Prolonged Sitting

Current Concepts on the Physiological Effects of Seated Postures at Work

By Christopher D. Studebaker and Brian P. Murphy

IN BRIEF
- Preventable lifestyle diseases such as cardiovascular disease, diabetes and obesity are on the rise throughout the U.S.
- Evidence suggests that sitting may affect many such disorders. The shift toward more sedentary, computer-based work and away from manual labor may be combining with an increased amount of sitting during leisure hours to adversely affect public health.
- The business and healthcare communities have begun to combat the adverse health effects of sitting by raising awareness of the issue and encouraging increased physical activity in the workplace and at home. This article reviews literature on the topic and describes potential solutions.

Preventable lifestyle diseases are on the rise. Obesity, diabetes and heart disease have become more prevalent, placing an enormous strain on the U.S. healthcare system (Hammond & Levine, 2010). According to CDC ("Overweight"), in 2012 more than one in three Americans was obese, up from 15% in the 1960s. During the late 1970s, the percentage of Americans who were overweight was a little more than 40%; today it is estimated at more than 70%. Similarly, diabetes incidence has risen dramatically during the same period and is predicted to exceed 30% of the population by 2050 (American Diabetes Association, 2013).

The rise in obesity, diabetes and cardiovascular disease has affected the U.S. on many levels. From poor health outcomes and quality-of-life indicators to medical expenses, the rise in preventable diseases has taken a heavy financial and social toll. The U.S. spent 17.9% of it gross domestic product (GDP) on healthcare in 2011, a figure that is expected to grow 4.2% in 2012 and 7.4% in 2014. From 2015-21, the expected rate of increase in healthcare spending is projected to average 6.2%. This will not keep pace even with an estimated GDP growth rate of 3.8% (CMS, 2012).

The treatment of obesity and overweight-related illness consumes a significant amount of the nation's medical costs (Cawley & Meyerhoefer, 2012; Lehnert, Sonntag, Konnopka, et al., 2013). The direct medical cost associated with obesity has been estimated by Finkelstein, Trogdon, Cohen, et al. (2009) to comprise more than 9% of total U.S. healthcare expenditures. Diabetes creates an even greater financial burden on the country's healthcare system; American Diabetes Association (2013) estimates that in 2012 diabetes-related healthcare expenditures topped $240 billion. In 2010, the average health plan in the U.S. cost more than $5,000 for an individual and more than $13,000 for a family, 66% of which was provided as an employee benefit (Kaiser Family Foundation, 2013; National Center for Health Statistics, 2011).

Private health insurers and consumers are not the only ones affected by the rise in preventable diseases. This trend has also had significant ramifications for employers. Research evidence strongly supports a correlation between obesity and workers' compensation costs, lost workdays and increases in costs per work-related injury (Finkelstein, Fiebelkorn & Wang, 2005; Thompson, Edelsberg, Kinsley, et al., 1998; Tucker & Friedman, 1998). The Duke Health and Safety Surveillance team found that employees with body mass index (BMI) scores greater than 40 were almost twice as likely to experience a work-related musculoskeletal disorder (Østbye, Dement & Krause, 2007).

Self-insured employers also face higher costs related to claims that fall outside of the workers' compensation system. Durden, Huse, Ben-Joseph, et al. (2008), found that private health insurance claims positively correlated with obesity and high BMIs for self-insured employers. They found that as workers' BMI increased so did their usage of medical services outside of work for various medical conditions.

In addition to injury rates and medical costs, worker weight, obesity and diabetes can reduce productivity and cause lost workdays (Bungum, Satterwhite, Jackson, et al., 2003; Ricci & Chee, 2005). Gates, Succop, Brehm, et al. (2008), reported a decrease in productivity for those with a BMI greater than 35 that equated to $507 per worker.

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Rise of Sedentary Behaviors at Home & Work

One common explanation for the increase in lifestyle diseases is the rise of sedentary behavior and the decline of physical activity, both at home and at work (Brownson, Boehmer & Luke, 2005). Before World War II, the manufacturing and agricultural sectors comprised a much larger percentage of the U.S. workplace than they do today (Church, Thomas, Tudor-Locke, et al., 2011).

Some researchers have attempted to compare modern activity levels with those from past centuries when more people were engaged in farming, raising livestock and similar activities. These studies compared the metabolic output of today's workers to volunteers who simulated the work and domestic lives of people from traditional agrarian societies. For example, Egger, Vogels and Westerterp (2000) found that their simulated preindustrial workers were 2.3 times more active than their modern counterparts. Bassett, Schneider and Huntington (2004) assessed the physical activity of an Amish community that still lives a preindustrial lifestyle. The researchers concluded that on average the Amish subjects engaged in much higher levels of physical activity than the rest of the modern North American population.

