercise, gardening or yard work, bicycling or exercise cycling, dancing, swimming, and golf, already popular in the United States, are activities with the lowest injury rates."[7]

The risk of injury is directly related to a person's usual dose or volume of physical activity. Dose is determined by the frequency, duration, and intensity of the activity (see the section on "Dose, Volume, and Dose-response for Aerobic Activities," above). Runners, for example, who run 40 miles per week are more likely to be injured than those who run 15 miles per week.

The risk of injury is directly related to the rate of progression or change in volume of physical activity.[7] Military recruits, for example, are commonly prescribed a specific type and volume of exercise. The type may change and the volume may increase over time, but all recruits are expected to do the same type and volume. Recruits who, before enrollment in the military, were doing lesser amounts of physical activity, incur more injuries than do recruits who had been doing greater amounts. Students in physical education classes and participants in aerobic dance classes have similar experiences; those who were less active before the classes are more likely to have a class-related injury than are those who were more active. A few experimental studies have assigned different doses of physical activity to groups of individuals with similar baseline physical activity practices. Injury rates are higher among those assigned the higher volumes.

"The findings in military recruits, students, and runners are consistent with the two major principles of exercise training programs: 1) overload and adaptation, and 2) specificity of response. The overload and adaptation principle states that function is improved when tissues (e.g., muscles) and organs (e.g., heart) are exposed to an overload (i.e., a stimulus greater than usual) and provided time to recover and adapt. Repeated exposures to a tolerable overload are followed by adaptation of the tissues and organs to the new load and improvements in performance and function. Too large an overload or insufficient

time for adaptation, however, leads to injury and malfunction. The principle of specificity states that the adaptation and improved function is limited to the tissues and organs that have been overloaded. Training the muscles of the legs, for example, does not improve strength in the arms and shoulders."[7]

The 2008 Advisory Report[7] noted that research determining the safest rate of change for individuals at differing habitual levels of physical activity is not available. That observation remains today. The 2008 Advisory Report did conclude, however, that "adding a small and comfortable amount of walking, such as 5 to 15 minutes 2 to 3 times per week, to one's usual daily activities has a low risk of musculoskeletal injury and no known risk of sudden severe cardiac events. Frequency and duration of aerobic activity should be increased before intensity. Increases in activity level may be made as often as weekly among youth, whereas monthly is more appropriate for older or unfit adults. Attainment of the desired level of activity may require a year or more, especially for elderly, obese, or habitually sedentary individuals."[7]

For more information about other aspects of physical activity-related adverse events, such as sudden adverse cardiac events, the value of proper equipment and safe environments, please see *Part G. Section 10: Adverse Events* in the 2008 Scientific Report.[7]

PROMOTION OF PHYSICAL ACTIVITY

The public health importance of developing approaches and programs to increase participation by the general public in regular moderate-to-vigorous physical activity grew from two observations. First was the evidence that regular physical activity reduced the incidence and mortality of cardiovascular disease, the leading cause of death in the United States. Second was the recognition that mechanization at worksites was reducing the prevalence of jobs requiring much moderate-to-vigorous physical activity.

Over the past 30 to 35 years, the field of health education and promotion has advanced considerably in its knowledge about the complex factors that underlie physical activity behaviors and the approaches most likely to increase population levels of physical activity. Major theories and conceptual frameworks that have been instrumental in this progress include the Health Belief Model,[51] Social Cognitive Theory,[52] the Transtheoretical Model,[53] and applications of a Social Ecological framework.[54] The application of such theoretical models and conceptual frameworks to the study of health behavior change, including physical activity behavior change, has led to several general conclusions, which include the following[55]:

- Physical and social environmental influences are important determinants of health behavior change.
- Behavior change is a process rather than an event, with factors that influence behavior changing over time.
- There is a difference between behavioral intention and action.
- Changing behavior initially and maintaining behavior change over longer periods of time are often two different challenges that may be governed by different factors.

