DESIGN AND HEALTH PROMOTION COMBATING SEDENTARY BEHAVIOR

Dosun Shin / Noe C. Crespo / Matthew Buman
Arizona State University
Dosun.shin@asu.edu / Noe.Crespo@asu.edu / Matthew.Buman@asu.edu

Obesity is a major public health challenge. Children and adults who are obese have greater risk of developing cardiovascular disease, diabetes, and premature death. Sedentary time is an important contributor to obesity, and the environments in which we live and work are engineered to promote sedentary behaviors. Experts in Industrial Design and Health Promotion at a major university in U.S. have forged a partnership to identify targeted solutions to reduce sedentary behavior in key contexts for children (i.e., classrooms) and adults (i.e., worksites). This paper introduces how expertise in design and health promotion was leveraged to form this collaboration and to target innovative designs and evaluations that will reduce sitting time in schools and worksites via redesigning school and office desks.

Key words: Design, Health Promotion, Sedentary Behavior, Design Collaboration

1. INTRODUCTION

Since the middle of last century, the physical and social environments of human have been changing dramatically to promote greater sitting behavior and reduce demands for physical activity. TV watching, computer- and game-console use, workplace sitting, sitting at school, and time spent in automobiles all contribute to prolonged sitting behaviors and are associated with severe health-related problems (Owen et al., 2010). A number of recent research and case studies have focused on reducing prolonged sedentary behavior to reduce risk of health consequences. A transdisciplinary collaborative project was initiated with the faculty members who are the authors of this paper and teach in the School of Nutrition and Health Promotion and The Design School (Industrial Design) at Arizona State University. This collaboration aims to discover ways of preventing negative health outcomes associated with prolonged sedentary behavior by sharing expertise from two disciplines; *Health Promotion* and *Industrial Design*. Based on a systematic literature review, prolonged sitting time has been reported among children at school and adults at work. Therefore, we propose to develop innovative designs of school and office desks to reduce sitting time and promote greater standing time at school and work. This paper summarizes the current health issues relating to the sedentary behavior, addresses the need to intervene in schools and worksites and introduces potential designs of new desks stemming from the collaboration of a transdisciplinary team.

2. SIGNIFICANCE

2.1. PUBLIC HEALTH PROBLEM: TOO MUCH SITTING

Americans spend a considerable amount of their waking-hours in *sedentary behavior* (from the Latin term '*seder*', to 'sit'). In a large representative epidemiological study (NHANES 2003-2004), children and adults spent about 55% (or 7.7 hours/day) of their waking time in sedentary behavior (as measured by accelerometry) (Mathews, et al., 2008). Sedentary behavior steadily increases with age. For example, children aged 6-11 spent 42% of time in sedentary behavior compared to 67% among 70-85 year old adults. Similar trends have been shown in other industrialized countries such as Japan. An important contributing factor to these trends is the introduction and increased reliance of labor saving technologies/devices and the invention of the personal computer and Internet. These devices have resulted in what is now called '*ubiquitous sitting*': i.e., sitting in many aspects of daily living (at work, at school, for transportation and while viewing TV/media). We have progressively designed environments that are not supportive of physical activity and that force individuals to sit for extended periods of time.

Public health recommendations have focused on promoting moderate-to-vigorous physical activity (MVPA) to improve and maintain health (e.g., ≥150 minutes of moderate-intensity PA per week for adults) (2008 PA guidelines for adults, US-HHS). These recommendations are based on extensive evidence of the health benefits achieved through regular physical activity. However, the physical activity recommendations have largely ignored the fact that individuals can achieve the physical activity recommendations while also spending a large proportion of their day sitting. For example, an office employee can sit all day at work and then go to the gym during their leisure time. This is known as the '*active couch potato*' and it is not fully known whether this behavioral pattern represents a unique risk factor for cardio-metabolic health.

