COMMENTARY

Is Being Physically Active Enough to Be Metabolically Healthy? The Key Role of Sedentary Behavior

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Mary O. Whipple,[1,2,3] Judith G. Regensteiner,[2,3] and Audrey Bergouignan[4,5]

Low levels of physical activity (PA) are now well recognized as a major public health problem, implicated in cancer, cardiovascular disease (CVD), metabolic syndrome, diabetes, and early mortality (1). PA guidelines (i.e., ≥150 min/week of moderate activity or ≥75 min/week of vigorous activity, collectively referred to as moderate to vigorous physical activity [MVPA]) are globally promoted to protect the population against the risk of developing chronic disease. But is this sufficient to promote metabolic health? The relationship between PA and health appears to be more complex than initially thought, and another component has been attracting attention over the past decade: sedentary behavior (SB). Although they are often used interchangeably, SB is fundamentally different from physical inactivity. While physical inactivity is defined as engaging in less PA than necessary to meet the current guidelines (2), SB describes "any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalents (METs) while in a sitting or reclining posture" (3). Thus, individuals can be both physically active and highly sedentary (4,5). Increased time spent sitting raises the risk for metabolic syndrome (6), incident CVD, CVD-related risk factors, and early mortality (7,8), even in people who exercise regularly. These observations raise obvious questions: Are the effects of SB independent from those of PA or simply the "other side of the coin"? What is the minimum level of MVPA needed to counteract the adverse health effects of SB?

A recent harmonized meta-analysis of data from more than 1 million adults showed that high levels of PA (i.e., about 60–75 min/day of MVPA) are needed to eliminate the effect of 9 h/day of SB on mortality (9). Even if this exceeds the current PA recommendations, this observation suggests that once we reach such levels, we should be free of the effects of SB on health. In this issue of *Diabetes Care,* Madden et al. report that SB adversely influences metabolic health even in the presence of large volumes of MVPA (10). In this study, the relationship between objectively measured SB, light physical activity (LPA), MVPA, and metabolic syndrome risk score was examined in 54 older adults. Notably, study participants had remarkably high levels of MVPA (2.6 h/day), 2 h more than the current recommendations (2) and more than seven times that of typical older adults (11). The authors found that greater sedentary time was associated with higher metabolic risk score, independent of age and sex. They conclude that even among highly active older adults, SB is associated with increased metabolic risk (Fig. 1). Thus, MVPA and SB appear to be independent predictors of metabolic risk, as the negative health effects of SB are not fully offset by even extremely high levels of MVPA.

This study adds to SB literature in several meaningful ways. Even in a population of Masters athletes reaching "ceiling levels" of PA who have likely been active most of their lives, SB is not only highly prevalent but also similar to sedentary levels of inactive older adults (11). Furthermore, SB is still strongly associated with metabolic risk. This highlights the importance of understanding and potentially intervening on both physical inactivity (too little exercise) and high levels of SB (too much sitting). This study is clinically important given that SB has been recognized as a major risk factor for many metabolic diseases (12). Studying a highly physically active group of older adults lays the groundwork for delineating the independent role of SB in the relationship between PA and health, as sitting too much may have different health implications than lack of MVPA.

[1]Division of Geriatric Medicine, Department of Medicine, University of Colorado Anschutz Medical Campus, Aurora, CO
[2]Division of General Internal Medicine, Department of Medicine, University of Colorado Anschutz Medical Campus, Aurora, CO
[3]Center for Women's Health Research, Department of Medicine, University of Colorado Anschutz Medical Campus, Aurora, CO
[4]Division of Endocrinology, Metabolism, and Diabetes, Department of Medicine, University of Colorado Anschutz Medical Campus, Aurora, CO
[5]Université de Strasbourg, CNRS, IPHC UMR 7178, Strasbourg, France

Corresponding author: Audrey Bergouignan, audrey.bergouignan@iphc.cnrs.fr

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The study by Madden et al. (10) has numerous strengths. First, studying the role of SB in a highly active group of people is an innovative approach to unraveling the importance (and unique contribution) of SB versus MVPA. Additionally, the focus on older adults is critical, as older adults tend to be highly sedentary (13) and are especially vulnerable to the negative effects of SB due to the high burden of cardiometabolic risk factors (14,15). Second, the use of an objective measure of SB is a significant strength, as self-report typically results in underestimation of SB (16). The use of a compositional analysis should also be commended, as it accounts for the codependence of time in different activity types and is one of the most robust choices for analyzing these types of data (17). Third, the use of a continuous score for metabolic risk, as opposed to dichotomous presence/absence of metabolic syndrome is important, as it enables evaluation of the association between SB and metabolic risk in healthier individuals, rather than simply identifying these associations once an individual reaches the threshold of a diagnosis of metabolic disease. Finally, the study included both sexes, which is important for our understanding of potential sex differences in relationships between SB, PA, and health (18).