Manufacturing in the U.S. has also declined as many physically active production jobs either became obsolete or were outsourced abroad (Federal Reserve Bank of St. Louis, 2012). The amount of physical labor needed to produce products has diminished as well due in large part to automation (French, Story & Jeffery, 2001).

While one can debate the benefits and detriments of the information age, it is clear that the pervasiveness of the computer has affected many aspects of everyday society. The Internet has increased the convenience and speed at which people can access and integrate information and services. However, this increased use of desktop and laptop computers has added to the time spent seated for most workers in the western industrialized world (Gilson, Puig-Ribera, McKenna, et al., 2009).

Most people spend at least 2 hours per day watching television in addition to the extensive amount of time most spend in front of a monitor at work (Wijndaele, Brage, Besson, et al., 2011). Matthews, Chen and Freedson (2008) and Bauman, Ainsworth, Sallis, et al. (2011), estimate that between watching television, driving, and using a laptop or other device, adults spend more than half of their waking hours engaged in seated or sedentary activities.

Sitting & Decreased Caloric Expenditure

While sitting for prolonged periods, the human body expends little energy. Relatively low-intensity activities such as walking and even standing can increase the caloric expenditure of the body dramatically. The Compendium of Physical Activities, a list of metabolic rates of a broad range of activities, summarizes much of the research that compares the energy demands of sitting and standing (Arizona State University, 2011).

Depending on the study, standing and performing other light activities such as office work can result in an increased metabolic output of 10% to 100% compared to sitting alone. Standing without moving or performing any tasks has been reported to require anywhere from 10% to 50% more calories than sitting at rest, according to the research listed in the compendium. Levine, Schleusner and Jensen (2000) found that standing and engaging in minor motions described as fidgeting resulted in an increase in metabolic activity of 94% above sedentary levels.

Back/Neck Pain & Sitting

Individuals who experience a stiff back following airline travel or long car rides may assume that a strong correlation exists between sitting and low back pain. However, the evidence is equivocal. Research has not shown a consistent difference between resting activation of trunk muscles during sitting compared to standing. Some authors have reported similar findings between the electromyelagram (EMG) readings of static standing and sitting while others have shown increased trunk musculature activation during sitting (Callaghan & McGill, 2001; Nachemson, 1975; O'Sullivan, Grahamslaw, Kendell, et al., 2002).

Findings about the effects of sitting on the intradiscal pressure of the lumbar spine have been more consistent. Studies have correlated the sitting posture with elevated levels of disc pressure in the lumbar spine (Andersson, Ortengren, Nachemson, et al., 1975; Nachemson, 1975). NIOSH (1997) offers a brief systematic review of the research on the link between static postures, including sedentary and seated work, and back pain. While some of those 10 studies reported some correlation between sitting and low back pain, NIOSH concludes that all the studies show a weak correlation between "static work postures and low-back disorder(s)."

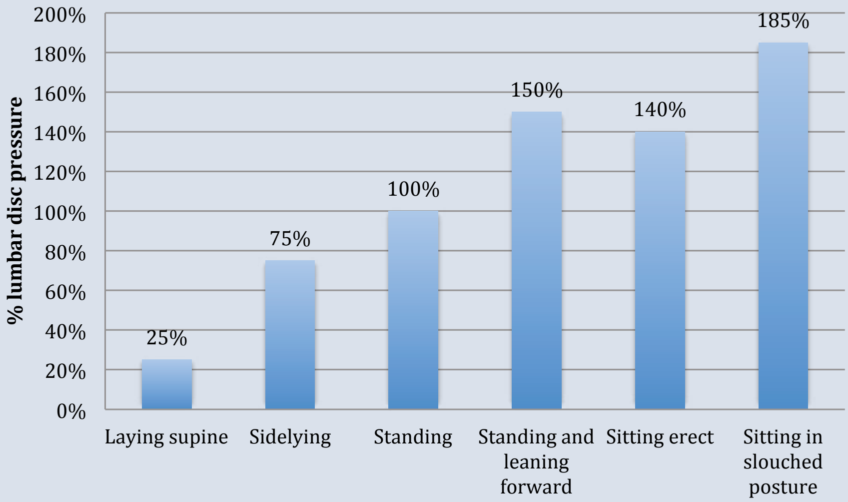
Research suggests a stronger link between neck pain and prolonged sitting than was found for the lumbar spine. Schuldt, Ekholm, Harms-Ringdahl, et al. (1986), found an association between a flexed neck posture with increased EMG findings in many cervical and scapular muscles compared to upright sitting. They suggest that the poor posture often associated with the seated position can place increased demands on the postural muscles of this region (Trujillo & Zeng, 2006).

