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【Review Article】

When Meeting Physical Activity Guidelines is not Enough: the Interplay of Sedentary and Active Behaviors

Geoffrey Whitfield[1] Kelley K. Pettee Gabriel[1] Harold W. Kohl III[1,2]

1) Division of Epidemiology, Human Genetics, and Environmental Sciences, University of Texas School of Public Health, Texas, USA

2) Department of Kinesiology and Health Education, The University of Texas, Texas, USA

ABSTRACT The combined effects of physical activity (PA) and sitting time on health have been inadequately studied. Sitting time has not been thoroughly measured in existing studies. The high prevalence of sitting in modern society may well present a situation where merely meeting guidelines is insufficient to realize health benefits. Identifying a dose of PA that negates the harmful effects of prolonged sitting should be a priority as research into the health effects of sitting progresses. Utilizing a group of high socio-economic status, highly active subjects of varying PA volume may allow identification of such a threshold, which may, in turn, shed light on more effective PA recommendations for highly sedentary individuals. Additional investigations into different sitting contexts, enhanced measurement techniques, and expanded surveillance may also be warranted.

Key words: sedentary behavior, sitting time, physical activity guidelines

Introduction

In recent decades, physical activity (PA) has been shown to protect against several chronic diseases including cardiovascular disease, diabetes, and cancers of the breast and colon[1]. The severity and public health impact of these conditions are clear: cardiovascular disease alone caused over 800,000 deaths in the United States (U.S.) in 2007[2]. In response to the vast public health burden attributable to chronic disease, the U.S. Association of Schools of Public Health released a document detailing public health priorities for the Obama administration[3]. Included in this document were five chronic diseases that are responsible for over 66% of annual deaths in the U.S.: heart disease, stroke, cancer, chronic obstructive pulmonary disease, and diabetes. Substantial evidence supports the protective role of PA against heart disease, certain cancers, and diabetes. By compliment, lack of physical activity increases ones risk for these diseases.

Currently, little doubt remains over the positive health effects of regular PA. The effect of PA on cardiovascular disease risk is particularly strong. Longitudinal studies in men and women have shown reductions in cardiovascular and all-cause mortality across categories of increasing volume of PA and physical fitness, which is a physiological consequence of PA[4-7]. The consistency of these findings, and many others, prompted the US Department of Health and Human Services to establish PA guidelines, published in 2008[8]. These Guidelines join a growing collection from around the world (WHO, Canada, UK, Japan). Despite this clear benefit, a recent analysis by Troiano et al of accelerometer data from the National Health and Nutrition Examination Survey showed that the prevalence of meeting PA guidelines may be as low as 5% of the US population[9]. This is countered by surveillance data that suggest nearly 70% of US adults can be classified as “meeting guidelines”[10]. World-wide, PA prevalence data are varied but World Health Organization estimates categorize 60% of the world’s

Address for correspondence: Geoffrey Whitfield; Division of Epidemiology, Human Genetics, and Environmental Sciences, University of Texas School of Public Health; 1616 Guadalupe Street, suite 6.300, Austin, TX 78701, USA; Geoffrey.P.Whitfield@uth.tmc.edu

population as insufficiently active[11].

Though PA is beneficial for health, technological progress has engineered PA out of various facets of daily life, replacing previously active behaviors with sedentary alternatives. Major examples can be seen in transportation and industry: since the Industrial Revolution, the automobile has replaced walking as a form of locomotion for many people while mechanization and robotics have reduced previously labor-intensive manufacturing jobs to manipulation of hand controls. The trend continues in the home with the mechanization of dishwashing and laundry. Even the smallest of movements are being eliminated, evidenced by power windows in automobiles that not only eliminate the hand-crank, but also eliminate the burden of fully depressing the “down” switch. The success and innovation of the human species have quietly reduced energy expenditure throughout the day. This has effectively reduced the minimum energy expenditure necessary to survive for our species. The continuing decrease in physical activity would seem to require a closer inspection of increased sedentary time and health.