2.2. POSSIBLE CONSEQUENCES OF TOO MUCH SITTING

The health consequences of prolonged sitting are just recently being explored. Recent evidence shows that prolonged sitting can be detrimental to health. Epidemiological studies show that sitting for ≥6 hours/day increases risk of mortality in both men and women (relative risk=1.34 and 1.17, respectively) (Patel, 2010). Of particular concern is that the increase risk of mortality from time spent sitting appears to be <u>*independent*</u> of physical activity level. In fact, even among individuals who meet the PA recommendations, time spent sitting appears to independently increase risk for obesity, diabetes, heart disease and mortality (Owen, 2009). Other evidence shows that sedentary behavior is associated with low hip mineral density (Weiss, 1999), greater waist-to-hip ratio (VanUffelen, 2010), increased risk of low back pain (Roffey, 2010), cancer (VanUffelen, 2010), depression (Teychenne, 2010), metabolic syndrome (Sisson, 2009), and all-cause and CVD mortality (Proper, 2011). In light of this evidence, some researchers are calling for a <u>*paradigm shift*</u> in the way we view health promotion of physical activity. Researchers are calling for a greater emphasis on reducing sedentary time (sitting) in all aspects of daily life (work, school, transportation and leisure-time), while simultaneously promoting maintenance of regular leisure-time physical activity (Hamilton, 2008; Katzmarzyk, 2010; Marshall, 2011). While this paradigm shift is gaining momentum, there are many unanswered scientific questions regarding the health benefits of reducing sitting time that are independent of increasing physical activity.

2.3. SEDENTARY PHYSIOLOGY (ANIMAL EVIDENCE)

In recent years, research on pathophysiologic mechanisms associated with prolonged sitting time has augmented. This new line of research is known as '*Sedentary Physiology*' (as distinct from *Exercise Physiology*). Animal studies provide several insights to the potential pathophysiological mechanisms related to prolonged sitting and unhealthy outcomes. A study in rats showed that unloading the hind limbs (via suspension) decreased triglyceride uptake by skeletal muscle resulting from decreased synthesis and activity of lipoprotein lipase (LPL), the enzyme responsible for hydrolysis of triglyceride-rich lipoproteins (Bey & Hamilton, 2003). In this study, the decrease in HDL cholesterol concentration, often observed with reduced triglyceride clearance from the circulation, was observed within a day of inactivity. In contrast to inactivity, intermittent spontaneous standing in rats leads to a ≥ 10 fold higher LPL activity in red (oxidative) muscle fibers. This suggests that there may be no minimal muscle contraction intensity threshold for the benefits on LPL regulation (i.e., some activity is better than no activity). Furthermore, after 12-hours of hind limb unloading, LPL activity returned to normal after only four hours of standing. This suggests that the negative effects of inactivity may be reversed with minimal amounts of activity (such as standing). Thus, the mechanisms involving adverse consequences of sedentary behavior appear to involve metabolic alterations in the muscle (as opposed to systemic alterations). This line of research is relatively new and more evidence is needed on the possible mechanisms involved in prolonged sedentary time and muscle activation.

2.4. CROSS-SECTIONAL EVIDENCE IN HUMANS

Cross-sectional evidence in humans also points to deleterious outcomes from prolonged sitting time. A large cross-sectional study showed that individuals in the highest quartile of TV viewing time and overall sitting time had the greatest odds of having the metabolic syndrome [OR=1.4] (Gardiner et al., 2011). In addition, TV viewing time was related to lower HDL concentrations and glucose intolerance in women, while overall sitting time was related to greater risk of high triglyceride levels in men and women, independent of physical activity and other important confounders. Healy et al. (2008) examined 'breaks' in sedentary time (defined as accelerometer counts of ≥100 counts/min) in relation to metabolic risk by analyzing a large cross-sectional accelerometer dataset. They found that increased 'breaks' in sedentary time was related to lower waist circumference, body mass index (BMI), fasting triglyceride concentrations and 2-hour plasma glucose. Thus, there appears to be a unique health benefit achieved through reducing sitting time.