Geertje, van Mechelen, Bongers, et al. (2000), performed an extensive systematic review of research that found a correlation, albeit a weak one, between sitting duration and neck pain, while Chiu, Ku, Lee, et al. (2002), found a correlation between "head down posture" during computer use with cervicalgia (Chu & Lamb, 2007). Ariëns, van Mechelen, Bongers, et al. (2000), found the risk for neck pain was almost double for workers who sat for more than 95% of their day compared to those who sat for little or none of their day. However, many other researchers have not found a correlation between sitting and neck pain. For example, Linton (1990) found, as with lumbalgia, that prolonged sitting did not elevate the risk of neck pain.

One common explanation for the increase in lifestyle diseases is the rise of sedentary behavior and the decline of physical activity, both at home and at work.

Figure 1

Lumbar Disc Pressure in Various Positions



Note. *Adapted from "Towards a Better Understanding of Low-Back Pain: A Review of the Mechanics of the Lumbar Disc," by A. Nachemson, 1975,* Rheumatology, *Vol. 14, No. 3, pp. 129-143.*

While some studies have correlated the sitting posture with elevated levels of disc pressure in the lumbar spine, overall results have been inconclusive.

Sitting & Thromboembolytic Events

While the literature on the effects of sitting on back and neck pain have produced inconclusive results, the evidence for a relationship between sitting and nonmusculoskeletal health conditions has been more strongly correlative. Thromboembolic events (TEEs) such as deep vein thrombosis (DVT) are potentially life-threatening conditions that have been linked to prolonged sitting. Various studies have correlated prolonged immobility during travel, especially via airplanes, with increased incidence of DVT (Ferrari, Chevalier, Chapelier, et al., 1999; Gallus, 2005; Kesteven & Robinson, 2002; Scurr, Maclin, Bailey-King, et al., 2001).

While earlier research focused on the effects of prolonged airline flight on DVT risk, more recent studies have assessed how people in a typical office environment are affected by sitting. Using case-control studies, several research teams have found evidence of a relationship between TEEs and prolonged sitting in the workplace (Aldington, Pritchard & Perrin, 2008; Suadican, Hannerz, Bach, et al., 2012; West, Perrin, Aldington, et al., 2008). Beasley, Heuser and Raymond (2005) used the term *seated immobility thromboembolism* (SIT) syndrome to describe the link between extended sitting time and DVT. Healy, Levin and Perrin (2010) found that professional occupations such as clerical, managerial and information technology positions were at an elevated risk for DVT.

Several theories have been posited to explain the proposed correlation between sitting and TEEs. One widely held explanation is that the seated position reduces active muscle contraction of the lower extremities, thereby reducing venous return of blood to the heart. Without active lower extremity muscle contractions, blood is not squeezed in the veins and a relative venous stasis results. Reduction in lower extremity venous return increases the risk for thromboses to form within the veins of the legs. These thromboses can then break free and travel to the lungs or the brain.

Direct compression of the lower extremities has also been hypothesized to contribute to venous stasis and an elevated risk for DVT. Hitos, Cannon, Garth, et al. (2007), report a reduction in popliteal vein blood flow of 40% in the seated position when the legs are hanging from the seat pan and being compressed from the front edge of the chair compared to baseline. For workers with shorter thighs, a chair with a deeper seat pan is thought to create increased compression of the popliteal fossa of the posterior knee, limiting blood flow by reducing the lumen size of the popliteal artery during the time spent sitting.

The Effect of Sitting on Diabetes & Obesity

Obesity and diabetes have taken center stage as growing healthcare epidemics during the past few decades and sitting has been hypothesized to contribute to both of these conditions (American Diabetes Association, 2013; Bowman, 2006; World Health Organization, 2000). Chau, van der Ploeg, Merom, et al. (2012), found a positive association between sitting time, both at work and at home, and obesity. Hu, Li, Colditz, et al. (2003), offer similar conclusions; they reported that for every 2-hour increment of sitting at work there was a "5% increase in obesity and 7% increase in diabetes." Interestingly, the correlation between obesity and sedentary behavior is present even if an individual participates in regular physical activity.

Is Sitting Lethal?