Recently, the classification of sedentary behavior has been refined. It is no longer acceptable to view sedentariness as the absence of PA[12]. It is quite possible to attain or exceed recommended levels of PA with a daily, thirty-minute exercise session while spending the rest of the day seated at or near 1.5 metabolic equivalents (METS). This supposition is strengthened by data from the 2009 American Time Use Survey (ATUS) that reveals less than 6% of leisure time is spent in “exercise, sports, and recreation”[13]. Under this all-to-likely scenario, up to 15.5 of 16 waking hours (97%) could be spent riding in cars, trains, elevators, and sitting at desks or on the couch. Researchers have coined the term “active couch potato” to describe this juxtaposition of active individuals that concomitantly display long durations of sedentary behavior[12](Fig.1). Additionally, sedentary behaviors have been further subdivided into levels of sedentariness, much the way PA is subdivided into intensities. For example, quiet standing requires contraction of postural muscles to counter gravity and provide stability. Sitting, on the other hand, allows many large support muscles in the legs and torso to remain unloaded for long periods: the surface upon which one sits bears ones weight and provides a measure of stability. As a consequence, recent research in this area has focused on sitting as an exposure that is distinct from inactivity[12,14-17]. The purpose of this paper is to review findings on the interplay of sitting behaviors and physical activity and discuss new avenues of research that may help advance this topic.

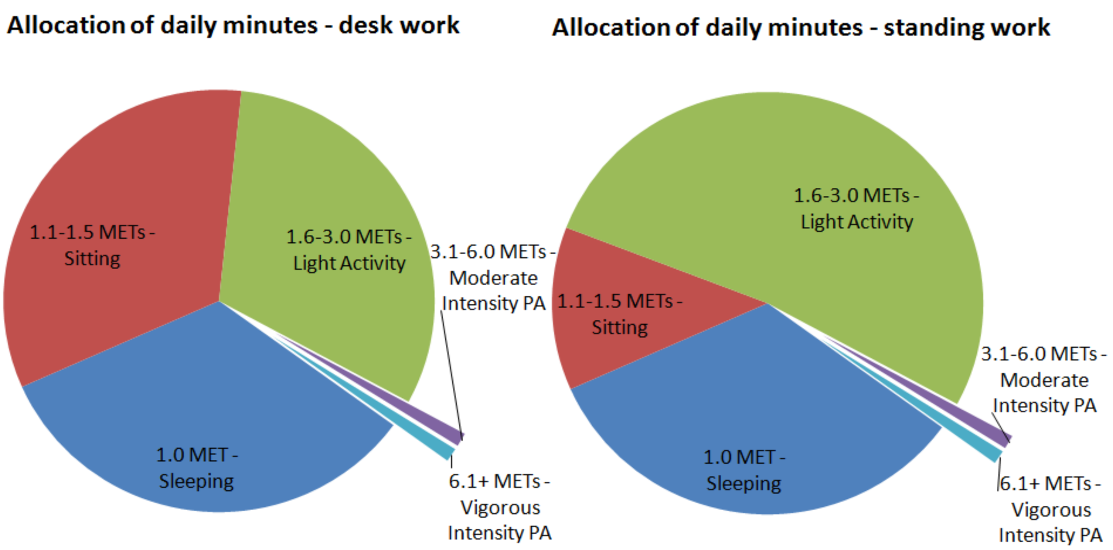

Figure 1. Hypothetical distribution of daily minutes in sufficiently active individuals with differing volumes

Research on sitting

Clinical research into the effects of muscle unloading began several decades ago, with the aim of understanding the effects of prolonged weightlessness, simulated by forced bed-rest or prolonged water immersion[18,19]. In animal models and human studies, changes to metabolic processes, including lipoprotein lipase dysfunction and insulin resistance, can begin only four hours after unloading occurs[20,21], providing a physiological precedent to acute effects of prolonged sitting.

In contrast to well-controlled clinical experiments, population studies on free-living sitting behaviors are relatively new. In these studies, it is presumed that variables used to assess sitting time are behavioral markers for the amount of time a person spends during her or his waking hours at or near resting metabolism. Moreover, a consistent definition of sitting behaviors has been elusive.

A prominent example of early research in this area is the AUSDIAB study that began in 1999 with follow-up studies in 2004 and 2009[22]. In this large sample, sitting time was assessed by proxy as self-reported daily television (TV) viewing time. This is used because the vast majority of TV viewing occurs while seated and the division of programming into regular blocks of time which facilitates more accurate recall via self-report measures.

