

Occupational Sedentary Behavior and Solutions to Increase Non-Exercise Activity Thermogenesis¹

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Original submission: 04/01/2016. Resubmitted: 08/10/2016.

Accepted: 09/05/2016. Published: 10/31/2016

Abstract

As the prevalence of obesity rises worldwide, researchers pursue explanations for the phenomenon, particularly those relevant to energy expenditure. Non-exercise activity thermogenesis, or NEAT, has been identified as an inconspicuous but appreciable component of total daily energy expenditure. Demands of certain occupations discourage time for planned physical activity and clearly diminish NEAT, and thereby contribute to sedentary behaviors that underlie increased adiposity. Prolonged sitting during the workday has specifically been identified as a risk factor for obesity and chronic disease independent of existing risk factors. Practical strategies have been launched by industry to increase NEAT during the workday. Workstations that involve maintaining balance while sitting on an exercise ball, standing, pedaling while sitting, and walking at a treadmill desk have been developed to counter extended periods of sedentary behavior at work. While data are limited particularly for chronic benefits, the stations that promote the most movement – the pedaling and walking stations – increase METS and energy expenditure more so than the other alternatives. The drawback to greater motion may be reduced attention to the desk job and therefore, reduced cognitive function; however, the data are inconsistent and the benefit for health may outweigh small distractions for some tasks at the desk.

Introduction

The present-day worldwide obesity crisis in industrially and technologically developed societies can be explained by a surplus of energy consumed compared to the amount of energy expended. The difference or balance between total daily energy expenditure, or TDEE, and the daily energy intake determines whether a human maintains or changes body weight. While efficiency of storage and of calorie usage can be debated as contributing factors, the laws of thermodynamics dictate that if energy intake exceeds output then weight gain will occur.

It is unclear which side of the energy balance equation has changed more dramatically in recent decades to arrive at the current healthcare predicament. Many would argue, though, that sedentary lifestyle is indeed a major factor. The warning, “sitting is the new smoking” embodies the concern (Mayo Clinic, 2014). Advances in technology and business-world objectives of ever-increasing productivity further promote inactivity as nearly all means of conducting business can be done for prolonged periods of the workday without leaving one’s desk.

¹ Original submission in English. Also available in the Spanish-translated version in this journal.

The objectives of this brief review are to a) define and characterize components of our daily energy expenditure; b) summarize the impact of sedentary lifestyle and prolonged sitting on risk factors of obesity and chronic disease, and c) identify and describe the impact of alternative workstations that may increase non-exercise activity thermogenesis, or NEAT, and promote movement while still allowing the worker to accomplish demands for the daily job. For the last objective, the acute and chronic effects of active workstations will be summarized as will the effects on cognitive function relevant to desk-job productivity.

The literature supporting this review was obtained from searches on PubMed and Google Scholar. The key words and phrases used included the following: calorie expenditure, cognitive, desk, energy-expenditure, energy-expenditure methodology, fidgeting, health, health risk factors, inactivity, non-exercise activity thermogenesis, occupational sitting, oxygen consumption, pedal workstation, physical inactivity, resting metabolic rate, risk factors, seated metabolic rate, sedentary, sedentary behavior, sitting, sitting metabolic rate, stability ball work station, standing, standing workstation, standing desk, thermogenic effect of food, total daily energy expenditure, workstation, workstation treadmill. For the sections on Prolonged Sitting and Workstations, the literature searches extended back to about 2000.

Total Daily Energy Expenditure

The energy expended by humans in a 24-h period defines TDEE. Figure 1 presents the components of TDEE as three distinct calorie-demanding processes: basal metabolism, the thermogenic effect of food (TEF), and physical activity (Levine 2005). Basal metabolic rate (BMR) is the energy used for cell, tissue, and organ homeostasis at rest. BMR contributes the largest proportion to TDEE, between 60 and 75%, and is largely dependent on the mass of the most metabolically active tissue, the lean tissue (Hill et al., 1995). Therefore, BMR is influenced by and can be predicted from age, height, body mass, and sex. TEF is the facultative and obligatory cost of digestion and metabolism of meals, and contributes the least at ~10% of TDEE. It appears to be largely unchangeable except for diet composition manipulation (Hill et al., 1995) but even that would have relatively little impact on TDEE (Hill et al., 1995). Physical activity accounts for the remaining 15 to 30%, it is the most variable, and can be most influenced by our behavior compared to the resilience of BMR and TEF.