Given the relationship between sitting, obesity and diabetes, it should be no surprise that a body of evidence links prolonged sitting with mortality, especially from cardiovascular disease. Dunstan, Barr, Healy, et al. (2010), studied 8,800 participants and found that as television viewing increased so did the risk of mortality from all causes. As one may expect, the relationship was dose-dependent, meaning that the more television the participants watched the more profound the relationship became.

Similar outcomes have been reported in North America as sitting more than 6 hours per day has been found to correlate with increased mortality from all causes, and cardiovascular disease in particular (Katsmarzyk, Church, Craig, et al., 2009; Patel, Bernstein, Deka, et al., 2010). These findings also appear to apply to people who meet CDC's recommendations for physical activity. Even when a person is exercising sufficiently during leisure time, prolonged sitting can still increase an individual's mortality risk (Owen, Healy, Matthews, et al., 2010; Pate, Pratt, Blair, et al., 1995).

One may assume that the relationship between inactivity and an elevated risk of mortality would stem from the effects of reduced caloric expenditure on adiposity and diabetes. However, because the risk is present for individuals who exercise, alternate hypotheses have been offered to explain the effect. Some evidence suggests that some of the risk for cardiovascular disease with prolonged sitting may result from a reduced capacity by skeletal muscles to produce lipoprotein lipase (LPL) (Bey & Hamilton, 2003; Hamilton, Etienne, McClure, et al., 1998).

LPL is an enzyme that is present in adipose and muscle tissue that is involved in the regulation of triglycerides and cholesterol (Beisiegel, Weber & Bengtsson-Olivecrona, 1991; Borensztajn, 1987; Camps, Reina, Llobera, et al., 1990). LPL levels have been reported to positively correlate with high-density lipoprotein, with more active individuals displaying higher concentrations of the enzyme (Borensztajn, Rone, Babirak, et al., 1975; Herbert, Bernier, Cullinane, et al., 1984; Kantor, Cullinane, Herbert, et al., 1984). When LPL production increases, HDL levels increase and a resistance to "diet-induced hypertriglyceridemia as well as hypercholesterolemia" occurs (Bey & Hamilton, 2003; Shimada, Shimano & Gotoda, 1993).

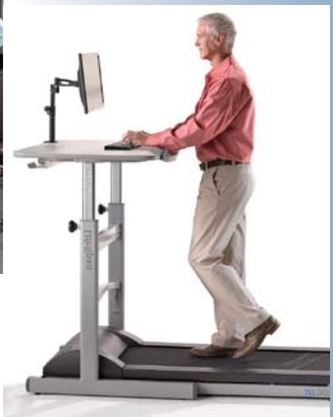
LPL may also aid in the regulation of lipoproteins that are associated with diabetes (Hamilton, et al., 1998). Therefore, even if an individual exercises moderately several days per week, s/he may still suffer from the effects of reduced levels of LPL if s/he sits for prolonged periods each day.

Possible Solutions to Prolonged Sitting

The negative health effects of prolonged sitting have prompted some employers, ergonomics professionals and healthcare providers to counteract the *sitting disease* (a term coined by Levine to describe what he feels is a growing problem in the U.S.). For example, some employers have attempted to increase workers' physical activity and offer alternatives to the traditional work environment to reduce healthcare costs and improve worker efficiency. Workplace wellness programs often include activity programs that encourage workers to be more active. These programs range from simple education programs about the benefits of exercise to organized walking programs or group exercise classes. Some programs distribute pedometers or provide them at a low cost to encourage workers to monitor their physical activity. Many (e.g., Virgin Pulse and Humana Vitality) incorporate specific step count goals for participants.

Use of pedometers has been shown to be an effective method for increasing physical activity in the workplace (De Cocker, De Bourdeaudhuij, Brown, et al., 2008; Gilson, et al., 2009). Bravata, Smith-Spangler, Sundaram, et al. (2007), analyzed 26 studies covering more than 2,000 participants and found that the use of pedometers resulted in significant increases in physical activity and reductions in BMI and blood pressure.

A small but growing number of companies are offering sit-stand enabled seating, postural break programs and active workstations that allow individuals to spend part of their working hours on video-display-terminal-enabled exercise equipment. Adjustable sit-stand desks, where the employee switches the work area between a high and low position, and chest-level kiosks with task stools allow workers to alternate between seated and standing positions. Sit-stand workstations may feature manual, electric or pneumatic controls, and can be either freestanding or desk mounted. Google and Facebook are among high-profile corporations that have adopted these workstations (Lohr, 2012).



L-R: PHOTO COURTESY STEELCASE INC.; PHOTO COURTESY LIFESPAN

As sit-stand workstations have become more commonplace, some manufacturers have taken the concept further by adding exercise equipment such as treadmills.

