IMPACT OF ALTERNATIVE WORKSTATION DESIGN ON DISCOMFORT, COMPUTER UTILIZATION AND SEDENTARY ACTIVITY AT WORK

A Dissertation

by

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ABSTRACT

Utilization of alternative workstations have become increasingly popular with researchers investigating workstation utilization trends in various populations. Much of the literature reports mixed results, likely due to the different types of workstations that have been lumped into the sit-to-stand category. Upon investigation, a more accurate all-inclusive term of stand capable workstations was identified (Pickens et al., 2016).

Previous studies have separated the stand-capable group into two categories: (1) a stand-biased group that works at a workstation that has a fixed height and a stool, which allows them to sit when desired; and (2) a sit-stand group that can adjust their work surface height to accommodate both standing and sitting work with the help of a traditional office chair.

Both the HSC Workstation Study and the HSC Stand-Biased Workstation HSC Stand-Biased Workstation Follow-up Study used these definitions to characterize participant's workstations. In addition, both of these studies utilized a questionnaire and two objective data collection tools to quantifiably measure computer utilization and occupational activity. The HSC Workstation Study found that stand-biased users typed more words per day and made more errors than their traditional counterparts, but they were not statistically different when the error rate (errors/500 words) were evaluated. The study also found that stand-biased workers spend more time standing and less time seated at the workstation than their traditional counterparts did, but they have statistically less transitions than either the sit-stand or traditional groups. The HSC Stand-Biased Workstation Follow-up Study indicated that the majority of individuals

who began using a stand-biased workstation continued over the 6-year time period with only 28% changing workstation types. Over time, the group reported an increase in the number of days that they walk, but did not report any statistical difference in time spent seated or standing to work.

The RSI-OES study lumped all sit-stand use into one group as a definition or listing of the type of unit used was not provided. However, the study utilized the same data logging software program to characterize computer utilization finding that sit-stand users spend more time actively computing. This included more active keyboard and more active mouse use than their traditional counterparts.

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NOMENCLATURE

aOR	Adjusted Odds Ratio
AP	activPAL^{TM}
B/CS	Bryan/College Station
BLS	Bureau of Labor Statistics
BMI	Body Mass Index
BRFSS	Behavioral Risk Factor Surveillance System
CAD	Computer-aided Design
CDC	Centers for Disease Control
CIS20-R	Checklist Individual Strength
DOL	Department of Labor
HHS	Health and Human Services
HSC	Health Science Center
HWQ	Health and Work Questionnaire
IRB	Institutional Review Board
LBP	Low Back Pain
MAF	Multi-dimensional Assessment of Fatigue
MEPS	Medical Expenditure Panel Survey
METs	Metabolic Equivalent
NIOSH	National Institute for Occupational Safety and Health
NMQ	Nordic Musculoskeletal Questionnaire

OES	Office Ergonomic Solution Software
OPM	United States Office of Personnel Management
TAMHSC	Texas A&M University Health Science Center
TAMU	Texas A&M University
TWH	Total Worker Health
WLQ	Work Limitations Questionnaire
WEMWBS	Warwick-Edinburg Mental Wellbeing Scale

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1 INTRODUCTION AND BACKGROUND

1.1 Public Health Problem of Obesity

While it is not making headlines on a daily basis, obesity rates in the United States remain a considerable public health issue. According to data from the Behavioral Risk Factor Surveillance System (BRFSS), the National Health and Nutrition Examination Survey (NHANES) funded by the CDC reported that 39.6% of the U.S. population, aged 20 years and older, are considered obese (BMI $\geq$ 30.0). While the percentages differ by state for both overweight and obesity, the sheer number of Americans that fall into these groups is staggering.

