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Physical Activity for Health: What Kind? How Much? How Intense? On Top of What?

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Abstract

Physical activity improves health. Different types of activity promote different types of physiologic changes and different health outcomes. A curvilinear reduction in risk occurs for a variety of diseases and conditions across volume of activity, with the steepest gradient at the lowest end of the activity scale. Some activity is better than none, and more is better than some. Even light-intensity activity appears to provide benefit and is preferable to sitting still. When increasing physical activity toward a desired level, small and well-spaced increments will reduce the incidence of adverse events and improve adherence.

Prior research on the relationship between activity and health has focused on the value of moderate to vigorous activity on top of an indefinite and shifting baseline. Given emerging evidence that light activities have health benefits and with advances in tools for measuring activities of all intensities, it may be time to shift to zero activity as the conceptual starting point for study.

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INTRODUCTION

A large and growing body of evidence demonstrates that regular physical activity provides numerous health benefits. Given the evidence, it is natural to ask about the type, amount, and intensity of activity that provides these many benefits. Since the 1970s, a number of organizations and agencies have issued recommendations (26, 96). The U.S. Department of Health and Human Services issued in 2008 the *Physical Activity Guidelines for Americans* (95). The guidelines are based on a thorough review of the activity-health relationship in the *Physical Activity Guidelines Advisory Committee Report: 2008* (68). The action-oriented *Guidelines* and the science-based *Committee Report* describe the "amount, types, and intensity of physical activity needed to achieve many health benefits" (95).

On the basis of evidence in the *Committee Report* (68), the *Guidelines* indicate that 150–300 min/week of moderate intensity aerobic physical activity provide substantial health benefits for the general adult population (70, 95). Equivalent benefits may be achieved by 75 min/week of vigorous intensity activity or by a combination of moderate and vigorous activity, with one minute of vigorous activity approximating two minutes of moderate. The *Guidelines* also indicate that some activity is better than none and that more than the suggested volume of activity is likely to provide additional benefits (**Table 1**). The *Guidelines* also recommend muscle and bone strengthening activities and, for older adults at risk of falls, balance-training activities to broaden the range of health benefits (95). These basic suggestions regarding the types and volume of activity are consistent with, but offer more flexibility than, previous recommendations.

The *Committee Report* provides a thorough review and summary of a large volume of scientific research, and the *Guidelines* convert with admirable consistency the primary findings into practical suggestions. We draw heavily from these documents for this article but do not review them. Persons wanting a more specific summary of scientific topics should examine the original documents (68, 95). Our purpose is to review and discuss four conceptual components of the physical activity and health arena. The components are

1. Physical activity, physiology, and health.
2. Volume, dose-response, and intensity.
3. Safely increasing the volume of physical activity.
4. Starting from zero.

PHYSICAL ACTIVITY, PHYSIOLOGY, AND HEALTH

The purpose of this section is to provide a qualitative overview of the physical activity and health relationship and the physiologic mechanisms that connect them. Different types of activity are associated with different types of health outcomes. Please see the sidebar on Important Terms and Concepts

Table 1 Weekly minutes of moderate intensity aerobic physical activity[a] and level of health benefit

Volume of activity	Health benefits	Comment
Baseline	None	Being inactive is unhealthy
Above baseline but <150 min/week of moderate intensity activity	Some	Low levels of activity are preferable to inactivity
150–300 min/week of moderate intensity activity	Substantial	Activity at the high end provides more benefits than at the low end
>300 min/week of moderate intensity activity	Additional	Current scientific information does not indicate an upper limit for benefits nor an amount that appears to be hazardous.

[a]One minute of vigorous intensity activity provides benefits roughly equal to two minutes of moderate intensity activity. The two intensities can be mixed in any ratio. Adapted from reference (95).

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Concerning Physical Activity, Physiology, and Health.

Physical activity provides a wide spectrum of health benefits, including reductions in risk for a variety of diseases and improvements in functional ability. Coronary heart disease was the first condition whose incidence was shown to be reduced by regular physical activity (21, 50, 61, 64, 65, 77). Subsequently, the list of established health benefits attributable to physical activity has grown. The recent *Committee Report* concludes that strong scientific evidence indicates that physical activity reduces the risk of early death, coronary heart disease, stroke, high blood pressure, type 2 diabetes, breast and colon cancer, excessive weight gain, injurious falls, depression, and loss of cognitive function; and moderately strong scientific evidence demonstrates that physical activity maintains functional ability in older adults, helps maintain weight loss, improves sleep quality, and reduces the risk of hip fracture and osteoporosis (70).

The mechanisms by which regular physical activity induces these benefits lie in the acute and chronic physiologic changes it causes. Voluntary contraction of skeletal muscles—the sine qua non of physical activity—requires the confluence of raw materials (e.g., oxygen, glucose, fat) for releasing energy and the metabolic and neurologic coordination to use the resources effectively to cause bodily movement. The specific physiologic adaptations depend on the type of activity performed.

