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Too Much Sitting
A Serious 21st Century Health Risk

Linda Eanes

While weekly moderate-to-vigorous physical activity (MVPA) is considered a well-established key determinant for regulating weight and reducing risks of obesity and associated noncommunicable diseases, MVPA alone may not be enough to offset excessive sitting time. This integrative literature review aims to advance the discussion about sedentary behavior as a significant independent health risk for obesity and associated noncommunicable diseases, to increase awareness, to synthesize important evidence on sedentary behavior and a number of negative health outcomes, and to present the application of a whole-day approach to physical activity as a feasible strategy to promote health.

Obesity has tripled across the globe and is considered a major challenging health concern affecting nearly 2 billion adults (World Health Organization [WHO], 2020), with 93.3 million residing in the United States (Centers for Disease Control and Prevention [CDC], 2019). Obesity (defined as a body mass index of ≥30 kg/m^2) has been shown to contribute to an overall diminished quality of life and increased risk of developing serious concomitant noncommunicable diseases, such as type 2 diabetes, metabolic syndrome, heart disease, stroke, and certain cancers (CDC, 2019; WHO, 2020; Wiklund, 2016). In the United States, an estimated annual direct medical cost of obesity exceeds $3 billion, whereas the indirect cost associated with decreased productivity approximates $8 billion (America's Health Rankings, 2018). Although a weekly minimum accumulation of moderate-intensity (150 minutes) to vigorous-intensity (75 minutes) physical activity (MVPA) is considered a well-established key determinant for regulating weight and reducing risks of obesity and associated noncommunicable diseases, regular structured episodes of purposeful MVPA alone may not be enough to offset excessive sitting time (Biswas et al., 2015; Katzmarzyk et al., 2019; Thyfault et al., 2016). Recent research evaluating both self-reported and objectively measured total sitting time suggests that high-volume sitting time (≥7 hours per waking hours or for frequent sitting episodes of ≥30 minutes) irrespective of MVPA may contribute to a harmful health profile that significantly increases the risk for developing multiple chronic conditions. Among the most notable include obesity, type 2 diabetes, cardiovascular disease, endometrial, colorectal, breast and lung cancers, and premature death (Booth et al., 2012; Eanes, 2018; Ford et al., 2010; Giné-Garriga et al., 2020; Grupta et al., 2016; Healy, Dunstan, Salmon, Shaw, et al., 2008; Healy et al., 2011; Joseph et al., 2016; Kim et al., 2015; Shen et al., 2014; Stamatakis et al., 2009; Suliga et al., 2018).

Despite public media campaigns, community programs, and clinical practice strategies given to promoting MVPA, people of all ages and demographics living in industrialized countries are spending growing amounts of time in physical, economic, and social environments that require less physical activity and more sitting time (Hamilton, 2018; Ng & Popkin, 2012; Owens, Sparling, et al., 2010). Over the past decades, whether at work, home, school, public spaces, or traveling, our environments have been increasingly redesigned to diminish energy expenditure and reduce human movement requiring large muscle groups (Church et al., 2011; Owen, Sparling, et al., 2010). According to Yang et al. (2019), an estimated total sitting time among the United States population from 2001 to 2016 has increased from 7 hours to 8.2 hours per waking day. Prevalent habitual sedentary behaviors that are integral to many people's lives may include television viewing time, computer and game console use, workplace sitting, and time spent in automobiles (Owen, Healy, et al., 2010). Thus, within the context of daily activities, it is not uncommon for individuals to spend 8–10 hours or 55%–70% of their waking hours sitting, much of which in uninterrupted episodes greater than 30 minutes (Dempsey et al., 2018). To put in perspective, MVPA only accounts for an estimated 1%–5% percent of one's total waking hours (Dunstan Howard, et al., 2012; Hamilton et al., 2008).

The author hopes to advance evidence-based changes among nurses, nurse scientists, and nurse educators in

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their efforts to prevent diseases and promote health among both individuals and populations. This integrative review synthesizes the current state of science regarding the impact of sedentary behavior on several essential physiologic systems and their relationship to negative health outcomes among adults 18 years and older. As vanguards in health promotion, nurses can champion the need to displace total daily sitting time with frequent short episodes of light-to-moderate intensity physical activity.