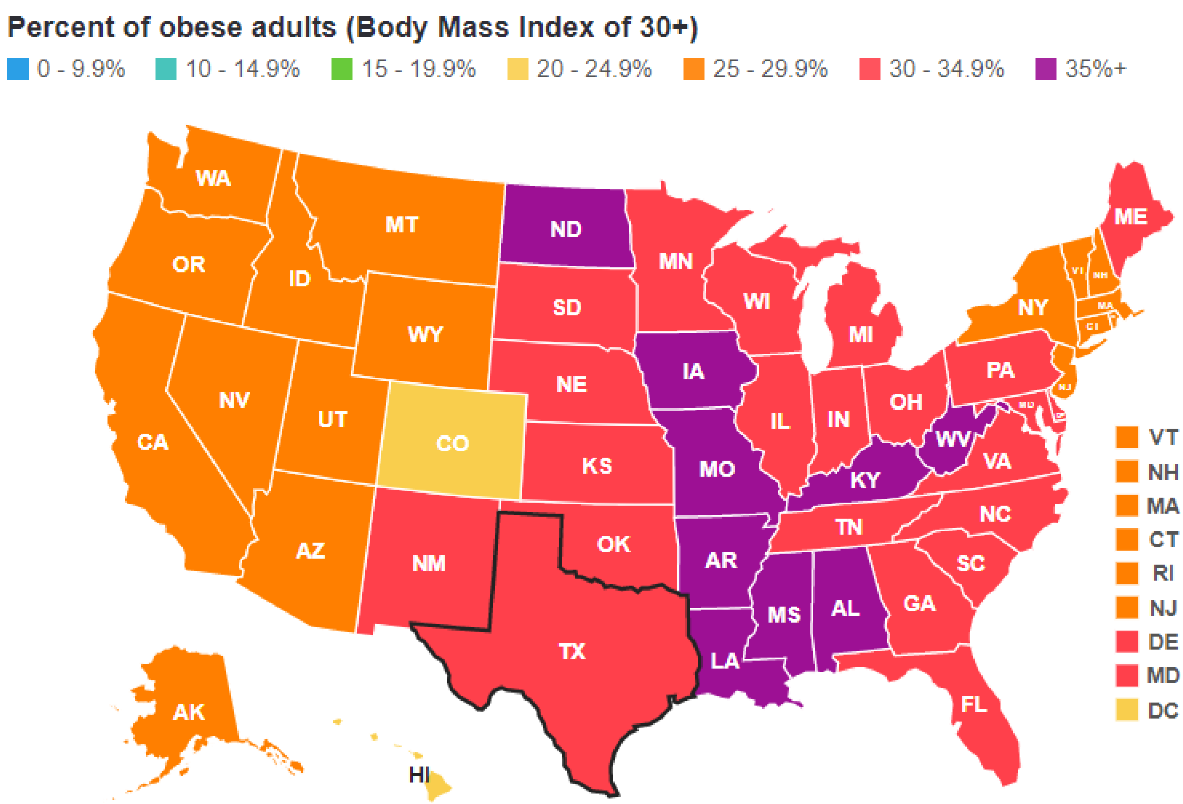

Figure 1.1: Percentage of adults ages 18 and older who have obesity – classified as BMI $\geq$ 30.0 (weight [kg] / height [m]^2) Data Source: Behavioral Risk Factor Surveillance System (BRFSS) Reprinted from: Robert Wood Johnson Foundation, State of Childhood Obesity 2019.

