Physical Activity, Sedentary Behavior, and Health: Paradigm Paralysis or Paradigm Shift?

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Perhaps the greatest barriers to achieving major public health advances in the 21st century will result from pandemic paradigm paralysis or the widespread inability to envision alternative or new models of thinking. One potential example of this phenomenon could turn out to be the continued focus on moderate and vigorous physical activity as the dominant health-related aspect of human movement. The current model of physical activity and health is well supported by over 60 years of scientific inquiry, and the beneficial effects of moderate-to-vigorous physical activity have been more clearly defined in recent years (1–4). However, if we are complacent with the existing paradigm—that increasing levels of moderate and vigorous levels of physical activity will result in the greatest improvements in public health—then we may not obtain the full return on investment with respect to improving quality of life and life expectancy through patterns of human movement. Emerging evidence for the role of sedentary behavior on health, which may be independent of physical activity per se, finds us at a crossroad with respect to prescribing optimal daily human movement patterns for health.

Human movement represents a complex behavior that is influenced by personal motivation, health and mobility issues, genetic factors, and the social and physical environments in which people live. These factors undoubtedly exert an influence on the propensity to engage in sedentary behaviors as well as in physical activity. However, the biological, social, and environmental pathways leading to sedentary behavior versus physical activity may be different. Further, the health effects associated with sedentary behavior and physical activity may be the result of different biological mechanisms (5).

Humans are designed for movement. Energy balance has been a central selective force throughout human evolutionary history, and humans have evolved to have high levels of energy expenditure, even more so than modern nonhuman primates (6). Obtaining dietary energy and nutrients from the environment traditionally required an expenditure of energy through human movement. Factors related to the expansion of the African grasslands between 2.5 and 1.5 million years ago and the emergence of *Homo* were major contributors to changes in both brain size and foraging behaviors (6,7). Early *Homo* (*H. habilis* and *H. erectus*) appeared at a time of rapid brain evolution with early *Homo* having an average brain size of 600–900 cc compared with earlier australopithecines with an average brain size of 400–500 cc (7). The larger brain size of *Homo* required higher quality diets, which necessitated larger foraging ranges, resulting in greater total energy expenditure. At the same time, the transition from a forest to savanna environment caused changes in resource distribution that would have also resulted in increases in foraging ranges and total energy expenditure (6). Much of human evolution has occurred as hunter-gatherers (3–4 million years), while recent advances in agriculture and technology have occurred over a short time frame (~10,000 years). Eaton and Eaton (8) have estimated that Stone Age humans had an energy efficiency ratio of 2.25 (i.e., expending 1 kJ of energy to acquire 2.25 kJ of dietary energy) compared with an efficiency ratio of 3.66 for modern humans, which represents more than a 50% increase in efficiency.

Modern humans in the Western world have relatively low levels of physical activity compared with contemporary hunter-gatherers. Hayes et al. (9) reported that the total energy expenditure/resting energy expenditure or Physical Activity Level (PAL) among subsistence-level human populations approximates 3.2, while among representative humans living in contemporary society, the PAL is ~1.67. The impact of the transition from a semi-subsistent existence to a Western lifestyle on physical fitness levels are exemplified by work in an Inuit community (Igloolik, northern Canada) (10,11). Studies in the population from 1970 through 1990 demonstrated marked reductions in average aerobic fitness ($ml \cdot kg^{-1} \cdot min^{-1}$) over time in all age-groups (10,11). Recent work among Old Order Amish living a traditional agricultural lifestyle indicates that this population engages in more daily movement than contemporary Americans. The average number of steps per day taken by Amish men and women were 18,425 steps per day and 14,196 steps per day, respectively (12). These values are considerably higher than recent estimates for contemporary U.S. adults (13,14) (Fig. 1).

The weighted evidence indicates that humans evolved in environments that required higher levels of human movement than are required today. By becoming more efficient at extracting energy from the environment, there is now a lower level of expenditure required to subsist. Some studies have documented lower levels of physical activity among contemporary humans compared with those living in more primitive societies. A negative consequence to the observed improvements in energetic efficiency is the proliferation of health concerns that are related to low levels of physical activity and/or high levels of sedentary behavior.