Results from the AUSDIAB studies have produced a wealth of information and an emerging trend. In 2004, Dunstan et al showed that, compared to those with the least TV viewing time, men and women with the most TV time were more likely to have undiagnosed diabetes. Additionally, women with the most TV time were more likely to have impaired glucose tolerance than those with the least TV time. Interestingly, these results remained significant after adjustment for covariates, including total PA time[17]. In a follow-up study in 2005, Dunstan et al showed that women watching TV for more than 14 hours per week were more likely to have the metabolic syndrome than those watching for seven hours or fewer. This relationship was only slightly attenuated when adjusted for other factors, including time spent in PA[14]. These results indicated that even among those attaining recommended levels of PA, sitting time, assessed as TV viewing time, may pose a health risk.

The AUSDIAB results are not alone. In 2003, Hu et al published an analysis of prospective data from the Nurses' Health Study[16]. They were able to show a significant trend for increasing obesity and Type II diabetes risk across categories of increasing TV viewing time. Again, this trend remained significant after adjusting for covariates including a measure of exercise participation.

As noted above, there exists a rationale for utilizing TV time as a proxy for total sitting, but the measure is far from perfect. First, it is unlikely that TV viewing time fully captures the extent of daily sitting. For example, an individual may spend 8-10 hours per day standing and walking during classroom teaching, while another spends 8-10 hours per day sitting while writing computer programs (as in figure 1). They may validly report equal TV viewing time while experiencing dramatically different exposures to total sitting time. TV time may also be accompanied by exercise: gyms frequently have banks of TVs in front of cardiovascular equipment to better entertain their clientele. Finally, TV time may be confounded by nutritional intake. Those watching more TV may be more exposed to food advertising which may, in turn, drive increased caloric consumption. Despite the limitations, TV time has contributed to our understanding of the sitting-health relationship, but improved measures are needed, as discussed below.

Sitting among the physically active

The previous studies hinted that excessive sitting may at best attenuate, or at worst overwhelm, the positive health effects of regular PA. To better examine the interrelationships among sitting behaveiors, PA, and cardiometabolic health, the AUSDIAB group analyzed a subset of their study population that met PA guidelines. Using multivariate linear regression across quartiles of increasing TV time, they showed significant trends for increasing waist circumference, systolic blood pressure, and two-hour plasma glucose in men, while women also showed significant trends for increasing fasting plasma glucose, triglycerides, and decreasing HDL cholesterol[15]. Thus, the “active” group met physical activity guidelines for health, yet the sitting time in which they participated had significant deleterious associations with markers of cardiometabolic health. Taken together, these studies suggest that the ill effects of prolonged sitting remain after accounting for the positive effects of PA.

In summarizing this literature, an important question emerges: is there a dose of PA volume that protects against the effects of prolonged sitting[12]? Evidence that such a threshold may exist is provided by Katzmarzyk, et al. In this prospective study of physical activity, sitting time and mortality, a significant dose-response relationship was observed between sitting time and both all-cause and cardiovascular disease mortality in a sample of Canadian adults. Stratification by physical activity revealed an attenuated, but still significant dose-response relationship among those with an energy expenditure equivalent to meeting PA guidelines[23]. Though the outcome in this study differs from those previous, it reinforces the question: if some PA attenuates a particular negative effect of sedentary time, will more PA eliminate it?

One avenue of research that may help answer this important question is the effect of prolonged sitting in highly active individuals: those who do not simply meet PA guidelines, but far exceed them. In practice, this line of research would study the upper tail of the PA distribution normally seen in population-based studies. Although limited in generalizability, seeking this population out and studying them directly would provide the sample sizes across several strata of high-volume PA needed to investigate the existence of a protective threshold of PA. In essence, if such a threshold is not seen in this population, it is not likely to be seen.