Given that less than half of U.S. adults and high school aged youth perform moderate-to-vigorous physical activity within the public health target range (see earlier information in this chapter), the promotion of physical activity has high public health importance. The 2018 Scientific Report includes, for the first time, a review of the recent evidence pertaining to physical activity promotion. Given the complexity and breadth of the physical activity promotion literature, a Social Ecological framework was applied in reviewing the evidence base in this area (see *Part F. Chapter 11. Promoting Regular Physical Activity*). The literature was divided into the following levels of intervention and impact: the individual, community settings, environmental and policy approaches, and information and communication technology approaches. These different levels are defined further in the chapter. In addition, interventions aimed specifically at reducing sedentary behavior were reviewed.

REFERENCES

1. Centers for Disease Control and Prevention. *Leading causes of death, 1900-1998*. https://www.cdc.gov/nchs/data/dvs/lead1900_98.pdf. Accessed January 15, 2018.

2. Powell KE, Thompson PD, Caspersen CJ, Kendrick JS. Physical activity and the incidence of coronary heart disease. *Annu Rev Public Health*. 1987;8:253-287. doi.10.1146/annurev.pu.08.050187.001345.

3. U.S. Department of Health and Human Services. *Physical activity and health: a report of the Surgeon General*. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion; 1996. https://www.cdc.gov/nccdphp/sgr/pdf/sgrfull.pdf. Accessed January 30, 2018.

4. Lalonde M. A New Perspective On The Health Of Canadians. A Working Document. Ottawa: Government of Canada; 1974. http://www.phac-aspc.gc.ca/ph-sp/pdf/perspect-eng.pdf. Accessed January 4, 2018.

5. U.S. Department of Health, Education, and Welfare. *Healthy people: The Surgeon General's report on health promotion and disease prevention*. Washington, DC: U.S. Department of Health, Education, and

Welfare; Public Health Service; 1979. https://profiles.nlm.nih.gov/ps/access/NNBBGK.pdf. Accessed January 30, 2018.

6. U.S. Department of Health and Human Services. *Promoting health/preventing disease: objectives for the nation*. Washington, DC: U.S. Department of Health and Human Services, Public Health Service; 1980.

7. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Report, 2008*. Washington, DC: U.S. Department of Health and Human Services; 2008. https://health.gov/paguidelines/guidelines/report.aspx. Published 2008. Accessed January 4, 2018.

8. U.S. Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans*. Washington, DC: U.S. Department of Health and Human Services; 2008.

9. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep*. 1985;100(2):126-131.

10. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act*. 2017;14:75. doi:10.1186/s12966-017-0525-8.

11. Cooper KH. Aerobics. Philadelphia, PA: Bantam Books; 1969.

12. National Institute on Aging. *Your everyday guide from the National Institute on Aging at NIH: exercise & physical activity*. Publication No. 09-4258. 2009:64-69. https://go4life.nia.nih.gov/sites/default/files/nia_exercise_and_physical_activity.pdf. Accessed January 30, 2018.

13. Lesinski M, Hortobágyi T, Muehlbauer T, Gollhofer A, Granacher U. Effects of balance training on balance performance in healthy older adults: a systematic review and meta-analysis. *Sports Med*. 2015;45(12):1721-1738. doi:10.1007/s40279-015-0375-y.

14. Morris JN, Heady JA, Raffle PA, Roberts CG, Parks JW. Coronary heart-disease and physical activity of work. *Lancet*. 1953;265(6796):1111-1120.

15. Paffenbarger RS, Hale WE. Work activity and coronary heart mortality. *N Engl J Med*. 1975;292(11):545-550. doi:10.1056/NEJM197503132921101.

16. Morris JN, Everitt MG, Pollard R, Chave SP, Semmence AM. Vigorous exercise in leisure-time: protection against coronary heart disease. *Lancet*. 1980;2(8206):1207-1210.

17. Paffenbarger RS Jr, Wing AL, Hyde RT. Physical activity as an index of heart attack risk in college alumni. *Am J Epidemiol*. 1978;108(3):161-175.

18. Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR Jr, Tudor-Locke C. Compendium of physical activities: a second update of codes and MET values. *Med Sci Sports Exerc*. 2011;43(8):1575-1581. doi:10.1249/MSS.0b013e31821ece12.