The physiologic changes caused by various physical activities overlap considerably. However, some activities are associated more closely with some physiologic changes than are others. For example, aerobic activities cause many changes to the cardiovascular system (e.g., increased stroke volume, increased capillary density, reduced peripheral resistance) that improve the capacity and efficiency of the delivery of oxygen and glucose to tissues that need them. Aerobic activities also improve cellular systems that release energy from substrates that can be used for movement. Outside the cardiovascular system, different aerobic activities have different effects. Ambulatory activities improve muscle and bone strength along the axial skeleton and lower extremities. Swimming, another aerobic activity, has greater impact on upper body musculature and less impact on the skeletal system. Weight lifting, generally not considered an aerobic activity, improves muscle strength and endurance with modest effect on the cardiovascular system. Balance-training activities improve postural

IMPORTANT TERMS AND CONCEPTS CONCERNING PHYSICAL ACTIVITY, PHYSIOLOGY, AND HEALTH

1. *Aerobic* activities such as walking, basketball, soccer, or dancing typically use large muscle groups in rhythmic repetitive movements and are conducted at a pace that can be continued for more than a few minutes. They improve the efficiency and capacity of the cardiorespiratory system.
2. *Anaerobic* activities such as sprinting or powerlifting require energy production systems that do not use oxygen because they exceed the capacity of the cardiorespiratory system to distribute oxygen and other metabolites. They can be maintained for 2–3 min (58).
3. *Cardiorespiratory fitness* is the ability of the circulatory and respiratory systems to provide oxygen during sustained aerobic physical activity.
4. *Functional ability* is the capacity to perform practical tasks, activities, and behaviors that fulfill one's role in society, maintain independence, and enhance quality of life.
5. *Health* has physical, mental, social, and psychological dimensions. Positive health is not merely the absence of disease or infirmity, but the capacity to withstand challenges and to accomplish life's activities with pleasure and energy (98).
6. *Physical activity* is any bodily movement produced by skeletal muscles that expends energy (11).
7. *Physical fitness* refers to attributes that people have or achieve that relate to their ability to perform physical activity (11). Several components of physical fitness, such as cardiorespiratory endurance, muscle strength and endurance, body composition, and balance are associated with health and functional capacity.
8. *Strength training* (also resistance training) refers to activities designed to improve the strength, power, endurance, and size of skeletal muscles.

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Table 2 Selected moderate and vigorous activities, physiologic pathways, and health outcomes[a]

Examples of Physical activities	Examples of Physiologic changes	Examples of Health outcomes
Gardening	↑ Autonomic balance	↓ Breast cancer
Home repair	↑ Bone density	↓ Colon cancer
Painting	↑ Capillary density	↓ Coronary heart disease
Raking	↑ Coronary artery size	↓ Depression
Shoveling	↑ Endothelial function	↓ Excess weight gain
Sweeping	↑ High density lipoprotein	↓ Fractures
Vacuuming	↑ Immune function	↓ Injurious falls
Basketball	↑ Insulin sensitivity	↓ Osteoporosis
Cycling	↑ Lean body mass	↓ Risk of death
Dancing	↑ Mitochondrial volume	↓ Stroke
Running	↑ Motor unit recruitment	↓ Type 2 diabetes
Skiing	↑ Muscle fiber size	↑ Cognitive function
Soccer	↑Neuromuscular coordination	↑ Physical function
Swimming	↑ Stroke volume	↑ Weight management
Tennis	↓ Blood coagulation	
Walking	↓ Inflammation	

[a]Arrows indicate direction of physiologic change or health outcome associated with increased physical activity. The Table is designed to be read from left to right but not line by line. Different physical activities act through a variety of physiologic pathways to influence different health outcomes.

musculature and neurocoordination, again with less impact on the cardiovascular system.

Therefore, different types of physical activity acting through multiple physiologic pathways influence a broad array of health outcomes (**Table 2**). For some of the health improvements, one can be reasonably certain which physiologic changes are important; for others, such as colon cancer or depression, the pathways remain obscure. And for some activities that are commonly accepted as healthful, such as stretching, the benefit has not been established (74). The complexity of types of activity, multiple pathways, and diverse health outcomes frustrates any effort to provide a single specific prescription for activity to provide health benefits.