Definition of Terms

In the context of this article, physical activity, moderate-to-vigorous physical activity, sedentary behavior, light-intensity physical activity, sedentary episode, and sedentary break are defined as follows:

- *Physical activity* refers to any body movement generated by the contractions of skeletal muscles that raises energy expenditure above the resting metabolic rate (Thivel et al., 2018). Physical activity encompasses the accumulation of movement occurring throughout waking hours (Physical Activity Guidelines Advisory Committee [PAGAC], 2018).
- *Moderate-to-vigorous physical activity (MVPA), also referred to as health enhancing exercise* (Keadle et al., 2017), is a subset of physical activity characterized by modality, frequency, intensity, and duration of a planned, structured, repetitive level of physical activity required to achieve optimal health benefits (Dunstan, Howard, et al., 2012; Thivel et al., 2018). Moderate physical activities are those activities, such as brisk walking (4 mph), that require 3.0–5.9 metabolic equivalents (METs), whereas any activity that burns 6.0 METs or more is considered a vigorous physical activity, such as hiking uphill or jogging (6 mph) (CDC, 2017). For substantial health benefits, adults should engage in a weekly minimum of 150 minutes of moderate-intensity physical activity, or a minimum of 75 minutes of vigorous-intensity physical activity, or an equivalent amount of both (PAGAC, 2018)
- *Sitting/sedentary behavior/physical inactivity* refers to waking activities of sitting, lying, or reclining posture that involve a very low energy expenditure (≤1.5 METs) (Gibbs et al., 2015; Katzmarzyk et al., 2019; Owen et al., 2012). For clarity, the terms sitting, sedentary behavior, and physical inactivity are used interchangeably throughout this article.
- *Light-intensity physical inactivity* occurs while upright, such as standing, slow walking, gardening, housework, or "incidental movement" but requires a very low energy expenditure (>1.5–2.9 METs) (Eanes, 2018; Owen et al., 2012).
- *Sedentary episode* refers to a minimum period of uninterrupted sedentary time, not allowing any time spent in nonsedentary behaviors (Tremblay et al., 2017).
- *Prolonged sitting time* refers to sitting continuously for 30 minutes of more (Bellettiere et al., 2017).
- *Sedentary break* is defined as a nonsedentary period in between two sedentary episodes (Tremblay et al., 2017).

Methods

Search Strategy

To identify pertinent literature, a comprehensive search using electronic databases Google Scholar, MEDLINE, PubMed, Web of Science, Cochrane, CINAHL, and hand-searched eligible articles for the years January 2000 through August 2020 was performed. The search was confined to this 20-year period because it most aptly reflects a shift in direction from exercise physiology toward focusing on inactivity physiology. To address the objectives of this report, articles on sedentary behavior were cross-indexed under several search phrases: too much sitting, prolonged sitting time, high volume sitting, sedentary behavior, sedentary lifestyle, sedentary physiology, skeletal muscle inactivity, and physical inactivity. The subject terms were combined with key words such as negative health outcomes, obesity, type 2 diabetes, cardiovascular disease, cardiometabolic diseases, cancer, and mortality in the search to identify articles specifically examining the relationship between sedentary behavior and chronic diseases. To identify literature pertaining to proposed biological pathways, keywords associated with skeletal muscle inactivity and lipoprotein lipase (LPL) regulation, skeletal muscle inactivity, and insulin resistance were added. The reference lists were also screened for relevant articles on health risk reduction including articles focusing on light-intensity physical activities and intervention measures. The initial search yielded 265 articles that addressed the relationship between sedentary behavior and health risk independent of MVPA, skeletal muscle functions in inactivity, and sedentary reduction measures and health outcomes. The search was then narrowed to exclude studies that relied only on self-reported data, studies on children and adolescents, bed rest and antigravity (space) studies, and studies specifically focusing on exercise where physical inactivity was not clearly defined, and duplicate studies. The search was limited to English-language, quantitative peer-reviewed studies, full-length peer-reviewed publications, integrative literature reviews, and position papers on adults 18 years and older. Quantitative studies on sedentary reduction measures and light-intensity physical activity and health promotion were also included. The final search consisted of 75 articles. Figure 1 shows the flow of study selection for this systematic review.