In addressing TDEE and sedentary lifestyle, the physical-activity component of TDEE has been further dissected into planned activity, i.e. exercise, and NEAT, which can be considered movement that doesn't reach a threshold for fitness but from a cumulative standpoint, could demand appreciable calories during the day. Spontaneous activity would be considered a part of NEAT. Early work to separate exercise and NEAT suggested that fidgeting, a form of NEAT, could contribute expenditures of up to 800 kcal per day (Ravussin et al., 1986). Using a room calorimeter and motion detectors, Ravussin and colleagues were able to dissect the components of total daily energy

expenditure in 177 subjects who remained in the chamber for 24 h (Ravussin et al., 1986). They attributed an average of 8.7%, with a range of 3.9 to 16.6%, of the TDEE to spontaneous movement based on oxygen consumption and motion assessment. A cumulative effect of NEAT over a period of years could help explain why some individuals remain relatively lean and at normal body mass without engaging in formal exercise or restricting caloric intake (Johannsen et al., 2008; Ravussin et al., 1986; Levine, 2002).

Interrelationships exist among the components making up TDEE such that changing one component may affect another. Hill et al. (1995) described the theoretical effects of planned exercise impacting body mass on an initial reduction of fat mass if compensation does not occur; in other words, when exercisers don't consume more energy. In time, once the body hits the settling point described by Hill et al. (1995), continued energy deficit from exercise will result in loss of fat-free mass, which would reduce BMR and TDEE. In practice, this relationship may not operate as expected and could be complicated by other factors such as race (DeLany et al 2014). Reducing energy intake, i.e., dieting, would lower daily TEF and could also result in decreased daily physical activity and total daily energy expenditure (Redman et al., 2009). Blaak et al., (1992) and Racette et al., (1995) showed that obese individuals undergoing a planned exercise program increase spontaneous activity and possibly TDEE because TDEE in these individuals increased beyond that predicted for the addition of the formal exercise.

Results from other studies are somewhat mixed with no decreases in spontaneous activity and energy expenditure as a result of engaging in an exercise program (Willis et al 2014) or an apparent decrease because of the lack of weight reduction (Thivel et al 2014). The effect of a planned exercise program on spontaneous energy expenditure may depend on the population studied, i.e. lean vs. obese or older vs. younger. In addition, the type of exercise program, i.e. aerobic vs. resistance training may have a different effect on energy expenditure in spontaneous activity (Drenowatz et al 2015). It is unknown whether the reverse is true, that increased activities that increase NEAT might also increase one's engagement in planned exercise.

Regardless, the contribution of NEAT to TDEE is intriguing enough that opportunities to increase NEAT are being explored in research and offered in the workplace that has otherwise been a major factor in promoting inactivity. A summary of that research is addressed in the last section of this review. Over the last two decades, the lack or reduction of daily physical activity is increasingly of concern for health and mortality and has resulted in the medical community united in recommending standard for exercise and health (Pate et al., 1995; Haskell et al 2007).

Prolonged Sitting and Health Risks

Sitting as a Sedentary Behavior

The experts continue to debate and refine the definition of sedentary behavior to distinguish it from physical inactivity, i.e. failure to achieve the recommended volume of

exercise per week for fitness and health benefits. Sedentary activities are those during waking hours that elicit a metabolic rate of 1.0 to 1.5 in metabolic equivalents (METS) according to the Compendium of Physical Activities (Ainsworth et al., 2000; Pate et al., 2008). The Sedentary Behaviour Research (2012) Network added position to the definition to help qualify the term: behavior that elicits metabolism ≤ 1.5 METS in a seated or reclined position. The debate is complicated by the observation that health benefits can be gained by behaviors that fail to exceed the METS limit in either definition but at least surpass the category of seated position, i.e. standing (Gibbs et al 2015). For the purposes of this review, prolonged sitting at a desk with minimal movement is considered sedentary behavior.