VOLUME, DOSE-RESPONSE, AND INTENSITY

The purpose of this section is to provide a quantitative understanding of the relationship between aerobic physical activity and health. It directly addresses the question of how much activity is needed. We focus on aerobic activities because they are associated with the broadest range of health benefits. We consider not only volume of activity but also the components of volume: duration, frequency, and intensity. Research on this topic is hampered by the difficulties of studying variation in a component of interest (e.g., intensity) while controlling for total volume and other components. Research design and funding have probably also been affected by the inexorable hardening of cautious recommendations into rigid requirements. Because experts have recommended durations of 20–30 min, frequencies of ≥3 days/week, intensities that are moderate to vigorous, and volumes of ≥150 min/week of moderate to vigorous activity, research on the value of activity outside those parameters has been limited. Please see the sidebar on Important Terms and Concepts Concerning Volume, Intensity, and Dose-Response.

Volume

The preponderance of evidence suggests that volume of activity is more closely related to the full array of health outcomes than to any of the components (68).

Dose-Response

From early summaries of activity and coronary heart disease (77) through the present body of evidence for a wide range of conditions (68), the volume of activity has consistently been directly related to the size of the reduction in disease or improvement in function. A composite of the dose-response relationship in 10 recent studies of activity and all-cause mortality is inverse and curvilinear (71) (**Figure 1**). Several aspects of the dose-response curve are noteworthy.

First, there is no lower threshold for benefits. Reductions in the risk of mortality appear to begin with the first increase in activity beyond baseline. The belief that a threshold of activity must be achieved before benefits accrue is common but inaccurate. Something is better than nothing (7, 70). Maintaining the current level of activity is better than becoming less active. "Just a little more" or "hold your own" may not be inspiring messages, but they are healthier than becoming less active.

Second, the rate of risk reduction is greatest at the lowest end of the activity scale. Given the large proportion of the population who are at this low level of activity (57, 92), the rapid improvement at the left side of the curve suggests that relatively small increases in activity volume by these groups will bring substantial health benefits even if they do not fully achieve recommended levels.

Third, in these population-based studies there is no apparent upper threshold where benefits begin to diminish. Although the reduction in risk for each increase in activity is smaller, there appears to be continuous growth in benefits. The direct relationship between volume of activity and musculoskeletal injury and the reports of diminished immune function among elite athletes at maximal training levels (22, 74) suggest that the risks overtake the benefits at some point. For the general population, however, this does not appear to be problematic.

IMPORTANT TERMS AND CONCEPTS CONCERNING VOLUME, INTENSITY, AND DOSE-RESPONSE

1. *Accumulation* is the assembling of short episodes of physical activity during a limited period of time (usually one day) to achieve a fuller amount. The concept of accumulation has been important in considering the value of varying durations (e.g., 10 min versus 30 min) of episodes of activity.
2. *Duration* is the length of time (usually minutes) an activity is continued.
3. *Frequency* is the number of times an activity is performed within a specified time period, usually expressed as bouts, episodes, or sessions per week.
4. *Intensity* (*absolute*) for aerobic activities is the rate of energy expenditure required to perform the activity; it does not consider the physiologic capacity of the person performing the activity. It can be measured in metabolic equivalents (METs; see item 6, below), kilocalories, joules, milliliters of O_2 consumption, or for some activities, speed (e.g., walking at 4 miles/h). Current practice is to categorize absolute intensity into four categories: sedentary $\leq$1.5 METs, light intensity 1.6–2.9 METs, moderate intensity 3.0–5.9 METs, and vigorous intensity $\geq$6.0 METs (66, 69).
5. *Intensity* (*relative*) describes the ease or difficulty with which an activity is performed. It is proportional to one's current maximal capacity. The relative intensity of aerobic activities can be described as percent of aerobic capacity (VO_{2max}), percent of maximal heart rate, or other similar measures. It can also be described by how hard an individual perceives an activity to be: very light, light, moderate, hard, very hard, or maximal.
6. *Metabolic equivalent* (MET) is a measure of energy expenditure. One MET is the rate of energy expenditure while sitting at rest, which, for most people, is an oxygen uptake of approximately 3.5 ml/(kg-min). The energy expenditure of other activities is expressed in multiples of METs. For example, standing requires ~2 METs. MET values for a large number of activities are available (2). An advantage to using METs rather than kilocalories or joules to describe energy expenditure is that METs control for body weight. Individuals performing the same activity expend roughly the same number of METs, whereas the expenditure of kilocalories or joules depends on body weight.
7. VO_{2max}, maximal oxygen uptake, is the highest rate at which one can transport and use oxygen during aerobic activities.

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Except for highly trained athletes, VO_{2max} is lower than it could be. For people who are very inactive, it is substantially lower than it could be.

8. *Volume* is the total amount of activity accumulated over a specified period of time, usually one week. Volume is commonly expressed in measures of energy expenditure such as kilocalories/week, MET-min/week, minutes/week, or miles/week. In most research, volume has included only moderate to vigorous activities.