Discussion

A Shift Toward Sedentary/Inactivity Research

Since the mid-1900s, much of the physical activity research by exercise and sports medicine scientist has concentrated on quantifying the type, amount, intensity, frequency, and duration of structured physical activity (often used interchangeably with exercise) needed above the normal lifestyle to reduce or counteract deleterious

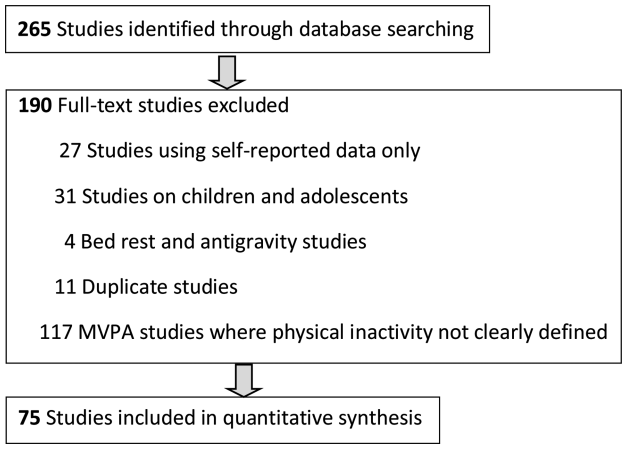

Figure 1. PRISMA flow diagram of study selection. MVPA = moderate-to-vigorous physical activity; PRISMA = Preferred Reporting for Systematic Reviews and Meta-Analysis.

health effects (Eanes, 2018; Hamilton, 2018). Such studies add to our body of knowledge and clearly support the need to participate in regular MVPA to promote health and prevent chronic disease. However, there are limitations to these studies. The differences in energy expenditure that occur with either sedentary behaviors or light-intensity physical energy have rarely been objectively measured, thus limiting our knowledge with respect to the effect that both sedentary behaviors and light-intensity may have on health outcomes notwithstanding MVPA (Pate et al., 2008; Ryan et al., 2015). Simply stated, any activity other than those meeting the physical activity guideline for MVPA has been categorized as inactive/sedentary or "other movements." Hence, compared with research on activity physiology, relatively little is known about the impact of too much sitting (inactivity physiology) on disease outcomes or about the optimal patterns of light-intensity activities needed to counterbalance any negative effects associated with high-volume sitting (Hamilton et al., 2007; Rosenberger et al., 2019). Thus, given significant reductions in physical activity demands, the prevalence of high-volume sitting, as well as the rise in obesity and associated non-communicable diseases, underscores the importance of increasing our understanding of inactivity science.

Sedentary/Inactivity Research on Cardiometabolic, Cancer, and All-Cause Mortality Risk

Over the past 20 years, mounting evidence specifically focusing on sedentary physiology indicates that sedentary behavior requiring very low energy expenditure and absence of whole-body movement is a major contributing factor in the development of cardiometabolic disorders, certain cancers, or all-cause mortality even if an individual meets the recommended MVPA guidelines (Panahi & Tremblay, 2018).

Cardiometabolic Risk

Evidence suggests that prolonged sitting involving the absence of whole-body movement is detrimentally associated with several cardiometabolic biomarkers. Table 1 illustrates research findings linking prolonged sitting to cardiometabolic biomarkers, independent of MVPA.

Cancer Risk

Research on sedentary behavior and cancer risk is relatively new with regard to understanding the risk of high-volume sitting in the pathology and progression of certain cancers or to establish a causal relationship; however, a number of systematic reviews have shown a positive link between sedentary behavior and cancer risk. Table 2 shows several systematic reviews addressing sedentary behavior as an independent variable to cancer.