Physical activity and health. The modern field of physical activity epidemiology arguably began with the studies

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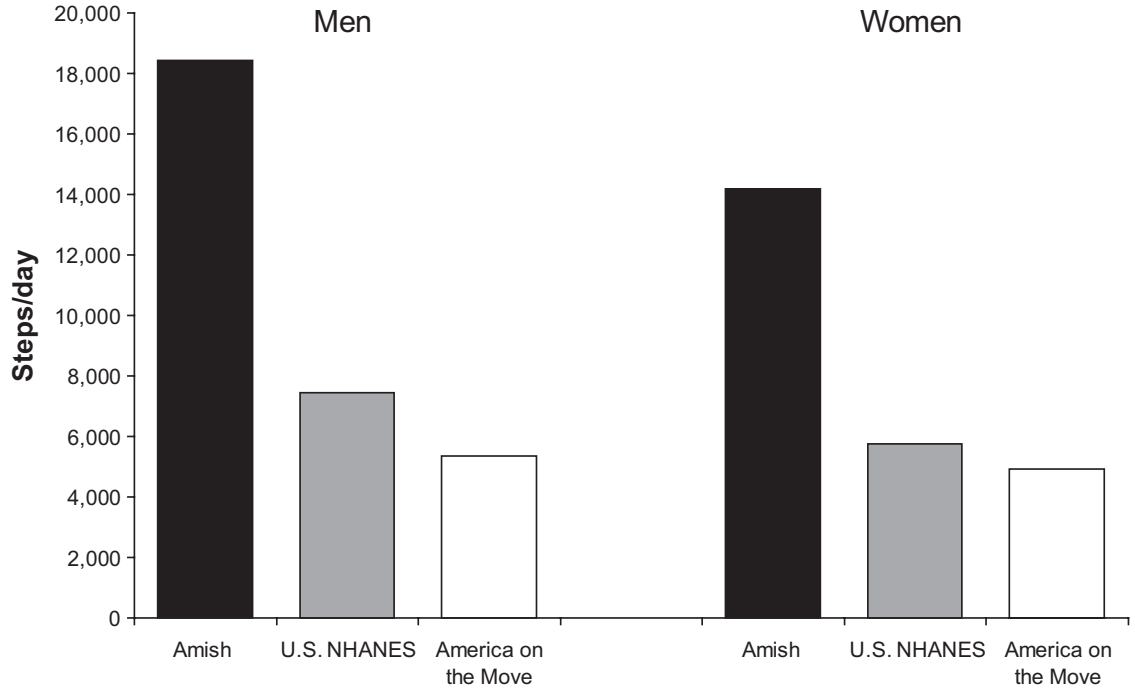

FIG. 1. Average steps per day among Old Order Amish men and women (12) compared with contemporary U.S. adults in the 2005–2006 U.S. NHANES (13) and the 2003 America on the Move Study (14).

of Morris et al. (15) conducted in the early 1950s among employees of the London Transport Executive and Post Office employees. Their results demonstrated that physically active men (bus conductors and postmen) had lower mortality rates from heart disease than less active workers (bus drivers and telephone switchboard operators). These early studies provided evidence for a role of physical activity in averting premature mortality; however, it has also recently been hypothesized that some of the observed associations may be explained by differences in time spent sitting rather than being less physically active per se (i.e., bus drivers sit more than conductors) (5). The independent roles of sitting versus physical activity cannot be determined from these early studies.

A great volume of evidence has accrued over the past 60 years on the relationship between physical activity and health. This culminated in the 1996 U.S. Surgeon General's report on *Physical Activity and Health* (3) and the *2008 Physical Activity Guidelines for Americans* (16).

Two classic studies are used here to illustrate the relationships between physical activity, cardiorespiratory fitness, and all-cause mortality. The first, the Harvard Alumni Study (Fig. 2*A*) (17), was an analysis of physical activity and all-cause mortality over 16 years among ~17,000 men that revealed an inverse dose-response relationship between physical activity and all-cause mortality rates. Greater physical activity was associated with a lower risk of death, and men expending >2000 kcal per week in physical activity had a 27% lower risk of mortality compared with men expending <2000 kcal per week (17).