19. Butte NF, Watson KB, Ridley K, et al. A youth compendium of physical activities: activity codes and metabolic intensities. *Med Sci Sports Exerc*. Sept 2017. doi:578 10.1249/MSS.0000000000001430.

20. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc*. 2008;40(1):181-188. doi:10.1249/mss.0b013e31815a51b3.

21. Matthews CE, Chen KY, Freedson PS, et al. Amount of time spent in sedentary behaviors in the United States, 2003–2004. *Am J Epidemiol*. 2008;167(7):875-881. doi:10.1093/aje/kwm390.

22. Matthews CE. Calibration of accelerometer output for adults. *Med Sci Sports Exerc*. 2005;37(suppl 11):S512-S522.

23. American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 9th ed. Baltimore, MD: Lippincott Williams & Wilkins; 2014.

24. Persinger R, Foster C, Gibson M, Fater DC, Porcari JP. Consistency of the talk test for exercise prescription. *Med Sci Sports Exerc*. 2004;36(9):1632-1636.

25. American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 8th ed. Baltimore, MD: Lippincott Williams & Wilkins; 2009.

26. Harrington DM, Tudor-Locke C, Champagne CM, et al. Step-based translation of physical activity guidelines in the Lower Mississippi Delta. *Appl Physiol Nutr Metab*. 2011;36(4):583-585. doi:10.1139/h11-053.

27. Tudor-Locke C, Leonardi C, Johnson WD, Katzmarzyk PT, Church TS. Accelerometer steps/day translation of moderate-to-vigorous activity. *Prev Med*. 2011;53(1-2):31-33. doi:10.1016/j.ypmed.2011.01.014.

28. Sadarangani KP, Hamer M, Mindell JS, Coombs NA, Stamatakis E. Physical activity and risk of all-cause and cardiovascular disease mortality in diabetic adults from Great Britain: pooled analysis of 10 population-based cohorts. *Diabetes Care*. 2014;37(4):10.

29. Centers for Disease Control and Prevention, National Center for Health Statistics. National Health Interview Survey (NHIS), 1997–2015: 2015 data release. https://www.cdc.gov/nchs/nhis/nhis_2015_data_release.htm. Updated November 3, 2017. Accessed January 11, 2018.

30. Kann L, Kinchen S, Shanklin SL, et al. Youth risk behavior surveillance—United States, 2013. *Morb Mortal Wkly Rep*. 2014;63(4):1-47. https://www.cdc.gov/mmwr/pdf/ss/ss6304.pdf. Accessed January 30, 2018.

31. Institute of Medicine. *Educating the Student Body: Taking Physical Activity and Physical Education to School*. Kohl HW, Cook HD, eds. Washington, DC: The National Academies Press; 2013:74. doi:10.17226/18314.

32. Centers for Disease Control and Prevention. Physical fitness. In *CDC Glossary of Terms*. https://www.cdc.gov/physicalactivity/basics/glossary/index.htm. Accessed January 30, 2018.

33. Ross R, Blair SN, Arena R, et al. Importance of assessing cardiorespiratory fitness in clinical practice: a case for fitness as a clinical vital sign: a scientific statement fom the American Heart Association. *Circulation*. 2016;134(24):e653-e699. doi:10.1161/CIR.0000000000000461.

34. Jackson AS, Sui X, Hébert JR, Church TS, Blair SN. Role of lifestyle and aging on the longitudinal change in cardiorespiratory fitness. *Arch Intern Med*. 2009;169(19):1781-1787. doi:10.1001/archinternmed.2009.312.

35. Garber CE, Blissmer B, Deschenes MR, et al.; American College of Sports Medicine. American College of Sports Medicine position stand: Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. 2011;43(7):1334-1359. doi:10.1249/MSS.0b013e318213fefb.

36. Lee DC, Sui X, Artero EG, et al. Long-term effects of changes in cardiorespiratory fitness and body mass index on all-cause and cardiovascular disease mortality in men: the Aerobics Center Longitudinal Study. *Circulation*. 2011;124(23):2483-2490. doi:10.1161/CIRCULATIONAHA.111.038422.

37. DeFina LF, Haskell WL, Willis BL, et al. Physical activity versus cardiorespiratory fitness: two (partly) distinct components of cardiovascular health? *Prog Cardiovasc Dis*. 2015;57(4):324-329. doi:10.1016/j.pcad.2014.09.008.

