

The Evolving Definition of “Sedentary”

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PATE, R.R., J.R. O'NEILL, and F. LOBELO. The evolving definition of “sedentary.” *Exerc. Sport Sci. Rev.*, Vol. 36, No. 4, pp. 173–178, 2008. *Studies that did not directly measure sedentary behavior often have been used to draw conclusions about the health effects of sedentariness. Future claims about the effects of sedentary, light, and moderate-to-vigorous activities on health outcomes should be supported by data from studies in which all levels of physical activity are differentiated clearly and measured independently.*

Key Words: physical activity, health, accelerometry, adult, child

INTRODUCTION

Learned scholars have associated “sedentary living” with reduced longevity and impaired health for many centuries. Hippocrates wrote extensively about the benefits of exercise for a variety of ailments, including both physical and mental illnesses. Claudius Galenus (Galen), whose writings dominated European medicine for centuries, believed that some form of exercise could be used to treat virtually every disease (10). For the past half century, epidemiologists and physiologists have validated the perceptions of the ancient scholars by demonstrating that persons who perform moderate-to-vigorous physical activity on a regular basis manifest a plethora of physiologic benefits and experience reduced risk of chronic disease and premature mortality (10). Scientists also have reported that sedentary behavior is associated with a variety of health risks (10). However, most studies have not measured sedentary behavior or differentiated it from light activity. It seems reasonable, therefore, to ask whether studies to date actually have examined the health implications of sedentary behavior or if they simply have defined sedentary as the absence of moderate-to-vigorous physical activity.

Although sedentary, light, moderate, and vigorous activities can be estimated via self-report instruments, the recent development of objective systems for measuring physical activity (in particular, accelerometry) now allows researchers

to monitor a wide range of intensities of activity, including sedentary and light activity, with considerable precision. The primary purpose of this review is to emphasize the distinction between sedentary behavior and the absence of moderate-to-vigorous physical activity. The central hypothesis is that researchers rarely have measured sedentary behavior and, therefore, confound efforts to identify the health effects of sedentary and light activity. We will note that, despite frequent claims regarding the harmful health effects of sedentariness, investigators rarely have measured sedentary behavior in direct ways. We will suggest that, in the future, investigators should focus as much attention on the lower end of the activity intensity continuum as has traditionally been placed on the higher end of that continuum, if valid conclusions about the independent effects of each activity intensity category are to be made.

HISTORICAL CONTEXT

Exercise scientists, although often decrying the deleterious effects of sedentary living, rarely have measured sedentary behavior. Even studies that have drawn conclusions about the effects of sedentary behavior on health have not actually measured such behavior. In the groundbreaking Harvard Alumni Study, for example, men who expended less than an estimated 2000 kcal·wk⁻¹ through walking, climbing stairs, and playing sports were classified as sedentary. Although sedentary behavior was not measured, the investigators concluded that sedentary men had a 31% higher risk of death than more active men (7). In a study of physical activity and other health behaviors in youth, an analysis of the 1999 Youth Risk Behavior Survey data classified participants as having a sedentary lifestyle if they did not report participating in moderate or vigorous physical activity at recommended levels (6).

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Rather than measuring sedentary behavior, or any activity at the low end of the physical activity continuum, exercise studies traditionally have focused on physical activity performed at rather high intensities. Much of our knowledge of the health-related physiologic effects of regular exercise has been generated from an extensive body of controlled exercise training studies. Both animals and humans have been studied. Ordinarily, exercise of at least moderate intensity has been imposed, and often, the exercise treatment has been vigorous in intensity and prolonged in duration. These studies have done much to advance our knowledge of the mechanisms by which regular exercise influences health outcomes. However, such studies cannot support conclusions about the effects of sedentary behavior on health because the experimental designs typically did not impose inactivity.

Important exceptions to the traditional focus on moderate-to-vigorous exercise have been studies examining the effects of bed rest and weightlessness. These studies certainly have imposed sedentary behavior on the subjects, and they have demonstrated convincingly that absolute inactivity produces dramatic reductions in function and health status. However, such treatments clearly are extreme and do not mimic the behavior of free-living humans who opt to engage in only sedentary pursuits and light physical activity. Perhaps more directly applicable to the topic of this article are studies of “detraining,” or cessation of regular moderate-to-vigorous physical activity. This is a literature of modest magnitude, but in general, it shows that persons who first train and then stop training tend to lose the physiologic adaptations to training within a few weeks. However, to our knowledge, no previous studies have systematically withdrawn typical forms of moderate-to-vigorous physical activity from the lifestyles of normally active persons and observed the health-related physiologic effects of such a treatment.