The second study, the Aerobics Center Longitudinal Study (ACLS), is reflected in Fig. 2*B* and displays the

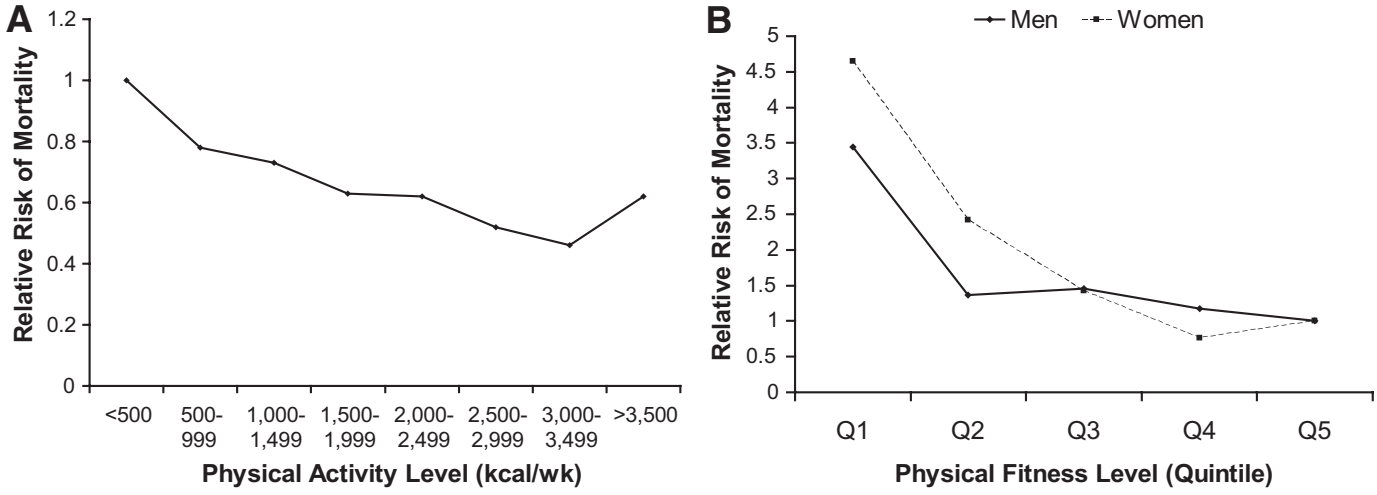

FIG. 2. RRs of all-cause mortality across levels of physical activity in the Harvard Alumni Study (17) (*A*) and cardiorespiratory fitness in the Aerobics Center Longitudinal Study (18) (*B*).

results of an analysis of ~10,000 men and 3,000 women followed for 8 years for all-cause mortality in relation to initial levels of cardiorespiratory fitness. Inverse dose-response relationships between cardiorespiratory fitness and all-cause mortality were observed in both men and women. Men and women in the lowest fitness quintile were 3.44 (95% CI 2.05–5.77) and 4.65 (2.22–9.75) times more likely to die compared with men and women in the upper quintile, respectively (18). Similar relationships with physical activity have been observed for the risk of developing several chronic diseases (19).

Nonexercise movement and health. The emergence of obesity as a major public health issue has prompted efforts to understand the contributions of both energy intake and expenditure. With respect to energy expenditure, an emphasis has been placed on understanding the role of moderate-to-vigorous physical activity in the prevention and management of obesity (20,21). However, some intriguing results have been published on the role of nonexercise activity thermogenesis (NEAT) on weight gain in humans (22–25). Nonexercise activities are those activities of daily living other than exercise per se, and encompass such things as sitting, standing, walking, and fidgeting (25). Nonexercise activities result in higher levels of energy expenditure beyond the supine resting metabolic rate (25), and increases in NEAT that accompany overeating account for a large fraction of the dissipation of energy required to preserve leanness (23). Indeed, NEAT behaviors differ between lean and obese individuals. For example, obese subjects in one study spent an average of 2 h per day more in a seated position compared with their lean counterparts (24). These results suggest that human movement patterns below the intensity thresholds of moderate or vigorous may play a significant role in the maintenance of energy balance. More research is required to understand the role of NEAT in influencing other health outcomes.

A recent study (26) has provided population estimates for lifestyle activities (those falling between sedentary [<760 accelerometer counts per minute] and moderate intensity [≥2020 counts per minute]) from the U.S. National Health and Nutrition Examination Survey (NHANES) 2005–2006. Using these thresholds, some NEAT behaviors would be captured in the definition of lifestyle activities, but some behaviors such as sitting and standing would be below the lower threshold. The results of this study showed that adults spent an average of 110 min per day engaging in lifestyle activities, and that obese adults spent significantly less time in lifestyle activities (26).