There are also a few limitations to this study. First, as the authors acknowledge, the study utilized a SenseWear armband, which has been shown to be inaccurate at high-intensity activity levels (19,20). Additionally, an upper-arm monitor is not as accurate as a posture monitor (e.g., activPAL mounted on the thigh) for classification of SB. Second, it is unclear how the increased metabolic risk score may translate into CVD in this population, although the authors do indicate that the mean difference noted between their high and low groups was associated with approximately 1.5-fold risk of cardiovascular events in the Multi-Ethnic Study of Atherosclerosis (MESA) cohort (21). Understanding if/how these differences in metabolic risk score lead to future metabolic disease and CVD, as well as how the metabolic risk of the subjects studied by Madden et al. compares to that of inactive older adults, is essential. Third, this study is cross-sectional, and future longitudinal and intervention research will need to investigate the impact of differences and/or changes in SB on metabolic risk.

Critically, we must determine what strategies or combination of strategies are effective in reducing SB through an increase in both MVPA and LPA. LPA, which includes everyday activities such as walking, housework, or taking the stairs (activities requiring 1.5–2.9 METs), is tightly related to time spent in SB, as one typically offsets the other. The literature on SB, LPA, and MVPA to date indicates that we must target and act on each in order to improve metabolic health (22). This is particularly important since efforts targeting an increase in MVPA among sedentary adults can inadvertently lead to behavioral compensation, in which an individual decreases their LPA and increases their SB in response to exercise (23,24). Additionally, the study by Madden et al. does not address the minimum amount of MVPA needed to offset the effects of SB. Even though these participants were highly active, this level of MVPA was not sufficient to offset the effects of spending an average of 9.4 sedentary hours per day among healthy older adults, unlike what was observed in the meta-analysis by Ekelund et al. (9). Finally, further work is needed to understand the biological differences between physical inactivity

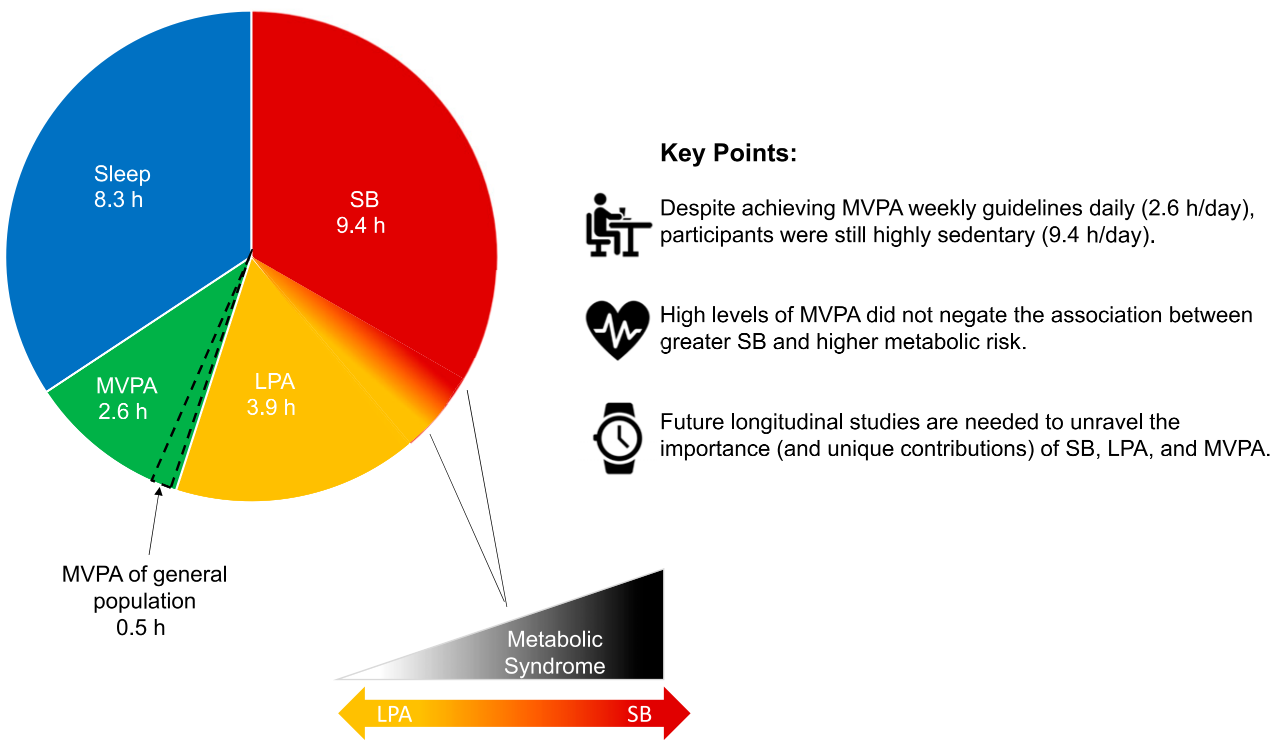

Figure 1—Diagram of study participant activity (10), with the dashed slice denoting much lower, typical MVPA levels. SB and LPA are tightly correlated and are related to risk of developing metabolic syndrome, with high SB and low LPA associated with greatest risk.

and SB. By better delineating the complex interrelationships between SB, LPA, and MVPA as well as the potential mechanisms linking SB to cardiometabolic risk (25), we can move toward more comprehensive public health guidelines that discuss SB recommendations for specific populations and specific exercise modalities that would be most beneficial.

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