All-Cause Mortality Risk

Distinct from inadequate exercise**,** there is compelling evidence demonstrating a dose-related association between prolonged leisure–time sitting (≥6 hours vs. <3 hours per day) and a greater risk for not only an increased risk of mortality from all causes, but for eight of the 14 leading causes of death in the United States, including cardiovascular disease, obesity-related systemic inflammation, diabetes, and cancer (Keadle et al., 2015; Patel et al., 2018; Patterson et al., 2018). Table 3 provides a summary of findings from several prospective studies linking prolonged sitting to all-cause mortality in adults who were free of major chronic diseases at baseline.

Unique Mechanical and Physiologic Pathways in Sedentary Behavior

There is compelling evidence that makes too much sitting particularly worrisome because it not only poses as a substantial health problem but appears to have a significantly negative impact on life expectancy comparable to smoking and obesity (Hamilton et al., 2007; Hu et al., 2001, 2003; Krishnan et al., 2009; Lee et al., 2012, U.S.

Table 1. Detrimental Associations Between Sedentary Behavior and Cardiometabolic Biomarkers

Study	Sample (*n*)	Results
Healy et al. (2008)	4,064	In men (*n* = 2,031) SB negatively alters waist circumference, systolic blood pressure, 2-hour plasma glucose; in women (*n* = 2,033) SB negatively alters fasting plasma glucose, triglycerides, HDL cholesterol
Healy et al. (2011)	4,757	SB negatively alters waist circumference, HDL cholesterol, C-reactive protein, triglycerides, insulin
King et al. (2017)	9,27	Sitting time ≥10-minute episodes is linked to diabetes, metabolic syndrome, elevated blood pressure, increased waist circumference
Knaeps et al. (2018)	425	SB negatively alters waist circumference, HDL cholesterol, triglycerides

Note. HDL = high-density lipoprotein; SB = sedentary behavior.

Table 2. Systematic Reviews Examining Link Between Sedentary Behavior and Cancer Risk

Study	Studies (*n*)	Results
Lynch (2010)	18	There is a statistically significant positive link to SB and colorectal, ovarian, and endometrial cancer risk
Shen et al. (2014)	17	A meta-analysis on 857,581 participants shows an increased risk of colorectal, lung, breast, and endometrial cancer risk, independent of BMI, physical activity, and energy intake
Rezende et al. (2014)	27	Five of the 27 articles reviewed show an increased risk of colorectal, endometrial, ovarian, and prostate cancer risk

Note. BMI = body mass index; SB = sedentary behavior.

Department of Health and Human Services, 2018) . This leads us to believe that high-volume sitting and prolonged uninterrupted sitting most likely influence unique mechanical and physiologic responses that not only negate the beneficial health effects of increased energy expenditure associated with MVPA, but have additional adverse effects (Eanes, 2018; Hamilton et al., 2007; Thyfault et al., 2016). Simply stated, potential harmful physiologic responses that occur during high-volume sitting may differ considerably from those potentially protective physiologic responses that occur with a bolus of MVPA several times a week (Hamilton et al., 2007). Given the greatest disease and mortality rates are among those who are the least active only increases the need to examine plausible cellular and molecular mechanisms that may influence disease risks during inactivity. Although the physiologic mechanisms involved in sedentary behavior and their relationship to negative health consequences are most likely a complex systemic network of responses, the effects that skeletal muscle LPL has on triglycerides and high-density lipoprotein (HDL) cholesterol and glucose uptake are considered potential biological pathways that may help explain the pathogenesis of sedentary behavior.

Table 3. Associations Between Sedentary Behavior and All-Cause Mortality

Study	Sample (*n*)	Results
van der Ploeg et al. (2012)	58,534 participants age ≥ 45 years	Prolonged sitting is significantly positively linked to all-cause mortality independent of PA
		Combined sitting and risk profiles show a clear dose-related relationship with all-cause mortality with those sitting more at a higher mortality risk
Chau et al. (2013)	6 studies, adults 59,286; deaths 20,162	An MA shows higher amounts of total ST are linked to increased all-cause mortality. Men: ≥7.6 hours/day; women: ≥7.2 hours/day
Ku et al. (2018)	19 studies, participants >1 million	There is a positive association between self-reported ST ≥7 hours/day and objectively measured ST ≥9 hours/day and all-cause mortality
Ekelund et al. (2019)	8 studies, participants 36,383	ST ≥9.5 hours/day shows a significantly higher risk of death; whereas the total volume of PA irrespective of any intensity is linked to a significantly lower risk of death

Note. MA = meta-analysis; PA = physical activity; ST = sitting time.