Healy et al. (27,28) reported associations between NEAT activities that were measured using accelerometry (defined as 100–1,951 counts per minute) and cardiometabolic risk factors. NEAT activities were significantly related to waist circumference, 2-h postload glucose, and a metabolic risk factor cluster score. Similarly, using accelerometry data from NHANES 2005–2006, Camhi et al. (29) reported on the relationship between lifestyle activities (760–2,019 counts per minute) and cardiometabolic risk factors. Lifestyle activities were negatively associated with most risk factors and the metabolic syndrome, even after adjusting for levels of moderate-to-vigorous physical activity. For every 30 min of daily lifestyle activity, there was a 15% lower odds of having metabolic syndrome (odds ratio 0.85 [95% CI 0.79–0.91]) (29). Thus, there appears to be a relationship between lifestyle activity and health, and the relationship may be independent of moderate-to-vigorous physical activity.

Sedentary behavior and health. There are several lines of evidence for a relationship between sedentary behavior and health, including epidemiological investigations of sedentary behavior and mortality or risk of chronic disease, as well as human intervention studies of physical activity reductions or bed rest and studies conducted in the laboratory using animals.

Sedentary behavior and mortality. Several recent epidemiological studies have reported inverse associations between sedentary behaviors and mortality in humans (Table 1). A clear dose-response relationship between daily sitting time and all-cause and cardiovascular disease (CVD) mortality was evident in the 12-year mortality follow-up of the Canada Fitness Survey in both men and women (30). However, the relationship between sitting and cancer mortality was not significant. Similar results were obtained in a 6.6-year follow-up of the Australian Diabetes, Obesity and Lifestyle Study (AusDiab), where there was a significant positive association between television (TV) viewing and mortality from all-causes and CVD but not from cancer (31). A recent analysis from the European Prospective Investigation of Cancer (EPIC)-Norfolk Study (32) also revealed a significant association between TV viewing and all-cause mortality (hazard ratio [HR] 1.05 [95% CI 1.01–1.09] per hour per day) and CVD mortality (HR = 1.08 [1.01–1.16]) but not for cancer mortality (HR = 1.04 [0.98–1.10] per hour per day) over 9.5 years of follow-up. The results of these three studies are remarkably similar; however, two other studies have shown somewhat different results. An analysis from the ACLS found a significant positive relationship between time spent sitting in a car and CVD mortality in men, but failed to show a relationship between TV viewing and CVD mortality (33). The Japan Public Health Center (JPHC) Study demonstrated that men who spent ≥8 h sitting each day had a significantly elevated risk of all-cause mortality (1.18 [1.04–1.35]) compared with men who sat <3 h per day; however, there was no corresponding association among women (34). Although these results are less striking, the upper end of the sitting continuum in this study was quite low (≥8 h). If people sit for an average of 8–10 h per day (35), perhaps higher thresholds are required to determine the ill-health effects associated with prolonged sitting.

Although there is compelling evidence that sedentary behaviors such as sitting and TV viewing are related to premature mortality, a question that remains to be answered is whether these behaviors are independent of total physical activity levels per se. The studies presented in Table 1 provide evidence on this question using two strategies. First, all of the studies included physical activity in a final multivariate-adjusted regression model, and the results were largely unchanged from the models that did not include physical activity as a covariate (30–34). Second, some studies stratified their analyses by physical activity level or included interaction terms in the statistical models. Interaction terms for sedentary behavior and physical activity in the AusDiab study, the Canada Fitness Survey, and the EPIC-Norfolk Study were not significant, and their inclusion did not significantly modify the observed relationships (30–32). Stratifying analyses by physical activity level has led to different results. In the ACLS, there was a significant linear trend across categories of time spent riding in a car and CVD mortality in physically

TABLE 1
Summary of prospective epidemiological studies of sedentary behavior and mortality in humans