During waking hours, the average person spends over half of the day engaged in sedentary behaviors (Matthews et al., 2008) and sitting is one of the most common forms. Sitting occurs while commuting, during most meetings, while doing selected leisure activities such as watching television or computer games, and at the desk station. Based on epidemiological studies, the volume of time spent sitting increases with age (Matthews et al., 2008). While it is possible to reduce time in sedentary behaviors by participating in leisure activities requiring movement, many people do not have the option to reduce time spent sitting because of work obligations.

Occupational Sitting

Careers such as in administration, transportation, and technology require employees to spend the majority of the workday at a desk with minimal movement. The term 'occupational sitting' has been coined to describe such inactive behavior. Examples of the magnitude are seen in studies of behaviors of workers. Employees at a call center spent an average of 6.6 h of the workday deskbound while another study found a similar duration 6.2 h of total time sitting on the job (Ryde et al., 2014; Thorp et al., 2012). Of further concern, for men a sedentary work environment fosters involvement in physically inactive leisure time activities outside of work (Gimeno et al., 2009). Combining sedentariness at work with sedentary leisure time compounds overall physical inactivity on a daily basis. Maintaining low energy expenditure throughout the majority of the day has implications for promoting overweight and obesity, accompanied by an increased risk for chronic disease over time (See table 1).

Health Risks

While it is generally accepted that physical inactivity has implications for various health risks and all-cause mortality, an expanding amount of research focuses on the health risks associated with occupational sitting independent from general inactivity. General physical inactivity, such as the absence of regular exercise, is clearly associated with the development of obesity, coronary artery disease, type 2 diabetes, various types of cancers, and premature mortality (Lee et al., 2012). Those who work in careers that require being sedentary for the majority of work hours may be doing additional harm to their bodies than realized. Contrary to the assumption that regular exercise at the beginning or end of the day is sufficient to undo the damage of the day's physical

inactivity, at least one study suggests this approach will not offset the ill effects of prolonged sedentary behavior including occupational sitting (Matthews et al., 2012). Additionally, in a study showing 7% of deaths were due to prolonged sitting, undergoing 30 minutes of moderate exercise per day (the ACSM recommendation) offered no reduction in risk, i.e., the hazard ratio was ≥ 1 , if an individual sat between 8-to-11 h of the day (van der Ploeg et al 2012).

The health risks of occupational sitting include being overweight and obese. A summary of several large scale studies supporting this are seen in Table 1. The work of Lin et al (2015) and Eriksen et al (2015) show the development of obesity linked to hours of sitting, indicating some element of cause-and-effect beyond merely an association. Extended periods of minimal calorie burning, such as sitting, increases likelihood of an energy surplus and onset of obesity in the individual. The study conducted by Eriksen and colleagues (2015) revealed that sitting for an average of 25 or more hours per week was associated with an increased BMI over a 5-year period in women. The combination of being overweight or obese *and* sitting motionless for long periods of the day potentially compound the health risks for individuals.

Being overweight or obese increases the risk of developing cardiovascular disease. A direct relationship between occupational sitting and development of cardiovascular disease independent of adiposity is not completely clear; however, an association has been identified (Altieri et al., 2004; Warren et al, 2010). The risk of developing cardiovascular disease or suffering from a related condition is increased with excess sitting time (Table 1). A study conducted by Altieri and colleagues (2004) determined that a greater amount of occupational sitting increased the risk of having an acute myocardial infarction over a 4-year span. These researchers found that prolonged sitting for work accounted for 11% of acute myocardial infarctions.

Metabolic dysfunction, including metabolic syndrome, is another outcome of excess energy storage, adiposity, and inactivity. Insulin resistance, elevated blood glucose, high cholesterol, and hypertension are components of the dysfunction and precede Type 2 diabetes and cardiovascular disease. Excess sitting including occupational sitting has been linked to metabolic dysfunction. A 12-year longitudinal study conducted in Finland found that the incidence of type 2 diabetes is much lower in those who are more physically active at work compared to those who are mainly sedentary (Hu et al., 2003). This association was evident following adjustment for sedentary behavior during commute as well as leisure time. While it is unclear whether this is a causal relationship, the results of this study indicate a need for decreasing the amount of time being sedentary while at work.