So it seems fair to conclude that the traditional focus of exercise science has been on studies of moderate-to-vigorous exercise. However, with the rise of physical activity epidemiology over the past three decades, our image of “health-promoting exercise” has undergone a noticeable shift. As the large epidemiologic data sets matured in the 1970s, 1980s, and 1990s, it became clear that important health benefits accrued to those who regularly participated in activities like brisk walking and yard work — forms of activity that are moderate in intensity. This observation prompted important changes in our recommendations to the public regarding the types of physical activity that are needed for health benefits, including a focus on “lifestyle activity” and accumulation of activity throughout the day.

This shift to an epidemiologic focus, although important, typically was based on self-report of activities that were thought to be of sufficient demand as to potentially impact health (and that could be recalled readily and reported). Given the historical footings of exercise science, it is not surprising that these instruments usually have included activities of moderate and vigorous intensity — but often have not queried participation in light intensity and sedentary behaviors. Hence, although epidemiologists often have observed subgroups of their study populations that were labeled “sedentary” or “physically inactive,” these terms rarely have been operationalized using data on measured

sedentary behavior. Much more typically, the sedentary group in epidemiologic studies has been composed of persons who did not report enough moderate or vigorous activity to be categorized as “active” or “highly active.” Often, subjects have been categorized as sedentary by default, not on the basis of measured participation in sedentary behavior.

THE DEFINITION AND MEASUREMENT OF SEDENTARY BEHAVIOR

To provide a frame of reference for readers from varying backgrounds, we provide the following definitions of sedentary behavior and light physical activity. **Sedentary behavior refers to activities** that do not increase energy expenditure substantially above the resting level and includes activities such as sleeping, sitting, lying down, and watching television, and other forms of screen-based entertainment. Operationally, sedentary behavior includes activities that involve energy expenditure at the **level of 1.0–1.5** metabolic equivalent units (METs). (One MET is the energy cost of resting quietly, often defined in terms of oxygen uptake as $3.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). **Light physical activity**, which often is grouped with sedentary behavior but is in fact a distinct activity construct, **involves energy expenditure at the level of 1.6–2.9 METs**. It includes activities such as slow walking, sitting and writing, cooking food, and washing dishes.

The development of accelerometry as an objective measure of physical activity has opened up new possibilities for **studying the health effects of all intensity levels of physical activity**. Researchers now can measure the entire range of activity, from completely sedentary to very vigorous, in free-living subjects over a number of days. Although **accelerometry has some important limitations, and standardized** procedures are still in development, it provides significant advantages over other methods for measurement of physical activity. First, its raw data can be collected and stored for extended periods in relatively short time increments (e.g., 15, 30, or 60 s). Second, calibration curves can be used to estimate the intensity of physical activity performed during each time interval. Thus, accelerometry allows researchers to determine the cumulative time spent each day in activity at all intensity levels, including sedentary, light, moderate, and vigorous.

To illustrate this point, **accelerometry data for two people with very different activity patterns are presented** in Figures 1 and 2. The person for whom data are shown in Figure 1 would be **classified as sedentary in** most research studies because she did **not participate in 30 min or more of moderate or vigorous physical activity**. However, it is clear that she was not sedentary for the entire day. Rather, she participated in **light activity during approximately 75%** of the time monitored (13 h) and was sedentary during the remaining **25% of the time monitored**. In contrast, the person shown in Figure 2 would be classified as “active” in most studies. This person engaged in 1 h of moderate-to-vigorous physical activity and, thus, met current physical activity recommendations. Nevertheless, it is clear that this person spent most of the assessed time in either sedentary **behaviors (70%)** or light intensity physical activities (23%).