2.5. EXPERIMENTAL EVIDENCE IN HUMANS

Experimental studies in humans are scarce. The few existing human studies corroborate experimental studies in animals and cross-sectional studies in humans with respect to the role of sedentary behavior on glucose control, LPL activity and other metabolic parameters. One study showed that three days of bed rest decreased glucose tolerance (Lipman et al., 1972). A more recent study showed that two-days of prolonged sitting increased the total area under the curve (AUC) on postprandial triglycerides and postprandial plasma insulin concentrations among healthy college-aged students (Park, 2011). These studies support a relationship between triglyceride and insulin metabolism since insulin down-regulates LPL activity in the muscle (Jindrichova et al. 2007). Thus, higher insulin levels could negatively influence triglyceride clearance and lead to a more proatherogenic lipoprotein profile. Lastly, a well-designed study among overweight/obese adults examined the effects of interrupted sitting bouts on glucose and insulin response. The results showed that interrupting sitting time every 20 minutes with 2-minute bouts of light- or moderate-intensity walking resulted in reduced glucose iAUC and insulin iAUC, compared to uninterrupted sitting time (Dunstan et al., 2012). To date, this is the first experimental study in humans that has shown that interrupting sitting time results in improved glucose and insulin response. Thus, more research is needed to study whether reducing sitting time (short-term and long-term) provides unique health benefits that are independent of physical activity.

3. POTENTIAL SOLUTIONS: RE-DESIGNING DESKS

3.1. STAND-BIASED DESK CLASSROOM INTERVENTIONS

Few interventions exist that have specifically focused on reducing sitting time in children through the use of standing desks. A stand-biased desk is designed to promote standing as the default position. Children can still decide whether they want to stand or sit on a stool, but the desk is already at a standing height. Hinckson et al. (2013) found that standing desks lead to an increased standing time and thus decreased sitting time during the school day. In their study, children were accepting of these desks but school staffs were either supportive or not open to this new approach. This study also showed that standing school desks did not lead to musculoskeletal pain or fatigue. Benden et al. (2011) showed that children using standing desks had an increased energy expenditure of 17% and burned 0.18 kcal per minute more compared to children sitting at traditional desks. Children over the 85th percentile (for age and gender) showed an additional increase in calorie expenditure of 32% for the treatment group compared to the control group. The difference in energy expenditure between traditional and standing desk ranged between 0.07-0.47 kcal/min.

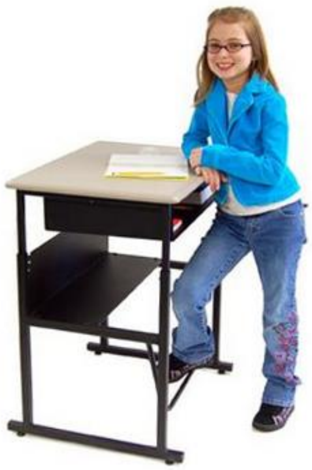

Figure 1. Standing school desk.

3.2. SCHOOL DESK DESIGNS

There are very few variations in the design of the school desk (see figure 2). The design of the traditional school desk has not evolved over time. One common feature that all traditional school desks share is that they are all designed for sitting. This design is probably based on tradition rather than scientific evidence that sitting is the optimal posture for learning. Based on the emerging scientific evidence for the potential detrimental health effects of prolonged sitting, it is now necessary to re-think and re-design the school desk to reduce sitting time in children during the school day. Children spend a substantial portion of their day in school (between 5 to 7 hours). In light of the pressure placed on school teachers and administrators to improve academic test scores, Physical Education has been largely eliminated in many schools. Recess time has also been reduced and few opportunities exist for children to engage in physical activity at school. For these reasons it is of scientific importance to design and evaluate the effects of reducing sitting time during school time on children's health as well as academic performance. The first step in this process is to create a new school desk design. Although there are some commercially available school standing desks, there are several design features that still need to be considered to optimize their use on a larger scale.

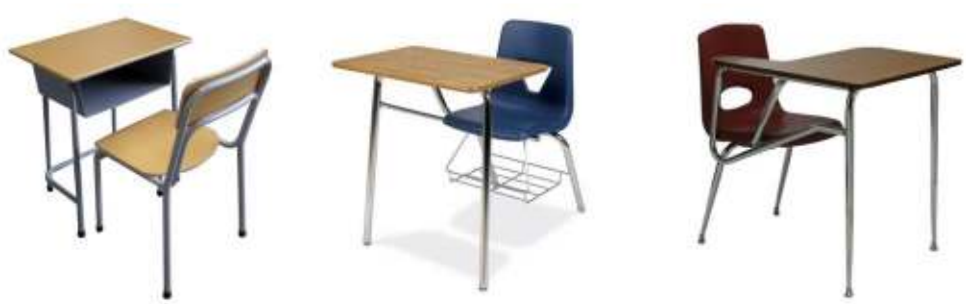

Figure 2. The variations of current school desk.