Potential Pathway: Skeletal Muscle Lipoprotein Lipase Regulation and Sedentary Behavior

Skeletal muscle LPL is an enzyme that binds to lipoproteins when present on the vascular endothelium and plays an important role in the regulation of plasma triglycerides and HDL cholesterol (Eanes, 2018; Hamilton et al., 2004). Skeletal muscle LPL regulation has become a focus of interest to inactivity scientists because the loss of LPL activity at the vascular endothelium during acute and chronic inactivity impairs lipid metabolism and may contribute to increased risk for metabolic diseases such as obesity, type 2 diabetes, and cardiovascular disease (Hamilton et al., 2007). Results from a laboratory study on rodents by Bey and Hamilton (2003) examining the regulation of skeletal muscle LPL activity during physical inactivity in comparison to low-intensity contractile activity controls found significant decreases in muscle LPL activity during both acute and chronic (11 days) inactivity but observed a significant rise in LPL activity following treadmill walking. These results may, in part, help explain why physical inactivity is considered a risk for cardiometabolic diseases, and why even light-intensity physical can provide some protection against developing conditions involving lipid metabolism.

Potential Pathway: Skeletal Muscle Insulin Resistance and Sedentary Behavior

Skeletal muscle is the primary site for insulin-mediated glucose uptake in the postprandial state, responsible for about 80% of the uptake of glucose, and is considered an initiating defect for insulin resistance and impaired glucose metabolism (prediabetes) (DeFronzo & Tripathy, 2009). Data examining the effects of basal and insulin-stimulated gene expression (a process whereby information encoded in a gene leads to the production of a protein important to cellular functioning) on 20 healthy young Caucasian men who remained in bed for 9 days showed that skeletal muscle contractile inactivity and reduced energy demand led to insulin resistance and altered gene expression of more than 4,500 genes. These genes were only partly normalized after 4 weeks of physical activity training. Additionally, they found that prolonged bed rest resulted in an increased response

to acute stimulation in the general expression of genes, most notably genes involved in inflammation and endoplasmic reticulum stress. These findings underscore the importance of daily physical activity in the prevention of insulin resistance and type 2 diabetes (Alibegovic et al., 2010).

Replacing Sedentary Time With Light-to-Moderate Intensity Physical Activity

There is a growing interest in increasing our understanding of the interrelationship between different levels of activity intensities (sedentary, light, moderate, and vigorous) during daily waking hours on health risks. Recent intervention studies on high-volume sitting have indicated that displacing prolonged sitting with frequent intermittent episodes of light-to-moderate intensity physical activity could attenuate the negative health effects associated with high-volume sitting (Bellettlere et al., 2017; Dunstan, Kingwell, et al., 2012; Ekelund et al., 2019; Healy, Dunstan, Salmon, Cerin, et al., 2008). Table 4 provides a summary of a number of studies showing positive effects from displacing sedentary time with frequent episodes of light-to-moderate physical activity on reducing negative health risks.

Future Research

Australia, the United Kingdom, and the United States (Australia Department of Health, 2014; PAGAC, 2018; UK Department of Health, 2011;) have included minimizing the amount of time spent sitting for prolonged periods in their public health recommendations. Although this should help reinforce the need to sit less and move more, their guidelines are broadly stated and nonquantitative (Stamatakis et al., 2018). Even though there has been a rapid and progressive growth of sedentary physiology research focusing explicitly on studying the impact of high-volume sitting on health outcomes, to date, there is insufficient evidence with respect to the limits of sitting time and health risks. There is a need for more controlled longitudinal studies examining causal relationships between dose–response sitting time and negative health outcomes among different populations and subpopulations. Additionally, there is a need for more rigorous intervention studies that examine sitting patterns across all waking hours and the effects of displacing sedentary behavior with light-to-moderate physical activities on reducing the risk for obesity, associated noncommunicable diseases, and premature death. Moreover, there is a need for research directed toward increasing our understanding of lifestyle factors (such as age, gender, race/ethnicity, cultural beliefs/practices, and socioeconomic status) that may influence sedentary behavior and health risks. Of particular importance is a need to address cultural and social inequities in health and the impact of sitting time for risk of disease.