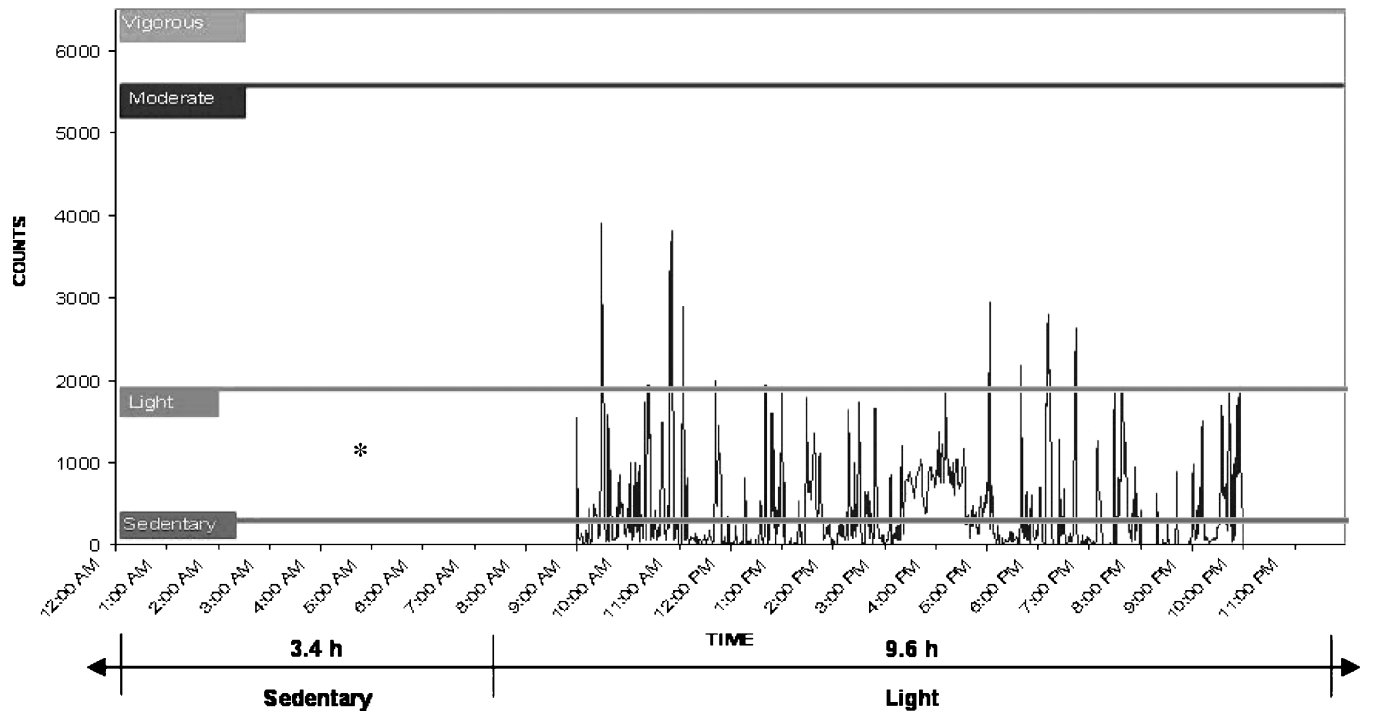


Figure 1. Actigraph representation of activity of a 30-yr-old woman. (Count cutoffs determined from the energy expenditure prediction equation developed by Freedson and colleagues (2).) *Monitor was not worn.

Although the subjects observed in these examples both spent significant portions of the observed time engaging in sedentary (e.g., sitting) and light (e.g., slow walking) activities, the proportions were markedly different between the two. Light activity increases metabolic rate, and the

energy cost of light activities accumulated throughout the day can contribute significantly to total daily energy expenditure. To illustrate this point, we estimated energy expenditure for the two subjects for the 13-h monitoring periods. Using the mean MET level for each intensity