Currently, endurance sports such as running, triathlon, and cycling are enjoying a surge in popularity. According to runningusa.org, participation in marathons in the US increased 10% from 2008 to 2009, the largest-ever single-year increase. The duration and intensity of training required for these events creates a population that far exceeds the recommendation for 75 or 150 minutes per week of vigorous- or moderate-intensity PA, respectively. The variety of distances offered, from sprint triathlons (roughly 400 m swimming, 20 km bicycling and 5 km running) and 5-kilometer runs to century (100-mile) bicycle rides, marathons, and iron-distance triathlon (3.6 km swimming, 180 km bicycling, 42 km running) likely creates meaningful strata of PA within this highly active population. Additionally, participation in these events tends to cater towards educated, upper-middle class individuals that may be more likely to hold seated occupations: the 2010 Austin Marathon (Austin, Texas, USA) reported a field that was 70% college-educated with a median annual income over $75,000[24]. These events create a base population from which to draw the active sample described previously. While many would argue against the generalizability of findings from such a sample, the opportunity for information on a dose of PA that protects against sedentary-related chronic disease should outweigh this criticism.

If such a dose of PA volume is identified, it may drive important policy and public health recommendations. For example, labor regulations may recognize the hazardous conditions experienced by seated workers and mandate appropriate interventions. Additionally, those in traditionally seated occupations such as computer programming or data entry may warrant a different PA guideline than those in occupations usually associated with standing and light activity such as classroom teaching or retail work. In this manner, it may provide a definitive recommendation that can replace the adage “some exercise is good, but more is better.”

Future directions

In addition to identifying a dose of PA that protects against the harmful effects of prolonged sitting, several other key areas of interest in this area deserve continued attention. One such question is whether different domains of sitting have differing health effects. One criticism of using TV time as a measure of global sitting is that the relationship between TV time and health outcomes may be confounded by exposure to food advertising and thus excessive snacking[12]. Hu et al showed differences in risk of obesity between sitting at work and sitting while watching television[16]. It is quite possible that other seated activities, including driving and the accompanying stress, may have differing effects. Individual instruments or combinations of measures that accurately assess sitting across different contexts are needed, and should allow more precise analyses of the relation between sitting and health outcomes.

In addition to improved self-report measures of sitting behaviors, direct measures of body position, such as the ActivPal[tm 25], may provide an important advancement in assessing sitting and related sedentary behaviors. As noted above, standing requires additional muscular contractions for postural stability and may provide a distinct physiological stimulus, thereby necessitating a distinction in measurement. Many activity monitors, including those used in NHANES 2003-06 (ActiGraph Model 7164; Pensacola, FL), cannot differentiate between quiet sitting and motionless standing. When stationary, both behaviors will be recorded as zero intensity counts. Recently, newer ActiGraph models such as the GT3X include an inclinometer, which can be used to detect positional change. Unfortunately, evidence for the reliability and validity of this feature in free-living situations is still emerging.

Public health significance is a function of prevalence and severity. A rare but highly fatal disease will draw attention, as will a minor, but widely spread condition. As noted previously, sedentary behaviors in general, and sitting in particular, have increased with industrial and technological modernization. In a recent analysis of nationally-representative US accelerometer data, Tudor-Locke et al found that greater than 50% of waking hours were spent in sedentary pursuits while only 20% of hours were spent in light, moderate, or vigorous intensity PA[26]. With such a large prevalence, even if the risk associated with prolonged sitting is minor, it may pose a significant public health hazard. This argues for enhanced surveillance of sitting and other sedentary behaviors in countries around the globe.

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【要旨日本語訳】

身体活動のガイドラインを満たすだけでは十分でないとき：

座業と身体活動の相互作用

身体活動と座位時間の組み合わせがどのように作用しているのかについては，研究が不十分である。座位時間の測定も現状の研究では十分に適切とはいえない。座位時間が長い現代社会では，単に身体活動ガイドラインを満たすだけでは健康効果を得るために十分ではないのかもしれない。座位時間が長時間な生活習慣であっても，その悪い効果を打ち消すような身体活動量がどの程度なのかを同定するような研究の必要性が高い。社会経済状況が高く，非常に活動的な集団を研究対象にすることによって，そのような身体活動量の同定が可能かもしれない。そして、このような研究によって、非常に座位時間が長い者を対象にした身体活動の推奨量が明らかになるかもしれない。さらに，座位の内容，座位の測定方法の改善，座位時間の調査を広く実施することが求められる。

（この日本語訳は，読者の利便性を考慮して著者の許可のもとに編集委員会が作成したもので，論文に含まれるものではありません。日本語訳が著者の意図にあっていない可能性もありますので，正確な意味を確認するためには原文をご確認ください）