The effect of sitting on the development of various types of cancer has recently been examined. Although the data are relatively scarce, an association has been made for occupational sitting and breast and colon cancer. A 13-year longitudinal study conducted by Thune and colleagues (1997) revealed that higher levels of physical activity at work are associated with a decreased risk of breast cancer. Levi and colleagues (1999) found that greater volumes of time in occupational sitting were

associated with the highest risk of developing breast cancer among their sample. The risk of colon cancer, but not rectal cancer, is also decreased with increasing levels of occupational physical activity (Tavani et al., 1999). Overall, long periods of sedentary behavior while at work appear to be a hazard to health and a catalyst to obesity and metabolic diseases.

Workstations

With workers desk-bound and potentially spending two-thirds of their day sitting, there is a pressing need to incorporate non-exercise activity or planned physical activity into their lives (Ryde et al., 2014). In considering alternatives to the typical sitting workstation to increase energy expenditure and movement during work hours, it is important that the activity does not interfere with work productivity. In situations in which prolonged sitting is necessary to accomplish job objectives, it may be beneficial to break up prolonged sitting time with walking breaks or intermittent activity/movement alternatives to use during work hours.

Currently, four alternative workstations exist to promote energy expenditure and movement. These include: 1) sitting on a stability ball, 2) standing or adjustable sit-stand desk, 3) pedal device attached underneath the desk, and 4) treadmill walking desk. We refer the reader to Tudor-Locke et al (2014) for a thorough summary of the terminology and critical aspects of workstations, but for the purposes of this review, we'll classify sitting on the stability ball and standing at a desk as reactive or static. The movements that occur with these alternatives are mainly due to weight shifting or postural changes in a fixed position. Overall, reactive workstations are very practical and widely available. However, they might not induce enough movement to significantly raise energy expenditure or derive health benefits. We classify workstations that involve pedal devices and treadmill walking desks as proactive or dynamic. These alternatives facilitate rhythmic movements at variable intensities. While proactive workstations elicit more movement and a higher energy expenditure, the cost and practicality may be limiting. In addition, because the physical effort is deliberate, redirected mental attention could reduce work productivity. The remainder of this review will address what the research shows about the acute and chronic health benefits, along with cognitive performance, when using the four primary alternative workstations.

Acute Responses to Alternative Workstations

By increasing movement through alternative workstations, acute physiological responses are expected for energy expenditure, heart rate, and blood pressure. Acute responses are easily measured and may explain why greater amounts of research exist for immediate effects than chronic effects. However, the cumulative effects of daily acute responses presumably would contribute to chronic changes that alter risk of diseases.

Energy Expenditure. The increase in daily energy expenditure through alternative workstations helps offset daily energy intake and cumulatively benefits the individuals in the long term. Evidence indicates that the rate of energy expenditure varies depending on the category of the workstation alternative. This can be seen in Figure 2, which summarizes the mean values in the literature for energy expenditure at various workstations. The pattern suggests that generally, while reactive workstations elevate metabolism, the expenditure remains lower than proactive workstations. In one case, the rate of energy expenditure while using a reactive workstation did not rise above that of merely sitting at a workstation (Speck and Schmitz 2011).

Examining the stability ball sitting further, slight increases in energy expenditure may occur due to the compliant surface and reactive movements to maintain balance. For example, Dickin et al. (2015) measured energy expenditure of workers on a flat chair, cushioned chair, and a stability ball. Average energy expenditure was calculated based on oxygen consumption and carbon dioxide production during three 10-minute tasks. Results showed a difference of 13% ($p < 0.05$) when comparing the flat chair (1.46 ± 0.25 kcal/min) and stability ball (1.65 ± 0.20 kcal/min). Use of the stability ball and the cushion promoted greater energy expended compared to the flat surface chair by 10.4%, ($p = 0.01$) and 9.6% ($p = 0.03$), respectively, indicating that the yielding surface may be an effective means to forcing muscle to contract. In addition, studies of standing desk question their value specific to energy expenditure as small increases or no statistically significant change has been reported in children (Benden et al., 2014) and adults (Reiff et al., 2012; Speck and Schmitz, 2011). Nonetheless, Benden et al. (2014) and Reiff et al (2012) explained the practicality of implementing the standing desks into classrooms. Despite relatively small increases in energy expenditure, the modest activity of standing by children and college-age students may be beneficial in the long term due to the accumulation effect over a lifetime. In contrast, Speck and Schmitz (2011) reported no differences in metabolism during computer performance at alternative workstations (stability ball or standing) in inactive adults who were generally overweight (BMI average 27) questioning whether these would contribute to NEAT and the related health benefits in all individuals.