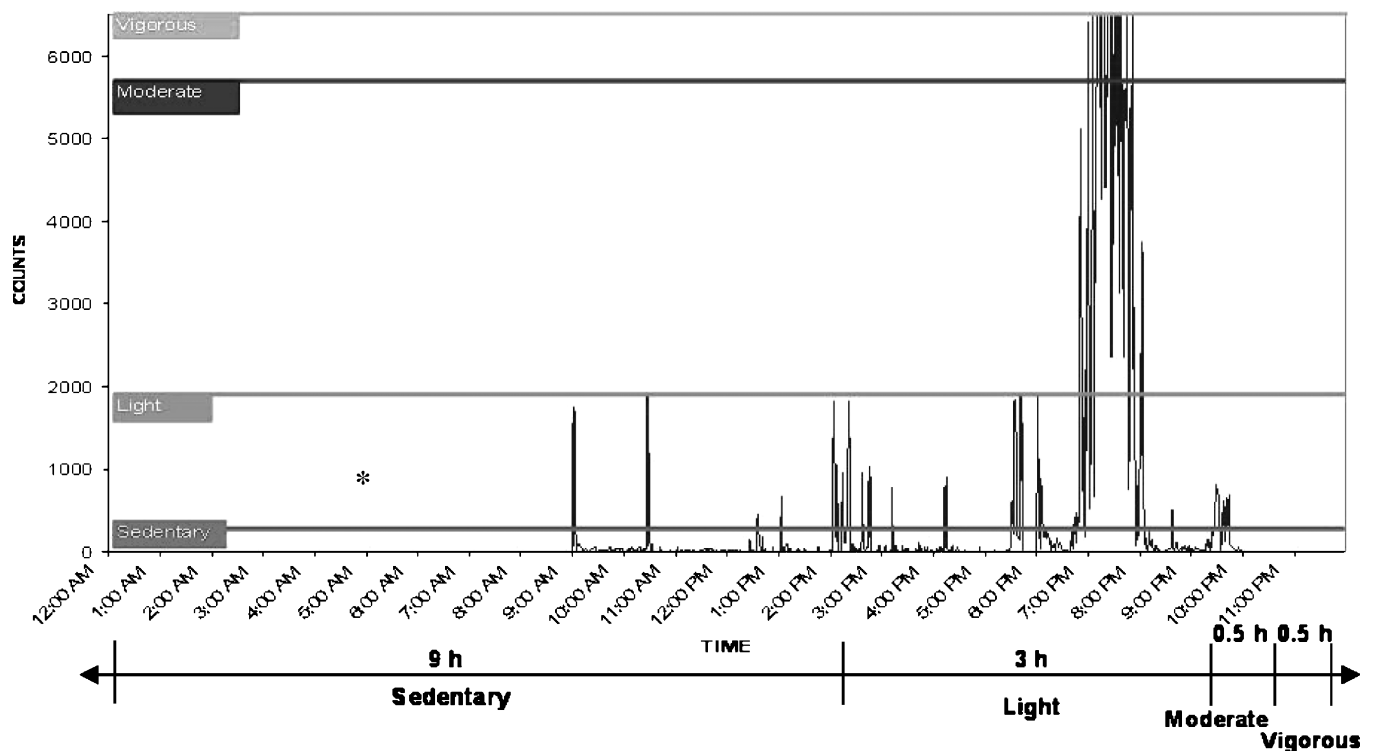


Figure 2. Actigraph representation of activity of a 28-yr-old man. (Count cutoffs determined from the energy expenditure prediction equation developed by Freedson and colleagues (2).) *Monitor was not worn.

category (1.25 METs for sedentary, 2.2 METs for light, 4.5 METs for moderate, and 7.5 METs for vigorous activities), we multiplied METS by the number of hours engaged in each activity intensity. The subject in Figure 1, who failed to meet recommended levels of moderate-to-vigorous physical activity, performed an estimated 26.3 MET-hours of activity during the monitoring period. The subject in Figure 2, who engaged in an hour of structured exercise at a moderate-to-vigorous level, performed an estimated 23.6 MET-hours and expended less energy than the other subject (assuming equal body weights for the two persons). This example points to the importance of considering the full range of energy expenditure rates observed in the activity range below moderate intensity.

For the purpose of applying accelerometry to the study of sedentary behavior, it is important to carefully establish accelerometer count cut points that identify sedentary behavior and to recognize that these cut points may be different for adults and children. Accelerometers have been calibrated against energy expenditure, and regression models have been used to translate accelerometer counts into specific physical activity intensity ranges. Most studies addressing sedentary behavior have used an absolute count cutoff, typically less than 50 or 100 counts per minute. However, such an absolute cut point may not work well across diverse age groups. More calibration research is needed to determine the best definition of cut points for sedentary behavior with accelerometry, among both youth and adults (11).

Although accelerometers have created new opportunities for validly measuring the full range of energy expenditure, in the future, improved accelerometers or entirely new instruments may allow researchers to better quantify the energy expenditure of common daily exercise and nonexercise activities. Some of these instruments are currently in development and testing, and they are promising because they detect the energy expended in activities that typically are considered sedentary, such as sitting, lying down, changing postures, moving limbs, and fidgeting, as well as light, moderate, and vigorous activities (13,14).