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Fourth, there is no obvious single volume of activity to choose as a recommended level. The U.S. *Guidelines* suggests 500–1000 MET-min/week of moderate- to vigorous-intensity activity as a range of activity levels that provide substantial health benefits. This volume of activity, equivalent to ∼150–300 min/week of brisk walking or 75–150 min/week of jogging, has strong scientific support. It provides a broad spectrum of health benefits.

The shape of the dose-response relationship curve likely varies from condition to condition because the physiologic pathways to different health outcomes vary. Although we are not aware of published composite dose-response curves for other conditions, line graphs or bar graphs depicting similarly graded associations are common for other conditions (34, 56, 65). In **Figure 2**, in addition to the composite curve for all-cause mortality, individual points representing the relative risk for a specific volume of activity are shown for cardiovascular diseases, diabetes, breast and colon cancer, hip fracture, and depression and dementia (70) (**Figure 2**). These points suggest that condition-specific dose-response curves have similar shapes but are likely to be incongruent. For some conditions (e.g., diabetes, hip fracture), risk reductions are greater and accrue at lower levels of activity, whereas for others (e.g., breast cancer) the risk reductions are more modest and require larger volumes of activity. The variations in curvature for different health outcomes are consistent with the fact that the benefits are achieved via different physiologic pathways. They also support using a range rather than a single volume of activity as a general guideline.

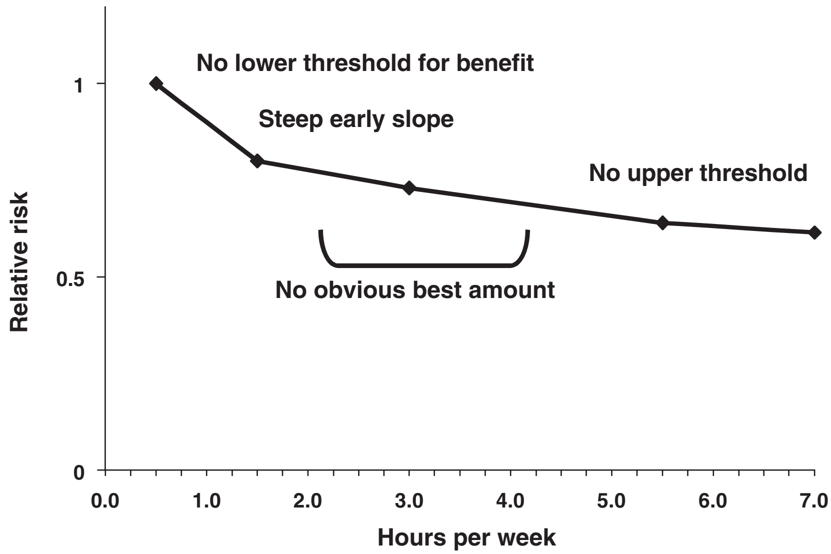

Figure 1

Risk of all-cause mortality by hours/week of moderate to vigorous physical activity. Adapted from Reference 71.

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Duration

A wide range of durations appear to provide equivalent benefits as long as daily accumulation and weekly totals are similar. However, only cardiovascular outcomes have been examined, and bouts shorter than 8 min have rarely been studied. Several bouts of 8–10 min of aerobic activity during the day appear equivalent to a single bout of 30 min in improving cardiovascular risk factors among unfit individuals (70, 72). Others have observed that 30-min bouts are as beneficial as bouts of ≥60 min in reducing the risk of coronary heart disease if weekly totals are equivalent (49). Because the volume of research is limited, bouts <8 min have not been recommended (95), although some research suggests they may be helpful for outcomes dependent on total energy expenditure, such as weight maintenance and control (85, 86).

Frequency

The benefits of frequencies ≥3 days/week are equivalent if total volume is constant (70). The value of frequencies <3 days/week has rarely been examined, and the reported findings are mixed (43, 48, 59).

Intensity: Moderate and Vigorous

The physiologic adaptations associated with high-intensity physical activity were one of the initial causes for interest in the activity-health relationship (37). If nothing else, vigorous activities (≥6 METs) expend energy at roughly twice the rate of moderate intensity activities (3–5.9 METs). Whether high-intensity activities per se, controlling for volume, provide more health benefits than do moderate-intensity activities is uncertain. A recent review comparing the cardioprotective benefits of vigorous- and moderate-intensity aerobic activity concludes that "vigorous activity appears to convey greater cardioprotective benefits" than does moderate intensity activity (88). The review included 15 epidemiologic studies and 20 clinical trials. Of the 15 epidemiologic studies, only 9 (median size 8,896 subjects) specifically controlled for total volume of activity; all nine reported either a lower incidence of coronary heart disease or a more favorable risk factor profile for those performing vigorous- rather than moderate-intensity activities. Of the 20 clinical trials with equal activity volume among subjects, only 7 studies (median size 40 subjects) reported a greater improvement in VO_{2max} among those exposed to higher rather than lower intensity. Among these seven, one of two showed greater improvement in blood pressure, one of five showed greater improvement in lipid profile, and zero of two showed greater improvement in body composition among those performing at higher intensity. Thus, some evidence indicates that vigorous activities are more cardioprotective than are moderate activities while controlling for total volume of activity, but this evidence is not highly persuasive. Certainly very vigorous activity induces physiologic changes that improve physical performance; every athlete concurs. Less certain is whether higher intensity adds to the already substantial health benefits derived from moderate-intensity activities if total volume is the same.