In contrast to reactive alternative workstations, proactive alternative workstations clearly elevate rates of energy expenditure. Carr et al. (2014) found that energy expenditure doubled from merely sitting to pedaling while sitting. Subjects pedaled for 30 minutes and burned an average of 69 ± 24 kcal. Data from Levine et al. (2007) for a treadmill workstation led to the conclusion that walking at just over 1 mph while working would elevate energy expenditure 100 kcal per hour compared to sitting. Active alternative workstations allow workers to engage in physical activity at their own intensity or intermittently. The higher the intensity and longer the duration, the more energy is expended.

Cardiovascular Responses. The cardiovascular system is negatively affected by prolonged inactivity including sitting. Acutely increasing heart rate and blood pressure with physical activity is beneficial for strengthening the heart, increasing blood flow, and promoting vessel dilation. Carr et al. (2014) tested physiological effects of actively

sitting with a pedal device underneath the desk. This study found that heart rate increased significantly between sedentary sitting and proactive pedal sitting (75 ± 12 vs. 89 ± 11 bpm). Systolic blood pressure also significantly increased (109 ± 11 vs. 122 ± 20 mmHg). Whether an alternative active workstation provides enough stimulus for adaptations over time, i.e., lowered resting heart rate and blood pressures will be addressed in the next section.

Prolonged sitting at a desk job has also been identified as a risk of deep vein thrombosis (Dunstan et al 2012a). More commonly thought of as a health concern for elderly and those doing prolonged air travel, the case study of a 32-y old male who spent extensive time motionless at a computer station brought the issue to light (Beasley et al 2003). Subsequent experimental research identified hematopoietic changes and the expression of skeletal muscle genes that could contribute to the development of thrombosis as a result of physical inactivity brought on by prolonged sitting or simulation of prolonged sitting (Howard et al 2013; Zderic and Hamilton 2012). Breaking up the workstation sitting by 2 min of walking at ~2mph three times an hour reduced the development of blood factors that promote pro-coagulation and the risk of thrombosis (Howard et al 2013). A case study of one individual and analyses of the animal tissue showed that subsequent bouts of physical activity did not reverse the suppression of lipid phosphate phosphatase-1, which would have a protective effect by degrading factors that promote thrombosis (Zderic and Hamilton 2012). This again suggests that intermittent activity to break up prolonged sitting is important, in this case to prevent hemostasis and risks of thrombosis.

Metabolic Responses. Low-level activity and interruptions to sitting at workstations may help increase glucose tolerance. By recruiting motor units for muscle contraction even at light intensities, it is possible that tissue sensitivity to insulin can be enhanced, which would explain reports of acute improvement in glucose tolerance (Dunstan et al., 2012b; Dempsey et al., 2016; Healy et al 2007). Whether this reduces the risk of Type 2 diabetes remains to be seen.

Chronic Responses

Long-term prospective studies on the effects of alternative workstations are limited. Chronic benefits of increased NEAT or physical activity with alternative workstations include weight loss, improvements in the cardiovascular system, lower blood pressure, reduction cholesterol levels, and reduced risk of diseases associated with sedentary lifestyle. This assumes that workers would engage in the workstation activity throughout the majority of if not the entire workday.

Weight Loss. Obesity occurs with a negative energy balance, with as little as 100 kcal excess intake per day if the deficit is consistently applied (Hill, 2003). The Center for Disease Control explains that a moderate amount of physical activity is roughly equivalent to physical activity that expends approximately 150 kcal per day, or 1,000 kcal per week (Health and Human Services, 2008). As previously discussed and

summarized in Figure 2, energy expenditure increases when using alternative workstations compared to the rate at a seated workstation. Even slight elevations in expenditure with some of the static alternative workstations (Reiff et al., 2012; Dickin et al., 2015), could compound over months and years to contribute to weight control benefits. We will start with the theoretical outcomes before looking at empirical finding.