Study (ref.)	Sample size	Follow-up	Sedentary behaviors	Outcomes	HR (95% CI)	*P* for trend
Japan Public Health Center (JPHC) Study (34)	83,034 men and women	8.7 years	Daily sitting	All-cause mortality*		
Men						
<3 h/day					1.00	
3–8 h/day					1.02 (0.95–1.11)	
≥8 h/day					1.18 (1.04–1.35)	
Women						
<3 h/day					1.00	
3–8 h/day					0.95 (0.85–1.06)	
≥8 h/day					1.10 (0.82–1.25)	
Canada Fitness Survey (30)	17,013 men and women	12.0 years	Daily sitting	All-cause, CVD, and cancer mortality‡		
All-cause mortality						
None					1.00	
¼ of time					1.00 (0.86–1.18)	
½ of time					1.11 (0.94–1.30)	
¾ of time					1.36 (1.14–1.63)	
All of time					1.54 (1.25–1.91)	
						<0.0001
CVD mortality						
None					1.00	
¼ of time					1.01 (0.77–1.31)	
½ of time					1.22 (0.94–1.60)	
¾ of time					1.47 (1.09–1.96)	
All of time					1.54 (1.09–2.17)	
						<0.0001
Cancer mortality						
None					1.00	
¼ of time					0.92 (0.71–1.20)	
½ of time					0.91 (0.69–1.20)	
¾ of time					0.96 (0.69–1.33)	
All of time					1.07 (0.72–1.61)	
						NS
Australian Diabetes, Obesity and Lifestyle (AusDiab) Study (31)	8,800 men and women	6.6 years	TV viewing	All-cause, CVD, and cancer mortality†		
All-cause mortality						
<2 h/day					1.00	
2–4 h/day					1.13 (0.87–1.36)	
≥4 h/day					1.46 (1.04–2.05)	
CVD mortality						
None					1.00	
2–4 h/day					1.19 (0.72–2.00)	
≥4 h/day					1.80 (1.00–3.25)	
Cancer mortality						
None					1.00	
2–4 h/day					1.12 (0.75–1.66)	
≥4 h/day					1.48 (0.88–2.49)	
Aerobics Center Longitudinal Study (ACLS) (33)	7,744 men	21.0 years	TV viewing, riding in car	CVD mortality§		
TV viewing						
<4 h/week					1.00	
4–8 h/week					1.02 (0.74–1.42)	
8–12 h/week					1.27 (0.90–1.78)	
>12 h/week					0.96 (0.68–1.36)	
						0.94
Riding in car						
<4 h/week					1.00	
4–7 h/week					1.09 (0.77–1.54)	

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TABLE 1
Continued

Study (ref.)	Sample size	Follow-up	Sedentary behaviors	Outcomes	HR (95% CI)	*P* for trend
7–10 h/week					1.33 (0.96–1.83)	
>10 h/week					1.37 (1.01–1.87)	
						0.01
EPIC-Norfolk Study (32)	13,197 men and women	9.5 years	TV viewing	All-cause, CVD, and cancer mortality‖		
All-cause mortality per h/day					1.05 (1.01–1.09)	
CVD mortality per h/day					1.08 (1.01–1.16)	
Cancer mortality per h/day					1.04 (0.98–1.10)	

*Adjusted for age, geographic area, occupation, history of diabetes, smoking, alcohol intake, BMI, total energy intake, heavy physical work or strenuous exercise, walking or standing, and leisure-time sports or exercise; ‡adjusted for age, sex, smoking, alcohol consumption, leisure-time physical activity, and physical activity readiness; †adjusted for age, sex, smoking, education, total energy intake, alcohol intake, diet quality index, waist circumference, hypertension, cholesterol, HDL cholesterol, triglycerides, lipid-lowering medication use, glucose tolerance status, and exercise time; §adjusted for age, physical inactivity, current smoker, alcohol intake, BMI, family history of CVD, hypertension, diabetes, and hypercholesterolemia; and ‖adjusted for age, gender, education level, smoking status, alcohol consumption, history of diabetes, family history of CVD, family history of cancer, total physical activity energy expenditure, and medication use for hypertension or dyslipidemia (not in models for cancer mortality). NS, not significant.

inactive men ($P = 0.02$) but not in physically active men ($P = 0.13$) (33). On the other hand, in the Canada Fitness Survey, there were significant positive associations between daily sitting time and all-cause mortality in both physically inactive ($P < 0.0001$) and physically active ($P = 0.008$) men and women (30). Figure 3 presents the results of an analysis of the combined influence of leisure-time physical activity and daily sitting time among 17,013 men and women over 12 years of follow-up in the Canada Fitness Survey. The physically active group that reported no daily sitting served as the reference group with which all other groups were compared. There are clear associations between levels of sitting and mortality risk in both physically inactive and active men and women in this study, with no interaction ($P = 0.18$). Taken together, the results of existing studies suggest an association between sedentary behavior and mortality; however, further research is required to better define the interactive effects between sedentary behavior and physical activity.