STUDIES OF SEDENTARY BEHAVIOR

To test our hypothesis that researchers have inadequately defined or measured sedentary behavior, we searched the literature for studies that reported effects of sedentary behavior on health status. Most of the studies we identified that drew conclusions about the health effects of sedentary behavior (including some of our own) did not actually measure sedentary behavior. Although a complete summary of our literature review is beyond the scope of this article, several examples of these studies are presented below.

The Relationship of Physical Activity and Body Weight With All-Cause Mortality

The relationships of physical activity and obesity with all-cause mortality were studied in 9824 Puerto Rican men followed from 1962 to 1965 as part of the Puerto Rico Heart Health Program (1). Physical activity was self-reported, and the referent-sedentary group (lowest quartile of activity)

included participants who reported engaging in little to no moderate or vigorous activities. All-cause mortality was significantly lower in the upper three activity quartiles, compared with the referent-sedentary group. Although sedentary activity was not measured, and the sedentary group included those who reported light activity, the authors concluded that “Puerto Rican men who are physically active experienced significant reductions in all-cause mortality compared with their sedentary counterparts.”

Physical Inactivity and Overweight Among Los Angeles County Adults

The association between physical activity and health status was examined in 8353 Los Angeles County adults (12). Using a telephone survey, the researchers obtained self-reports of physical activity, body mass index, and mental health status variables. Individuals were defined as sedentary if they reported less than 10 min·wk⁻¹ of continuous physical activity. In this report, being classified as sedentary was associated with an overall perception of poor health and with feelings of sadness and depression. In addition, obese adults were more likely to be classified as sedentary than overweight and normal weight adults. Although sedentary behavior was not measured in this study, the authors concluded that “mental and physical health status were prominent correlates of sedentariness.”

The Association Between Television Viewing and Overweight Among Australian Adults

The authors studied the effect of physical activity on the association between television viewing and overweight in 3392 adults from New South Wales, Australia (8). Walking, moderate and vigorous leisure-time physical activities, television viewing habits, and body mass index were assessed using self-reports. Across low, moderate, and high physical activity categories, those who reported watching more than 4 h of television per day were twice as likely to be overweight as those who reported less than 1 h of television per day, irrespective of their physical activity level. Despite the fact that only one sedentary activity was measured and that an effect interaction was tested only for the total volume of leisure-time physical activity, the authors concluded that, “in order to reduce the prevalence of overweight and obesity or at least prevent weight gain, it may be not only important to increase participation in purposive physical activity, but also to reduce the time spent in sedentary behaviors.”

Physical Activity and Determinants of Physical Activity in Obese and Nonobese Children

This study compared the physical activity levels of 54 obese and 133 nonobese children (9). Moderate, vigorous, and moderate-to-vigorous physical activity were measured with accelerometry, but the authors did not directly assess sedentary or light physical activity. Obese children engaged in less moderate, vigorous, and moderate-to-vigorous physical activity compared with nonobese children, but the authors concluded that, “Our findings are consistent with the hypothesis that physical inactivity is an important contributing factor in the maintenance of childhood obesity” (9(p826)).

These examples point to the tendency of investigators to draw conclusions about sedentary behavior without having measured it. However, we did find some examples of studies that did directly measure sedentary or light activity or that avoided drawing conclusions about sedentary behavior after having measured only one sedentary activity. Several of these studies are presented below.

Objectively Measured Light-Intensity Physical Activity Is Independently Associated With 2-h Plasma Glucose

The associations between time spent in sedentary, light, and moderate-to-vigorous activity with glucose metabolism were studied in 67 men and 106 women participating in the AusDiab study (4). Physical activity was assessed objectively during 7 d with an Actigraph accelerometer; and glucose metabolism, with an oral glucose tolerance test. In analyses that adjusted for potential confounders, including waist circumference, sedentary time was positively associated with, and both light and moderate-to-vigorous activity time were negatively associated with, 2-h postchallenge plasma glucose levels. The authors concluded that “light-intensity physical activity is beneficially associated with blood glucose and that sedentary time is unfavorably associated with blood glucose.”