Using expenditure for sitting on a stability ball, the added expense of about 0.55 kcal per minute compared to merely sitting would compound to 260 additional kcal per 8-hour workday (Faries et al., 2011). This increase could allow workers to expend 1,300 extra kcal per week. Dickin et al. (2015) suggested that even though there is a slight elevation in calories expended for the stability ball sitting at work, over the course of a year it is possible to burn 1.8 to 2.3 kg of fat. Using data in college-age students, Reiff et al. (2012) extrapolated to middle-school-age children and speculated that young students would expend an additional 114 kcal per school day, or 20,461 kcal per year based on average desk time in middle school. This could translate to a potential weight loss of about 2.6 kg per year from standing desks. The relatively minor acute effects of reactive movement workstations may provide chronic health benefits when compared to sedentary sitting, if the behavior is consistently applied.

Proactive alternative workstations showed even higher rates of energy expenditure, which could further facilitate weight loss or control with regular use and if workers do not compensate by ingesting more energy or becoming less active outside of work. The pedal workstation study done by Carr and colleagues (2014) showed an increase of 68 kcal expended per hour. The authors believe this effect may be adequate to reduce the risk of diabetes by facilitating weight loss and improved glucose and insulin intolerance (Carr et al., 2014). Similarly, Levine et al. (2007) showed that with treadmill walking, energy expenditure could be increased by 119 kcal per hour or 952 kcal per workday. For obese individuals, treadmill walking at work for two to three hours per day could equate to a weight loss of 20 to 30 kg a year if other components of energy balance were constant (Levine et al., 2007).

The empirical data while showing benefits, indicates the projections are overpromising. In the lone longitudinal study, Koeppe et al. (2013) conducted a 1-year observation of employees in otherwise sedentary jobs. Employees had treadmill desks installed to use for a year and were instructed to walk on the treadmill while performing all normal work activities. With the treadmill-desk intervention, the employee average weight loss was 1.4 kg and among those who were obese, the average weight lost was 2.3 kg after 12 mo. Waist circumference significantly decreased in all subjects (95 ± 19 vs. 91 ± 18 cm) as well as in those who were obese (101 ± 26 vs. 96 ± 25 cm). A control group was not included in this study, but among the 23 subjects that enrolled and waited 6 mo until the treadmill workstation intervention began, body weight remained stable. Although the study design did not use classic components of an experiment, the results suggest that proactive workstations appear to provide increased opportunities for workers to be voluntarily active throughout the day and may promote increase weight loss, especially for obese individuals.

Cardiovascular and Metabolic Diseases. The study by Koepp et al. (2013) also examined the chronic effects of the treadmill workstation on the cardiovascular system, blood glucose, cholesterol, and triglyceride levels before, during, and after over the one-year intervention. For the entire group (n=36), resting systolic blood pressure decreased slightly but statistically (132 ± 13 vs. 129 ± 13 mmHg, $p<0.05$), and HDL increased from baseline (55 ± 20 vs. 59 ± 23 mg/dl, $p<0.05$). There were no statistically significant changes observed in glucose, LDL, TSH, and triglyceride levels. Overall, positive changes in blood pressure and HDL are promising outcomes for improving the health of individuals, specifically in obese individuals, and reducing the risks of cardiovascular disease, metabolic syndrome, and mortality.

Cognitive Function

A critical objective for an alternative workstation that promotes activity is to not distract workers or disrupt their capacity to be productive. The worker as well as the employer who would invest in active workstations has a vested interest here. On the surface one would assume that reactive, lower intensive workstations are less likely to be intrusive, while proactive workstations could demand mental attention to keep sustained movement, thereby shifting concentration from the subject matter of deskwork. The research is equivocal on this and some evidence actually shows alternative workstations, both reactive and proactive may actually improve cognitive work productivity, perception of the quality of work, cognitive functioning, and mood after workers switch from a sitting workstation (Dutta et al., 2014; Koepp et al., 2013; Larson et al., 2015; Mehta et al., 2015; Roemmich et al., 2014).

Mehta et al. (2015) studied the neurological benefits of standing desks for students. A preliminary finding reported about a 7 to 14% improvement in cognitive performance in several memory tasks (Mehta et al., 2015). Also, teachers perceived the desks to facilitate student learning without causing a distraction (Mehta et al., 2015). In addition, workers who replaced 50% of their sitting time with standing also increased their sense of well-being and energy, decreased fatigue, and had no impact on work productivity (Dutta et al., 2014). At the beginning of this intervention, participants had pain in the lower-extremities and back as the duration of standing increased. By the second week, these discomforts resolved, and participants were willing to continue using the sit-stand workstation even after the conclusion of the study.