Intensity: Sedentary and Light

Sedentary to light activities have been the unhealthy foil to moderate and vigorous activities. Recent research, however, indicates that health benefits accrue when sedentary activities are replaced by light-intensity activities and the volume of moderate and vigorous activities is constant. More time spent sitting or watching TV has been associated with increased risk for all-cause and cardiovascular disease mortality, diabetes, obesity, and risk factors for cardiovascular disease (28, 29, 33, 38, 93) when either controlling for total volume of moderate to vigorous activity or restricting the comparison group to people who meet current recommendations. These studies imply or document (29, 33) that light activities are beneficial. One study reported that it is helpful to interrupt prolonged sitting with bouts of activity that may be

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as short as one minute or less (27). Physiologic studies of light activities, such as standing, report not only substantial muscular activity but also healthful metabolic change, thereby providing support for the evidence that light activities are beneficial with respect to sedentary activity (24, 25, 51, 52, 91, 100).

SAFELY INCREASING THE VOLUME OF PHYSICAL ACTIVITY

The purpose of this section is to consider the adverse events that occur when inactive people become more active. Activity-related adverse events encompass a broad array of misfortunes including musculoskeletal injuries, cardiac arrhythmias, heat injuries, and exposure to infectious diseases. We focus on musculoskeletal injuries because they are quite common and cause many people to stop or not even begin to be active (19, 31, 44, 45) and on sudden adverse cardiac events, which are rare but commonly feared. Adverse events are related to type of activity (e.g., walking, rugby, weight lifting) (16, 30), volume of activity (e.g., accumulated MET-min/week) (10, 32), personal characteristics (e.g., demographic, behavioral, health status), protective gear, equipment, and environmental conditions (74). We focus our discussion on the risks associated with increasing volume and intensity because they (volume and intensity) are the focus of our review.

When considering activity-related adverse events, it is important to remember that the benefits of regular physical activity outweigh the risks. Studies of broad health outcomes, those that encompass both positive and negative effects of physical activity, show that, compared with inactive individuals, physically active people have lower all-cause mortality rates (71), higher levels of functional health (73), and lower medical expenditures (74). Please see the sidebar on Important Terms and Concepts Concerning Safely Increasing the Volume of Physical Activity.

IMPORTANT TERMS AND CONCEPTS CONCERNING SAFELY INCREASING THE VOLUME OF PHYSICAL ACTIVITY

1. *Adaptation* encompasses the changes that occur in response to repeated overloads. Adaptation enables the body to function at the new level with reduced stress.
2. *Overload* is the application of a stimulus greater than normal. The repeated application of a small overload causes adaptive changes in tissues and organs that, over time, improve function and capacity. Overloads that are too large risk not only excess fatigue but also tissue and organ malfunction or breakdown (injury).
3. *Progression* is the application of a stimulus of greater size after the system has adapted to repeated applications of a previous smaller dose.
4. *Specificity* indicates that the improved function is limited to the tissues and organs subject to the progressive overload. Lifting weights with the left arm does not make the right arm stronger. Swimming does not prepare the legs for running.

Musculoskeletal Injuries and Risk of Rate of Change

In observational and experimental studies, the risk of activity-related musculoskeletal injury is directly related to the relative size of the overload or increase in dose. Studies of military recruits consistently report that recruits who have been least active and are least fit prior to entry suffer musculoskeletal injuries at 2–3 times the rate of more fit members of their cohort (74). Because all recruits are assigned an equal dose of activity, those who were least active before entry experience a relatively larger overload.

Recent experimental trials in which activity has been prescribed, carefully augmented, and of moderate intensity report low rates of musculoskeletal injuries, often indistinguishable from problems in the control group (14, 18, 40, 41, 53, 62). Some reports, however, especially those from older studies in which doses and intensities were higher, support the epidemiologic observations that rapid increases in activity raise the risk of injury. Early studies of males, 25–60 years of age, using vigorous activity as the overload reported injury rates of nearly 50%

(39, 55, 81). The few experimental trials that have specifically studied the relationship between volume and incidence of injury report a direct relationship between size of overload and incidence of injury (75, 76, 79, 87). Others have reported that injuries were more common during the early weeks of the trial (55, 78), during early stages of overload and adaptation. A systematic review of interventions to prevent lower limb soft-tissue running injuries concluded that "it is not possible to suggest an optimal training load" (99) but that injuries are associated with frequency, duration, intensity, or total amount of training.