Research has assessed whether sit-stand work schedules are effective in improving increasing physical activity and improving employee health. Levine (2007) proposes that nonexercise activity thermogenesis (NEAT) plays a significant role in regulating human metabolism. He contends that fidgeting, short-duration ambulation, weight shifting and other small movements that would not otherwise be considered exercise actually combine throughout the day to burn a significant number of calories. In addition to increased metabolic activity, the sit-stand stations have been reported to decrease musculoskeletal discomfort (Hedge, 2004; Roelofs & Straker, 2002). Husemann, Von Mach, Borsotto, et al. (2009), found that musculoskeletal discomfort was reduced when workers' sitting time was reduced. The positive health effect of the sit-stand concept does not appear to be accompanied by a decrease in productivity or efficiency, although compliance with its use has been reported to be suboptimal (Healy, et al., 2010; Wilks, Mortimer & Nylen, 2006).

As sit-stand workstations have become more commonplace, some manufacturers have taken the concept further by adding exercise equipment. Treadmill desks have platforms that attach to standard treadmills, allowing a worker to view a laptop screen while walking. Various companies offer basic plastic platforms that fit over the back of a treadmill, while others offer more elaborate work areas on the equipment. Bicycle and step machines connected to computer platforms are available as well.

The positive health impacts of active workstations appear promising. Levine and Miller (2007) report an estimated loss of 44 to 66 lb per year for workers if they replaced seated work with 2 hours of treadmill computer station use. Similarly, McAlpine, Manohar, McCrady, et al. (2007), report an increase of metabolic rate for office workers using a step-device while using a computer. These researchers estimated that if a worker used the step device for 2 hours of the normal seated workday, some workers could lose 44 lb per year.

Although a standing station does not appear to reduce efficiency, exercise stations may reduce fine motor control and data entry speed during some tasks. Research also reports that attributes such as coordination, math skills and typing are adversely affected by treadmill workstation use (John, Bassett, Thompson, et al., 2009; Ohlinger, Horn, Berg, et al., 2011; Straker, Levine & Campbell, 2009; Thompson & Levine, 2011). Additional research is needed on the safety and efficiency of using exercise stations.

As lifestyle diseases such as diabetes, heart disease and obesity continue to affect many workers, combating the sitting disease may ultimately become a major weapon in the fight to improve employee health.

In addition to new workstation designs, many companies have attempted to limit workers' exposure to prolonged static postures during office activities by introducing periodic rest (Balci & Aghazadeh, 2003; Galinksy, Swanson, Sauter, et al., 2007). These breaks typically include 5- to 10-minute sessions during which office workers are reminded to change their static posture, perform short exercise activities and conduct similar activities. Some employers have installed software that encourages employees to reduce prolonged sedentary behavior (Morris, Brush & Meyers, 2008; Roelofs & Straker, 2002; Slijper, Richter, Smeets, et al., 2007; Trujillo & Zeng, 2006). Products vary but most provide onscreen prompts to remind seated workers to periodically alter their posture, stop and stretch, or get up and walk.

Research that has analyzed the effect of using these softwares shows promising results. Irmak, Bumin and Irmak (2012) report that office workers experienced reduced musculoskeletal complaints when they received prompts to periodically stop and engage in small exercise breaks. Similarly, van den Heuvel, de Looze, Hildebrandt, et al. (2003), report a reduction in upper extremity musculoskeletal complaints in office workers who utilized microbreak software. Swartz, Squires and Strath (2011), report an increased caloric usage when participants adopted a regimented active break schedule during sedentary office work.

Conclusion

As the U.S. has transitioned toward an information and technology-based economy, the amount of sitting at work has increased. The amount of time workers spend sitting, both at work and at home, has been correlated with health issues ranging from musculoskeletal complaints and TEEs to cardiovascular disease mortality. Many individuals and companies are attempting to reduce the risk for adverse health issues in the workplace by incorporating enhanced microbreaks into daily schedules, installing sit-stand workstations and even offering active treadmill or bike-enabled workstations.

As lifestyle diseases such as diabetes, heart disease and obesity continue to affect many workers, combating the sitting disease may ultimately become a major weapon in the fight to improve employee health. The literature suggests that a relatively small investment in sit-stand office furniture and postural break reminder software could result in a profound long-term health improvement. Several large companies are already addressing the health effects of prolonged static postures on office workers. As the evidence that links sitting to adverse health conditions grows and as public awareness increases thanks to media coverage, it remains to be seen whether employers will adopt standing or active workstations on a large scale. **PS**

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