Concerns have been raised about alternative dynamic workstations negatively affecting work productivity. Certainly the concern for personal safety while moving on a treadmill and carrying on intellectual work for one's occupation is reasonable but not necessarily justified. Pedal and treadmill workstations can be set to certain intensities that are comfortable and manageable for the workers. Duration of these activities may also be intermittent throughout the day, such as 10 minutes of pedaling or walking per work hour. In support of this, Elmer et al. (2014) conducted a study in which participants had to transcribe the Gettysburg Address while sitting stationary at a desk and while pedaling at a desk. This study found that when participants pedaled at a power output of 38 W, there was no statistical difference in the typing time and number of errors

compared to sitting (7.7 ± 1.5 vs. 7.6 ± 1.6 min, 3.3 ± 4.6 vs. 3.8 ± 2.7 errors). Koepp et al. (2013) also concluded that in a 1-year treadmill workstation study, work performance was unaffected based on supervisor input and weekly surveys. Alternatively, Thompson et al. (2011) showed a decrease in productivity with treadmill workstations. After being trained for 4 hours using the treadmill workstations, the participants were asked to transcribe tapes for 8 hours both while sitting and walking on the treadmill. Accuracy did not differ; however, the speed was 16% slower while on the treadmill compared to sitting. The potential health benefits are immense for treadmill walking, so it was recommended that greater than 4 hours of training needs to occur to avoid compromising work productivity (Thompson, 2011).

Conclusion

The detrimental effects of prolonged sitting are well established, and occupational deskwork is clearly part of a sedentary lifestyle that contributes to obesity and other risks of chronic disease. Cautiously, we conclude, based on current research, that alternative workstations may counter the negative effects of extensive periods of sitting at a traditional desk workstation. For elevating metabolic rate, dynamic and active workstations such as treadmill walking or pedaling appear to have a greater impact than static or reactive stations such as standing or sitting on an activity ball; however, the data are limited to a few studies at this point. Additional options need to be investigated. The acute and chronic physiological improvements associated with alternative workstation activities are promising for health benefits particularly if they do not diminish cognitive performance needed for the job. Presently it is not clear whether the benefits originate from muscle contraction or energy expenditure. Regardless, the benefits of alternative workstations should not be misinterpreted to imply that very low intensity activity can be a replacement for planned exercise. Rather they should be an adjunct intervention in the grand scheme of lifestyle strategies for body weight management and optimal health.

Acknowledgments

We thank Laura Swan for her diligent review and feedback during the preparation of the manuscript.

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Table 1. Summary of studies on health risks associated with occupational sitting.

Source: The Authors.

Health Risk	Study	Design	Sample	Variable	Occupational Sitting	Results
Overweight/Obesity	Mummery et al, 2005	Cross-sectional	n = 1,579	BMI \geq 25	>6 hours/day	Overweight & obesity associated with occupational sitting time in men
	Lin et al, 2015	Longitudinal - 8 year study	n = 5,285	BMI	Avg: 3 hr/day	Increased sitting time significantly associated with increased BMI
	Eriksen et al, 2015	Longitudinal - 5 year study	n = 4,732	BMI	Avg: \geq 25 hr/week	Association between occupational sitting time and increased BMI in women
Cardiovascular Disease	Katzmarzyk et al, 2009	Longitudinal - 12 year study	n = 17,013	Death from CV disease	Total daily sitting time	Dose-response between sitting time and death from CV disease
	Warren et al, 2010	Longitudinal - 21 year study	n = 7,744	Death from CV disease	>23 hr/week commuting/ watching TV	64% increased risk of death from CV disease
	Altieri et al, 2004	Case-control - 4 year study	n = 507	Incidence of acute myocardial infarction	Level of occupational physical activity	Inverse association between occupational physical activity and incidence of acute myocardial infarction
Metabolic Dysfunction	Hu et al, 2003	Longitudinal - 12 year study	n = 14,290	Incidence of type 2 diabetes	Light occupational physical activity	Incidence of type 2 diabetes was highest in those with lowest levels of occupational physical activity
	Chu & Moy, 2013	Cross-sectional	n = 686	Incidence of factors associated with metabolic disease	Low levels of occupational, transport, and household physical activity	Low levels in all areas of physical activity associated with higher odds of metabolic disease
Cancer	Thune et al, 1997	Longitudinal - 13 year study	n = 25,624	Incidence of breast cancer	Level of work phys. activity - (sedentary to manual labor)	Higher levels of occupational physical activity associated with lower risk of breast cancer
	Levi et al, 1999	Case-control - 5 year study	n = 620	Risk of breast cancer	Occupational sitting - "mainly sitting"	Highest risk of breast cancer associated with highest level of occupational sitting
	Tavani et al, 1999	Case-control - 5 year study	n = 5,379	Risk of colon and rectal cancer	Occupational sitting - "mainly sitting"	Occupational physical activity protective against colon cancer