Sudden Adverse Cardiac Events and the Risk of Intensity

Although sudden adverse cardiac events (e.g., death, arrhythmia, infarction) are, more accurately, a risk of inactivity rather than activity (9, 72), the fear of these events during activity is prevalent. During periods of vigorous physical activity, all individuals, even regularly active individuals, are at higher risk of sudden adverse cardiac events than during periods when they are being less active (47, 74). However, the risk is directly related to the relative size of the overload. As demonstrated by data from one of the few studies that has addressed the issue (**Table 3**), active people are at substantially less risk than are inactive people during activity. Active people are also at lower risk during inactivity and when risks are averaged over the whole day (84).

Table 3 Incidence[a] of primary cardiac arrest overall, during, and not during vigorous activity

Usual min/week of vigorous activity	Overall	During activity	Not during activity
0	18		18
1–19	14	732	13
20–139	6	66	5
≥140	5	21	4

[a]Per 10^8 person-hours at risk. Adapted from reference (84).

All the research on activity and sudden adverse cardiac events has studied the risk of vigorous activity (74) largely because, even during vigorous physical activity, the events are rare, ~1 event per 100 years of vigorous activity (3, 84, 97). The risk of moderate-to light-intensity activity is expected to be substantially lower (74).

Therefore, musculoskeletal injuries are more likely when the volume of activity is increased, and sudden adverse cardiac events are more likely when unaccustomed high-intensity activity is performed. In both cases, the risk is proportional to the relative size of the increase. Relative size of increase is determined by a person's current habitual physical activity practices. For example, the addition of 50 MET-min/week is relatively greater for a person whose habitual level is 50 MET-min/week (100% increase) than for a person whose habitual level is 500 MET-min/week (10% increase).

Unfortunately, little to no research has focused on the proper beginning dose of activity for safely advancing one's activity level. Because the people who will benefit most from increased activity are those who are sedentary and unfit, it is important that they begin their program prudently. The principles of overload, adaptation, and progression suggest that increments should be small and time should be allowed for adaptation. Because sedentary and unfit individuals have reduced cardiorespiratory capacity and cardiovascular risks have a greater association with intensity than with frequency or duration (89), activity should be based on relative intensity. Frequency and duration of activity should increase before intensity (4). On the basis of expert opinion, the *Physical Activity Guidelines Advisory Committee Report* suggests that new activities should have a relative level of effort that is light or moderate. Adding a 5–15-minute walk two to three days per week would be a reasonable beginning for people who are unfit or old (68). Building to 20–30 minutes per session for several weeks should be achieved before considering an increase in relative intensity. Cardiovascular adaptation to an augmented activity regimen may take as long as 20 weeks or more for older people (35), suggesting that the elderly

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should increase their activity levels at monthly rather than weekly intervals.

STARTING FROM ZERO

The purpose of this section is to suggest a greater emphasis on learning about the health effects of lower volumes and intensities of physical activity. Our intention is not to devalue the well-established health benefits of higher volumes and intensities. However, a more complete understanding of which and how activities provide benefits will enable the design and implementation of improved public health programs.

Baseline Activity

Physical activity guidelines from many agencies and countries recommend that moderate to vigorous activity be added to baseline levels of activity (95, 96). The concept of baseline physical activity, however, has always been soft. It undoubtedly varies among cultures and over time. It is possible that people in baseline categories 25–50 years ago were more active than people who meet current guidelines. Baseline activity, as currently defined (see sidebar, Important Terms and Concepts Concerning Starting from Zero), includes all sedentary and light activities (<3 METs) and encompasses a range of total energy expenditures from 10,000 to 30,000 MET-min/week, a total far greater than the 500–1000 MET-min/week increment suggested by the *Guidelines* for substantial health benefits. Given the emerging benefits of light-intensity activities and the inherent fuzziness of baseline activities, it is time to develop alternative conceptualizations and descriptions of physical activity.

IMPORTANT TERMS AND CONCEPTS CONCERNING STARTING FROM ZERO

1. *Activity energy expenditure* is the energy expended in physical activity. It is the most variable component of total energy expenditure and represents 15%–45% of daily energy expenditure (13, 20).
2. *Basal metabolic rate* is the rate of energy production necessary to maintain normal function of vital organs while at rest in a comfortable environment with no food in the digestive process.
3. *Baseline activity*, as currently defined, includes all sedentary and light-intensity activities (i.e., <3 METs) of daily life (e.g., lying, sitting, standing, walking slowly, lifting light objects) and including no bouts of moderate to vigorous intensity exceeding 10 minutes in length (95).
4. *Metabolic response to food* (also, dietary-induced thermogenesis, specific dynamic action of food, and thermic effect of feeding) is the energy required for the ingestion, digestion, absorption, transport, and metabolism of nutrients. The metabolic response to food increases total energy expenditure by ~10% of the BMR (13, 20).
5. *Total energy expenditure* is the sum of basal metabolic rate, metabolic response to food, and physical activity energy expenditure.