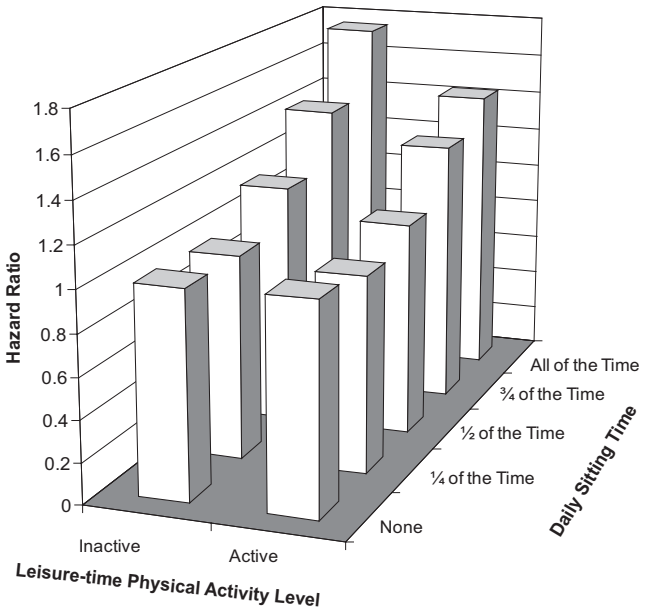

FIG. 3. HRs for all-cause mortality across categories of leisure-time physical activity (active defined as expending ≥7.5 MET · h · wk^{-1}) and daily sitting time in 17,013 men and women from the Canada Fitness Survey Follow-Up Study.

Sedentary behavior and risk of chronic disease. In addition to studies that have used mortality as the primary end point, several studies have also examined the influence of sedentary behaviors on the development of chronic conditions such as obesity, type 2 diabetes, and CVD using prospective research designs. For example, TV viewing was associated with an increased risk of developing obesity and type 2 diabetes over 6 years of follow-up in the Nurses' Health Study (36) (Fig. 4). The relative risk (RR) of obesity was approximately double (RR 1.94 [95% CI 1.51–2.49]) and the risk of type 2 diabetes was 70% higher (RR 1.70 [1.20–2.43]) in those watching >40 h per week of TV compared with women watching ≤1 h per week (36). The relationship between TV viewing and type 2 diabetes over 10 years was even stronger in men from the Health Professionals Follow-Up Study (HPFS). The multivariate-adjusted RR of developing type 2 diabetes was 3.02 (1.53–5.93) in men watching ≥40 h per week of TV compared with men watching ≤1 h per week, and these effects were largely independent of leisure-time physical activity (37).

Among Spanish university graduates followed prospectively for 40 months, those in the upper quartile of sedentary behavior had an RR of 1.48 (1.01–2.18) for developing hypertension compared with the lower quartile (38). However, in sub-analyses, the association with incident hypertension was evident only for driving and computer use and not for TV viewing. Among the participants in the Women's Health Initiative Observational Study (WHI-OS), the RR of incident CVD over 5.9 years of follow-up was 1.68 (1.07–2.64) among women sitting for ≥16 h per day compared with those sitting <4 h per day (39). Overall, the epidemiological evidence suggests that there is a strong association between sedentary behaviors and a variety of health outcomes.