38. Kraemer HC, Kiernan M, Essex M, Kupfer DJ. How and why criteria defining moderators and mediators differ between the Baron & Kenny and MacArthur approaches. *Health Psychol*. 2008;27(2 suppl):S101-S108. doi:10.1037/0278-6133.27.2(Suppl.).S101.

39. Kraemer HC, Frank E, Kupfer DJ. Moderators of treatment outcomes: clinical, research, and policy importance. *JAMA*. 2006;296(10):1286-1289. doi:10.1001/jama.296.10.1286.

40. Last JM, ed. *A Dictionary of Epidemiology*. 4th ed. New York, NY: Oxford University Press; 2001.

41. King AC, Kiernan M, Oman RF, Kraemer HC, Hull M, Ahn D. Can we identify who will adhere to long-term physical activity? Signal detection methodology as a potential aid to clinical decision making. *Health Psychol*. 1997;16(4):380-389.

42. Hickson RC, Hagberg JM, Ehsani AA, Holloszy JO. Time course of the adaptive responses of aerobic power and heart rate to training. *Med Sci Sports Exerc*. 1981;13(1):17-20.

43. Australia Department of Health. Australia's physical activity and sedentary behaviour guidelines; 2014. www.health.gov.au/internet/main/publishing.nsf/content/health-pubhlth-strateg-phys-act-guidelines#npa05. Accessed January 10, 2018.

44. Tremblay MS, Warburton D, Janssen I, et al. New Canadian physical activity guidelines. *Appl Physiol Nutr Metab*. Feb 2011;36.

45. Tremblay MS, Chaput JP, Adamo KB, et al. Canadian 24-hour movement guidelines for the early years (0-4 years): an integration of physical activity, sedentary behavior, and sleep. *BMC Pub Health*. 2017;17(suppl 5):874. doi:10.1186/s12889-017-4859-6.

46. Rutten A, Pfeifer K, eds. National recommendations for physical activity and physical activity promotion. Erlanger, GER: Florida Atlantic University Press; 2016. https://www.sport.fau.de/files/2015/05/National-Recommendations-for-Physical-Activity-and-Physical-Activity-Promotion.pdf. Accessed January 10, 2018.

47. Department of Health, Physical Activity, Health Improvement and Protection (Scottish Government). Start active, stay active. a report on physical activity for health from the four home countries' chief medical officers; 2011. https://www.sportengland.org/media/2928/dh_128210.pdf. Accessed January 10, 2018.

48. U.S. Department of Health and Human Services, Office of Disease Prevention and Health Promotion. HealthyPeople.gov. https://www.healthypeople.gov. Accessed January 26, 2018.

49. Pate RR, Wang CY, Dowda M, Farrell SW, O'Neill JR. Cardiorespiratory fitness levels among U.S. youth 12 to 19 years of age: findings from the 1999-2002 National Health and Nutrition Examination Survey. *Arch Pediatr Adolesc Med*. 2006;160(10):1005-1012. doi:10.1001/archpedi.160.10.1005.

50. American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 7th ed. Baltimore, MD: Lippincott Williams & Wilkins; 2006.

51. Rosenstock IM, Strecher VJ, Becker MH. Social learning theory and the health belief model. *Health Edu Q*. 1988;15(2):175–183.

52. Bandura A. Social cognitive theory: an agentic perspective. *Ann Rev Psychol*. 2001;52:1-26. doi:10.1146/annurev.psych.52.1.1.

53. Marcus BH, Simkin LR. The transtheoretical model: applications to exercise behavior. *Med Sci Sports Exerc*. 1994;26(11):1400-1404.

54. Sallis JF, Owen N. Ecological models of health behavior. In: Glanz K, Rimer BK, Lewis FM, eds. Health behavior and health education: theory, research, and practice, third edition. San Francisco, CA: Jossey-Bass; 2002.

55. Glanz K, Bishop DB. The role of behavioral science theory in development and implementation of public health interventions. *Annu Rev Public Health*. 2010;31:399-418. doi:10.1146/annurev.publhealth.012809.103604.