Conclusions

MVPA remains a cornerstone in promoting optimal health. However, in recent years there has been a shift away from this conventional physical activity (MVPA) paradigm characterized by the FITT formula (frequency, intensity, time, duration, and type of purposeful physical activity) toward a model that emphases the total daily accumulation of physical activity during waking hours needed above MVPA to promote health and avoid disease (Hamilton et al., 2004; Haskell et al., 2007; PAGAC, 2018; Tremblay et al., 2010). Even so, within the context of healthcare, many nurses and other health professionals continue to view sedentary behavior and MVPA as opposite ends of a linear physical activity continuum, whereby sedentary behavior is defined as the absence of MVPA (Owen, Healy, et al., 2010; Owen, Sparling, et al., 2010). Hence, using the conventional physical guidelines, an individual who meets or exceeds the minimum recommended physical activity guidelines by engaging in a 30-minute episode of MVPA in the morning but remains primarily sedentary throughout the day would be considered active. Conversely, a construction worker who engages in long hours of light-to-moderately intense physical activity but spends very little time sitting would be considered sedentary simply by not meeting the prescribed physical activity guidelines. From this narrow perspective, both the significance of high-volume sitting and light-intensity physical activity on health outcomes may be overlooked. Given modern-day societies are replete with high-volume sitting time, rather than concentrating exclusively on MVPA as a determinant for maximizing health, utilizing a whole-day approach (an approach that takes into account the total

Table 4. Effects of Displacing Sedentary Time With Light-to-Moderate Episodes of Physical Activity

Study	Sample (*n*)	Results
Healy et al. (2015)	Participants: 698 Ages: ≥35 years	Displacing 2-hour sitting time with equivalent increases in stepping time is significantly linked to a decrease in BMI, waist circumference, lower triglycerides, and higher HDL cholesterol.
Duvivier et al. (2013)	Participants: 18 healthy subjects Age: 19-23 years BMI: 22.6 ± 2.6 kg/m^2	One hour of daily MVPA cannot compensate negative effects of inactivity on insulin sensitivity and plasma lipids if the remainder of the day is spent sitting.
Dohrn et al. (2018)	Participants: 851 Ages: ≥50 at follow-up in 2015	Replacing 30 minutes of daily ST with light-intensity PA reduces all-cause mortality and CVD mortality risk by 11% and 24%, respectively. Replacing ST with 30 minutes of MVPA significantly reduces CVD mortality and all-cause mortality risk by 38% and 77%, respectively. Daily MVPA lasting 10 minutes/episode shows no significant risk reduction.

Note. BMI = body mass index; CVD = cardiovascular disease; HDL = high-density lipoprotein; MVPA = moderate-to-vigorous physical activity; PA = physical activity; ST = sitting time.

time and frequency of meaningful muscular activity over the course of waking hours) with the primary goal of replacing as many hours as possible of unhealthy sedentary time with the best type of physical activity, whether light, moderate, or vigorous, may be a more feasible and effective method for individuals and populations across all age groups (Amagasa et al., 2018; Ekelund et al., 2019; Elhakeem et al., 2018; Hamilton et al., 2014; Hamilton, 2018; Loh et al., 2019; Mann et al., 2011).

Although engaging in MVPA has been shown to play a well-established role in the prevention of a number of primary and secondary chronic noncommunicable diseases (Biswas et al., 2015), as vanguards of health promotion, nurses must also recognize the potential accumulative negative effects of high-volume sitting on a person's health. To optimize health, nurses must go beyond simply recommending regular sessions of continuous structured exercise (MVPA) and focus on assisting individuals in safely replacing as many daily hours and episodes of sedentary time as possible with light- to moderate-intensity physical activity (Hamilton, 2018; Thyfault et al., 2016).

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