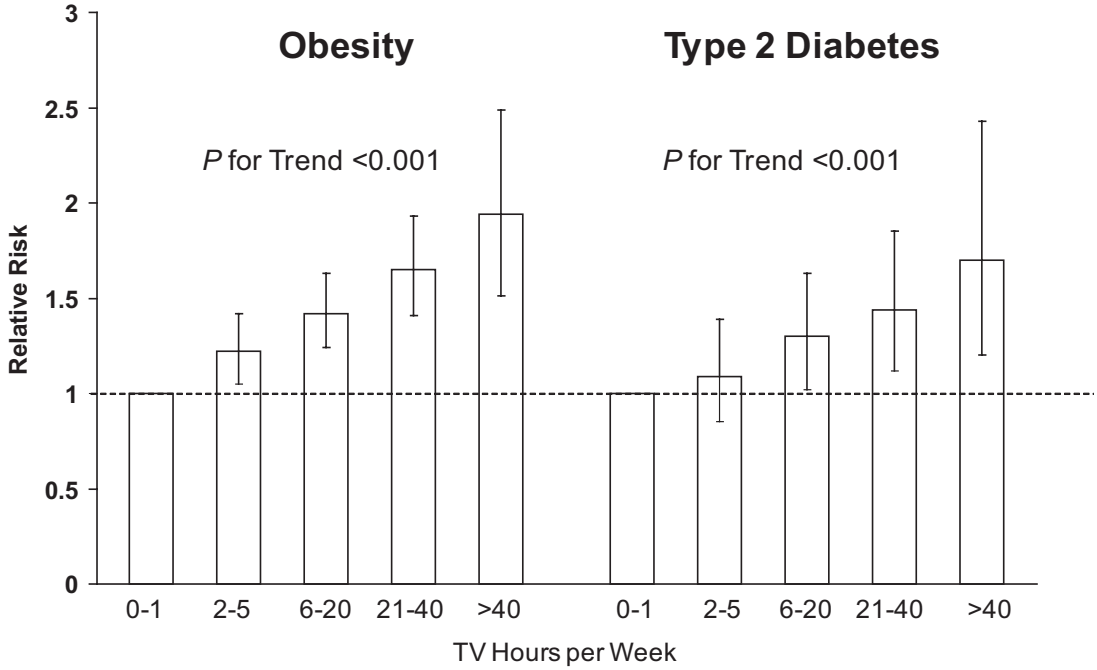

FIG. 4. Relationship between TV viewing and the development of obesity and type 2 diabetes over 6 years of follow-up in women 30–55 years of age from the Nurses' Health Study (36). Models are adjusted for age, smoking, alcohol use, hormone use, physical activity, total fat, cereal fiber, glycemic load, and total calories.

Sedentary behavior and chronic disease risk factors. Numerous cross-sectional studies have investigated the association between sedentary behaviors and chronic disease risk factors using both subjective and objective measurements of sedentary behavior. Self-reported measures of TV viewing have been associated with a number of health conditions, including obesity (40–44), CVD risk factors (blood pressure, triglycerides, HDL cholesterol) (40,45,46), markers of insulin resistance (45,47), and clustering of cardiometabolic risk factors or metabolic syndrome (47–52). Although TV viewing represents only one specific sedentary behavior, there is consistent evidence that it is associated with several risk factors. In addition to TV viewing, a recent study reported significant, graded associations between self-reported sitting time and several CVD risk factors in both men and women, even after adjustment for waist circumference (45).

The relationship between objectively quantified sedentary behavior and chronic disease risk factors has also been explored. Sedentary time (<100 accelerometer counts per minute) was positively associated with waist circumference, 2-h postload glucose, and a metabolic risk factor cluster score in middle-aged Australian men and women (27,28). The results of a 5.6-year prospective study (53) showed that baseline sedentary behavior (heart-rate monitoring) was significantly associated with fasting insulin at follow-up, independent of age and several other covariates. Further, among healthy European adults, sedentary time (<100 accelerometer counts per minute) was significantly associated with carotid artery intima-media thickness, independent of age and traditional CVD risk factors (54). These results suggest that sedentary behavior is associated with risk factors and subclinical CVD. However, sedentary time (<100 accelerometer counts per minute) was not associated with metabolic risk factors among individuals with a family history of type 2 diabetes (55), and baseline sedentary time (<100 accelerometer counts per minute) was not associated with fasting insulin or homeostasis model assessment of insulin resistance after 1 year of follow-up in the ProActive U.K. trial (56). More studies using prospective designs are required to determine the independent associations between objectively assessed sedentary behavior and chronic disease risk factors.

Physical activity reduction and bed rest studies. Several studies have investigated the effects of volitional reductions in ambulatory physical activity in humans, ranging from reductions in free-living physical activity to studies of extended best rest. Studies of endurance athletes who have discontinued training have documented marked impairments in several physiological and metabolic parameters (57); however, little information exists about the effects of decreasing physical activity or increasing sedentary behavior among sedentary or normally active individuals. One notable exception is an intervention study to reduce daily steps among healthy, normally active (nonexercising) men in Denmark (58,59). In this study, reducing the number of daily steps from an average of 10,501 to 1,344 over 2 weeks resulted in marked increases in intraabdominal fat, decreases in aerobic fitness, and impairments in several metabolic markers (58,59). These results suggest that short-term decreases in normal physical activity can have marked physiological consequences. Further research is required using randomized designs to better delineate the dose-response association between reductions in daily stepping or increases in sedentary behaviors and health.

Although bed rest does not completely mimic sedentary behavior, it has been suggested that it may be a helpful short-term model to investigate the effects of sedentary living (60). A classic bed rest study conducted by Lipman et al. (61) provides intriguing evidence for the role of sedentary behavior on glucose intolerance. The investigators reported significant decreases in glucose tolerance in

men with just 3 days of bed rest, and subjects who were allowed to exercise for 1 hour per day (while in bed) had a less marked increase in glucose intolerance than subjects who did not exercise during 35 days of bed rest (61). More recent studies have also reported significant metabolic deterioration in humans associated with short-term bed rest of 3–10 days (62–65). The use of exercise during bed rest has also been further investigated as an intervention to maintain work capacity and prevent physiological decline during prolonged periods of best rest (66). Studies such as the one by Højbjerre et al. (67) published in this issue of *Diabetes* represent the next generation of bed rest studies in which the tissue-specific effects of physical inactivity are being explored in detail. Their results indicate that 10 days of bed rest results in marked changes in adipose tissue metabolism, including decreases in lipolysis and increases in glucose uptake.