Zero Activity

The scientific study of physical activity and health began with higher intensities. Roughly 30 to 40 years ago, vigorous activities were the first to be clearly associated with health benefits (60, 63). They are the most accurately measured using self-reported activities (23, 80, 83). Moderate-intensity activities are less easily assessed, but their health value has been established and they have been recommended since the mid-1990s (67). Now evidence has emerged that light-intensity activities—long considered impossible to measure directly and accurately with self-report instruments—are healthier than sedentary activities.

About the time that higher-intensity activities were associated with reduced incidence of coronary heart disease, scientists more interested in energy balance were developing methods to measure total energy expenditure using doubly-labeled water (42, 82), a method that has become a gold standard for measuring total energy expenditure in free-living subjects. Also during the past 30 years, the need and desire for unobtrusive and objective measures of physical activity have fostered rapid expansion and progress in the development of instruments

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to measure physical activity. Although still being refined, these scientific advances in the objective measurement of physical activity provide an opportunity to consider the full range of physical activity, starting from zero, rather than continuing to struggle with a fuzzy baseline and limiting our appreciation to the upper intensities.

Quantitative estimates of total energy expenditure combined with measurement of basal metabolic rate and estimates of the metabolic response to food have enabled quantitative estimates of physical activity energy expenditure. For example, physical activity level (PAL) is the ratio of total energy expenditure to basal energy expenditure. The PAL has been used for several years, primarily by nutritionists, and values $\geq$1.70 are said to represent active individuals (17, 36). A similar ratio, but one that corrects for the metabolic response to food (i.e., 0.9 $\times$ total energy expenditure/basal energy expenditure), has shown an inverse relationship between total physical activity-related energy expenditure and mortality among older adults (54).

Instrumentation

Activity-measuring instruments of various types offer the hope of estimating not only total activity-associated energy expenditure but also the proportions coming from different intensities of activity as well. Although accelerometers are currently ascendant, several types of devices are used to measure physical activity. Heart rate monitors, pedometers, uni-, bi-, and triaxial accelerometers, and others have been used alone or in combination and affixed to various body parts. Currently under study is a combination skin temperature sensor, near body temperature sensor, heat flux sensor, galvanic skin response sensor, and biaxial accelerometer (5), as is a device combining inputs from sensors at five bodily sites (101). Recent technological progress has enabled lighter, smaller, and more sophisticated instruments. They have already contributed importantly to surveillance and etiologic studies, especially with respect to lower-intensity activities (29, 57, 92).

Just as we have learned the foibles and limits of self-reported activity information, we need to understand better the advantages and disadvantages of various instruments. Instruments are subject to defects and failures. Even when instruments are functioning as designed, their accuracy describing physical activity requires human inputs and decisions. Humans, for example, set the sensitivity with which the instruments detect motion, and thereby the ratio of physical activity to extraneous noise (12). Humans must estimate what types and intensities of physical activity the various outputs represent. Information about the specific activity (e.g., walking, cleaning), its purpose (e.g., pleasure, transportation), or its relative intensity—all important aspects of physical activity from a behavioral perspective—is unknown via instruments. The number of days instruments need to be worn to provide a reliable estimate is still uncertain (6, 15, 90). Compliance with instructions on how and when to wear the instruments may vary by the subjects' usual physical activity practices, creating a potential for bias (94). Some instruments are limited in their ability to assess certain activities, such as cycling or swimming. These difficulties can be managed; the use and value of instruments to measure activity will continue to grow and to add importantly to existing knowledge. But the best use of the instruments will require skepticism, careful evaluation, and combination with other methods including self-report.

SUMMARY AND DISCUSSION

A recent list of anticipated technological advances included "physical video games" to help us be active and "domestic robots" to give us rest (1). The irony of the juxtaposition is apparent. The volume of physical activity has declined (8) just as we have been learning how important physical activity is for health. The value of regular vigorous activity was demonstrated first because the necessity for vigorous activity diminished first. The value of light activity is only now being recognized because

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current technology has and continues to reduce the need for even light activities.

What Type?

Our bodies, engineered to meet the needs of 500,000 years ago, still need physical activity to be healthy. We need different types of activity to maintain different physiologic systems that, in turn, produce health. Aerobic activities maintain the metabolic systems to provide energy and the cardiorespiratory systems to circulate the raw materials. Ambulatory and strength-training activities maintain the strength and function of our muscles and bones. Balance training, especially when older, helps to keep us from falling.