3.3. OFFICE DESK DESIGNS

The average worker spends one third of the adult life at work (WHO, 2007), and the majority of this time is spent sitting (Brown & Miller, 2003). As with school settings, traditional office desk designs are oriented almost exclusively toward sitting postures, perhaps due to the popular belief that sitting is the posture that results in the most productivity. In light of recent evidence that prolonged sitting is detrimentally associated with poor health outcomes (Healy et al., 2003) (Thorp et al., 2011), and workplace sitting represents the majority of sedentary time in employed adults (Thorp, Dunstan & Clark, 2009), new office desk designs are needed to address this public health problem. There are a number of designs that have been developed for the workplace. Most notably is the walking workstation which includes a standing-height desk combined with a low-speed treadmill (Thompson et al., 2008). Thompson et al. found increased energy expenditure throughout a day, however these increases were coupled with small but significant reductions is work productivity (Straker, Levine & Campbell, 2009). A major limitation of this design is the cost and size, making it difficult to be adopted in most workplaces on a large scale. Other height-adjustable desk and after-market products have been developed to decrease sitting (without treadmill features) have been developed with mixed results in terms of efficacy in reducing overall workplace sitting time (Alkhajah et al., 2012) (Gilson et al., 2012).

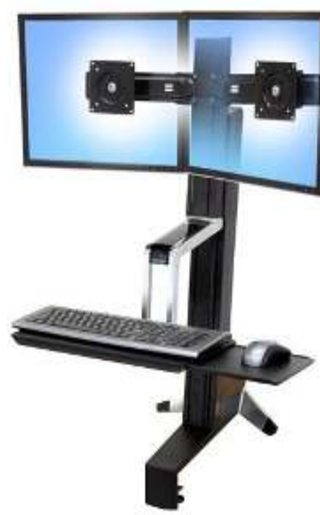

Figure 3. Sit-Stand Workstation (Ergotron).

Figure 4. Walkstation treadmill desk (Steelcase).

4. TRANSDISCIPLINARY DESIGN

Transdisciplinary collaboration between experts in Industrial Design and Health Promotion will help to transfer the research findings relating to sedentary human behaviors into the designing of desks for the two targeted environments; the school setting for children and the worksite for adults. The goal of this collaboration is to explore new innovative desks that promote standing and activity. This research will be conducted in a graduate level design studio course in Industrial Design through group projects; one group for elementary school desk and one group for adult work desk. Student groups will present the research discoveries to the faculty in the School of Nutrition and Health Promotion. Based on inputs and recommendations from the experts in Health Promotion, students will work on an individual design project for the rest of semester.

The following steps will be taken by students to implement the design project.

- Literature review (group work): Public health research, current product market research
- Secondary research (group work): Interviews, survey, observations, data collection, data analysis, design guidelines
- Design exploration (individual work): Concept generation, human factors, prototyping
- Product assessment (individual work): Product interaction, functional testing, user experience

The innovative design solutions stemming from this collaboration will be presented by the students at the end of semester, and the two most promising/innovative solutions from each group will be chosen by faculty members to be fully developed with engineering supports in another semester. Not only will this opportunity provide design students a great experience of working with experts from Health Promotion, but it also offers a potential to patent a new product. A new business proposal with the fully developed product solution will be introduced to potential investors to establish an entrepreneur team along with the students and faculty.

5. CONCLUSION

Children and adults are largely inactive during the school- and work- day (i.e., prolonged sitting). New and innovative desks are needed to reduce sitting time and possibly prevent health-related consequences. This collaborative project will engage university students and faculty with diverse expertise in the design process and is expected to open new avenues for health promotion and to produce products that may be sustainable and large scale public health solutions.

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