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Figure 1. Components and approximate proportions of total daily energy expenditure.

Source: The Authors.

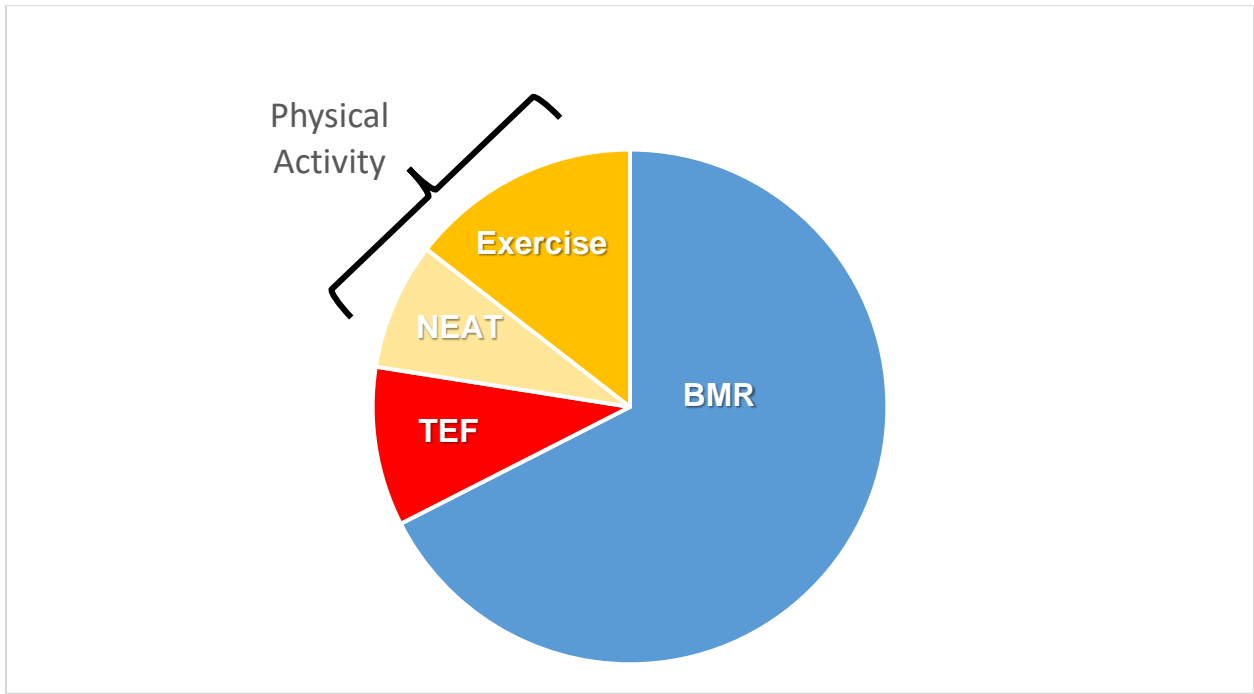


Figure 2. Summary of literature values for mean rate of energy expended at traditional and alternative workstation alternatives. Adapted and updated from Tudor-Locke et al 2014). References: (A) Wright et al., 2015 [normal weight]; (B) Wright et al., 2015 [overweight]; (C) Wright et al., 2015 [obese]; (D) Dickin et al., 2015; (E) Speck et al., 2011; (F) Benden et al., 2014 [Fall]; (G) Benden et al., 2014 [Spring]; (H) Reiff et al., 2012; (I) Carr et al., 2014; (J) Levine et al., 2007.

Source: The Authors.