How Much?

An accurate short answer is, "More," or "Some is good, more is better." Describing the amount of these activities needed to maintain and foster health is more complicated. The dose-response curve for volume of moderate and vigorous aerobic activities and all-cause mortality is a smooth inverse relationship with the most rapid reduction in risk occurring at the lowest volumes of activity. For inactive people, even small increases in the volume of physical activity provide important health gains. Dose-response curves for other conditions appear to be similarly shaped but with varying slopes, some faster and some slower. The 2008 *Physical Activity Guidelines for Americans* effectively translates these smooth curves into practical guidelines: Avoid being sedentary. Some activity is better than none. Additional benefits occur as the volume of activity increases. A range of 500–1000 MET-min/week provides substantial health benefits.

How Intense?

Until recently, the consensus was that benefit is limited to moderate- and vigorous-intensity activities, with ongoing discussion about the possible unique value of high-intensity activities beyond time efficiency in accumulating volume. Recent evidence that light-intensity activity is healthier than sedentary behavior, reflecting both advances in measurement and society-wide reductions in the volume of light-intensity activities, broadens the discussion. It will require a shift in the way we study, analyze, and interpret the type-volume-intensity relationships. Intensity is a continuous variable that we have categorized for convenience. The categories and cut points may need to be changed. Volume may not compensate as completely for intensity across the full range of intensities. Regular fast running requires physiologic capacities that cannot be developed by walking slowly no matter how much slow walking is done. The extent to which these augmented capacities contribute to improved health remains to be determined. From a public health perspective, it is likely more important to understand the relationships among type, volume, and intensity for sedentary, light-intensity, and moderate-intensity activities than for vigorous activities. Our guess is that light- and moderate-intensity activities are important at the lower end (left) of the dose-response curve, where benefits are gained or lost more quickly; vigorous activities become important at the high end (right) of the curve, where changes in relative risk are slower.

What Is Safe?

An inactive lifestyle is not safe. The scientific literature is nearly silent about the specific quantities and rates of change for becoming more active, but it is apparent that the risks of musculoskeletal injuries are directly related to the relative increase in volume and that cardiac risks are directly related to the relative increase in intensity. Well-conducted intervention studies demonstrate that elderly and unfit adults can, with patience and gradual progression, increase their physical activity levels with no serious and minimal minor adverse effects (14, 18, 40, 41, 53, 62). Starting and continuing with small increments and allowing adequate time for adaptation, especially among the elderly, will keep injuries and other adverse events at low levels and improve the probability of long-term behavioral change.

On Top of What?

The fuzzy and shifting baseline plus evidence that light-intensity activities are healthier than sedentary activities indicate a need to rethink the anchor point for considering and studying physical activity. We offer zero activity as a place to begin discussion.

Final Words

We have focused on the types, volumes, intensities, and other aspects of the activity-health relationship, saying nothing about the vital importance of physical activity promotion. We could not cover both. We hope that all readers will recognize and support the current efforts to promote physical activity and will continue to do research to improve our promotion activities.

We have not, until this final paragraph, used the word exercise. Did you miss it? Were you ever uncertain about what we were talking about? Although usefully defined (11), its meaning in both common and scientific usage varies considerably from user to user, inviting misunderstanding. The relationship between physical activity and health is more clearly described and discussed without it.

FUTURE ISSUES

1. The interplay among volume, duration, frequency, and intensity still needs attention, especially because of evidence supporting health benefits of light-intensity (1.6–2.9 METs) activity.
2. The principles of overload, adaptation, and progression provide a conceptual framework for safely increasing activity levels. Lacking is empirical information to support specific volumes and rates of increase, especially for older persons and unfit persons of any age.

DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

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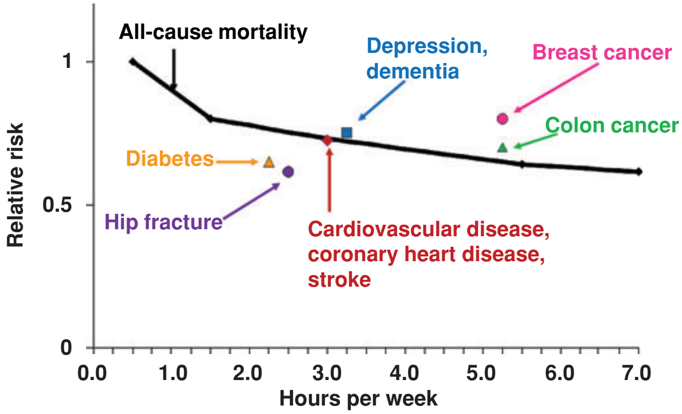

Figure 2

Risk of selected health events by hours/week of moderate to vigorous physical activity.

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