Although bed rest studies have provided some insights on the health effects of sedentary behavior, this model is not ideal because the postural changes associated with lying in bed also cause hemodynamic shifts that mimic reduced gravity. These postural changes do not reflect many typical sedentary behaviors performed by free-living humans, such as sitting. However, results from the study by Lipman et al. (61), where the investigators immobilized monkeys in an upright position, showed significantly decreased glucose tolerance in immobilized monkeys compared with control animals, suggesting that the effects were caused by the inactivity per se as normal gravitational effects were maintained. Studies that experimentally increase or decrease sedentary behaviors such as sitting are needed to better understand the insights that can be drawn from the studies of bed rest on the relationship between sedentary behaviors and health among free-living humans.

Evidence from animal models. The evidence presented in the preceding sections has highlighted several potential negative health effects associated with sedentary behavior. Some studies have begun to explore the pathophysiological mechanisms using animal models (15). For example, removal of intermittent standing and ambulation in rats by hind limb suspension (unloading) results in marked decreases in lipoprotein lipase (LPL) activity (the enzyme responsible for hydrolysis of triglyceride-rich lipoproteins), triglyceride uptake into red skeletal muscle, and reductions in the concentration of HDL cholesterol within a day's time (62). Importantly, these rapid effects operate through a process that markedly reduces LPL protein and activity without affecting LPL mRNA concentration, whereas both exercise (>twofold increase) and continuous chronic inactivity (>threefold decrease) impact LPL mRNA. These different mechanisms suggest that the processes governing metabolism during common sedentary behaviors could be quite distinct from the effects observed in exercise studies.

Further, a global gene-expression profiling study has identified 38 genes that are upregulated by just 12 h of physical inactivity (hind limb unloading) in rats, and 27 of these genes remained above control levels after returning to standing and ambulation of the hind limbs for 4 h, suggesting that some of the effects of sedentary behavior will persist long after the behavior is changed (63). Taken together, these results indicate that the gross metabolic disturbances observed with sedentary behavior result from metabolic alterations at the level of the muscle. Further research is required to elucidate the full spectrum of potential mechanisms in different organs and tissues that play a role in explaining the health effects associated with sedentary behavior.

Conclusions. The current public health recommendations for moderate and vigorous physical activity are the result of more than 60 years of scientific inquiry that has produced evidence for a causal link between physical activity and health. This evidence comes from a spectrum of study designs including prospective observations, clinical intervention trials, and mechanistic studies in the laboratory. By comparison, the evidence for an independent effect of sedentary behavior on health is just now emerging. Given the rapid accumulation of this evidence over the last few years, it has been suggested that public health recommendations targeting sedentary behavior are needed (68).

The evidence for an independent effect of sedentary behavior on health is both intriguing and convincing; however, several important questions remain. What are the dose-response relationships between sedentary behaviors and various health outcomes? Are health risks equivalent across all types of sedentary behaviors? Do reductions in sedentary behavior result in changes in health parameters or disease incidence? What types of interventions to reduce sedentary behavior are feasible from a public health standpoint? Given the ubiquitous nature of sedentary behaviors, what activities could feasibly be used to replace them? What are the distinct pathophysiological mechanisms linking sedentary behavior and health? These questions will provide a fertile area of research in the coming years. At present, the available evidence suggests that it is prudent to recommend that time spent in sedentary behaviors be minimized; however, optimal levels of sedentary behavior to recommend are not currently known.

The emergence of the physical inactivity paradigm (5) has highlighted the potential role that all aspects of human movement can play in impacting health. Most current physical activity guidelines focus on achieving 30 min per day or 150 min per week of moderate-to-vigorous physical activity. This represents only 1.5% of a total week (10,080 min), or perhaps 3% of the time we spend awake. Recent data from NHANES 2003–2004 from objective physical activity monitoring (accelerometry) indicate that less than 5% of the population is obtaining the recommended level of physical activity (69). Thus, efforts must be redoubled in order to achieve demonstrable increases in physical activity levels. On the other hand, sedentary behaviors (<100 accelerometer counts per minute) account for ~55% of an American's typical day (70). We must begin to explore novel approaches to reduce the widespread exposure to sedentary behaviors, as the potential health benefits to be gained could be substantial.

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