Ethnic Differences in Physical Activity and Inactivity Patterns and Overweight Status

The relationship between physical activity and overweight status was examined among 12,759 11- to 19-yr-olds participating in the National Longitudinal Study of Adolescent Health from 1995 to 1996 (3). Participants self-reported their low, moderate, and vigorous intensity activities over the past week. *Light activity* was defined as low-intensity activities ranging from 2–3 METs. Although both boys and girls reported the same amount of low-intensity activity per week, the change in low-intensity physical activity over 1 yr modestly affected overweight status in girls. The authors correctly identified low-intensity physical activity as such and concluded that “girls had 8% higher odds of overweight with 1-year change in low-intensity physical activity.”

Television Watching and Other Sedentary Behaviors in Relation to Risk of Obesity and Type 2 Diabetes Mellitus in Women

Data from 50,277 women in the Nurse’s Health Study cohort were used to investigate the longitudinal relationship between several sedentary and light-intensity activities and the risk of obesity and type 2 diabetes mellitus while adjusting for leisure-time exercise activities (5). Participants self-reported a range of activities, from sedentary and light intensity to vigorous. Each increment of 2 h·d⁻¹ in television watching or sitting at work was associated with a 23% and 5% increase in obesity and a 14% and 7% increase in risk of diabetes, respectively. In contrast, standing or walking around at home (2 h·d⁻¹) was associated with a 9% reduction in obesity and a 12% reduction in diabetes. The authors concluded that, “Independent of exercise levels, sedentary behaviors, especially television watching, were associated with significantly elevated risk of obesity and

type 2 diabetes, whereas even light to moderate activity was associated with substantially lower risk.”

These examples illustrate that, to date, few studies have measured sedentary behavior among adults and youth, and the health effects of very low activity levels are still unclear. In addition, the potential health benefits of accumulated light activity are unclear because, in most studies, light activity and no activity are combined in a sedentary or low-active category. Of the four summarized articles that measured sedentary or light activity, one study (4) used accelerometry to objectively measure light activity. More research is needed to measure the lower end of the activity continuum and to test its association with health outcomes.

RECOMMENDATIONS

Because of advancing methodologies and developing bodies of knowledge, we believe that several conventions should be applied widely and consistently in future studies of the relationships between physical activity, sedentary behavior, and health. Specifically:

1. Whenever feasible and appropriate to the study aims, the full range of activity intensities should be observed, reported, and used analytically. This should include sedentary behavior and light physical activity as well as moderate and vigorous physical activity.
2. While the full range of activity intensities (sedentary to vigorous) contribute to total energy expenditure, activity performed within a narrow intensity range (e.g., vigorous) may influence health in ways that are unique from other activity intensities. Accordingly, activity intensity categories should be treated as potential independent influences on health outcomes.
3. Conclusions of studies should be phrased carefully so as to be consistent with the activity variables that were actually measured in the study. Conclusions regarding the influence of sedentary behavior should be drawn only if sedentary behavior was measured and used analytically. Likewise, study conclusions about the influence of physical activity should specify clearly the range of intensities included in the physical activity variable.
4. If specific surrogate behaviors are used to study sedentary activity (e.g., television watching) or physical activity (e.g., walking), conclusions should be stated in terms that are limited to those behaviors.
5. Operational definitions of activity constructs should be presented clearly by investigators. For example, accelerometry cut points for differentiation of sedentary, light, moderate, and vigorous activity should be reported. The same principle should be applied in studies using self-report instruments.

SUMMARY AND CONCLUSIONS

Although scientists have reported that being sedentary is associated with significant health risks, few studies to date have measured sedentary or low active behavior. In most cases, study participants who are reported to be sedentary or

inactive are actually those who did not meet the study's criteria for moderate or higher levels of activity. This grouping of people at the lower end of the activity continuum may confound efforts to identify the health effects of sedentary and light-intensity activity behavior. To date, few self-report instruments have been developed to detect sedentary behavior and light-intensity physical activity, and even fewer have been validated. Recent advances in accelerometry have made possible the measurement of the full range of physical activity levels, from completely sedentary to extremely vigorous, with a single instrument. Thus, accelerometry is emerging as a valuable tool for exploring the independent associations of various activity levels with health outcomes. Future studies should measure sedentary and light activity to determine their independent and joint contributions to health outcomes.

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