A 2018 report generated by the Commonwealth Fund, indicated that in 1985 no single state had an obesity rate of above 15%, while in 2018 not a single state reported a rate less than 23.0% and 9 states fell into the highest category of between of over 35% obesity (Figure 1.1). The report also suggests that obesity, while not as dramatic, is just as big a public health issue as the opioid and smoking epidemics. The U.S. Department of Health and Human Services published a special report from the Surgeon General, which identified that there are 1300 American deaths every day, which equates to one-in-five (or 20%) per year that can be attributed to smoking cigarettes (2014). This is similar to the 18% of deaths in the U.S. that are related to Obesity (2017). There are also substantial economic losses that can be associated with obesity in the U.S. A study based on the Medical Expenditure Panel Survey Data found a 29% increase in obesity rates from 2001 to 2015, which was statistically significant (Biener, et al., 2018). The study also identified that the additional burden in medical costs for obese individuals was $3429 per year in 2013 dollars. Biener and colleagues determined that the total medical costs for obesity in 2013 was $342.2 billion, which equates to 28.2% of all health care costs being related to obesity in the US (2018). These numbers do not include the indirect costs in the form of lost productivity, lost workdays, increased mortality and increased risk of disability (Tremmel, M et al., 2017). It is also important to realize that obesity is considered a co-morbidity for a variety of diseases. According to the CDC, it has been linked to a wide range of medical issues including, sleep apnea, asthma, liver disease, stroke, heart disease, diabetes, arthritis, gout, female infertility, gallstones and various cancers (CDC Vital Signs, 2010). Even more startling is that due to biochemical changes in the body, approximately 55% of cancers in women and 24% of cancers in men are associated with being overweight or obese. Thirteen specific cancers are thought to be associated with overweight or obesity including; meningioma, adenocarcinoma, myeloma, kidney, uterine, ovarian, colon and rectal, pancreatic, stomach, gallbladder, liver, breast and thyroid cancers (CDC Vital Signs, 2017, Massetti et al, 2017).

If the increase in risk for the previously mentioned medical conditions was not enough, obesity is also considered a risk factor for low back pain (LBP). One of the most common musculoskeletal issues in the general population, with a reported worldwide lifetime prevalence of 39.9% ± 24.3% in 2012, the condition is often physically disabling for individuals (Peng, 2018). A study investigating the burden of low back pain globally, indicated that of the 291 conditions considered worldwide, the disability- adjusted life years, which is a measure of loss of healthy years, for low back pain ranked number six (Hoy et. al., 2014). The Hoy study also reported that prevalence of LBP is higher in women than men with varying differences in prevalence for different ethnic and racial groups. A study by Peng et al. reported that the adjusted Odds Ratio (aOR) of low back pain for overweight individuals compared to those with normal body weight was 1.21 (1.11-1.32) and 1.55 (1.44-1.67) for obese individuals when adjusted for age, sex, race/ethnicity, BMI, highest level of education and leisure-time physical activity. A study on the cost of illness by Dagenais et al., identified that direct costs for treatment of LBP ranged anywhere between $12.2 and $90 billion (2008). Dieleman and colleagues evaluated the factors associated with increased health care costs from 1996 to 2013 and found that low back and neck pain had the second highest increase in spending nationwide at $57.2 billion (2017). Thus, the cost of treating low back pain was only eclipsed by treatment of diabetes and all-cause mortality, all of which are also associated with obesity. If you continue down the list of the top 10 most costly conditions; hypertension, hyperlipidemia, depressive disorders, falls and osteoarthritis are also often associated with obesity.

1.2 Indirect Costs of Obesity

The previously mentioned costs for both obesity and low back pain do not include the indirect costs that are related to productivity, absenteeism, presenteeism, quality of life, earning potential, disability, and altered life expectancy. One study identified that obese workers are less productive at work than those with a normal weight (Ricci & Chee, 2005). They attribute the difference to the health status of the individual, which is plausible, as increased illness often requires more time away from the job to attend medical appointments and receive treatments. The same study calculated the financial cost of lost productivity, citing an annual cost of lost production of $358 per worker. Another study by Gates et al. utilized data from the manufacturing industry and calculated that the cost was $575 per person (2008). Similarly, a report on the financial burden of overweight and obesity in the U.S. highlighted five studies that evaluated absenteeism and obesity utilizing datasets that represented the U.S. as a whole. Only one study by Finkelstein et. al. provided a cost estimate of absenteeism associated with obesity (2005). In 2009 dollars, the additional cost associated with missed workdays was $730 for severely obese males and $1,063 for severely obese females (Finkelstein et al., 2005). Utilizing the 20% increase in inflation from 2009 to 2019 and not accounting for any increases due to other factors, the estimated cost in 2019 dollars would be $876 for males and $1,275 for females per year. While many researchers, reviewing a variety of national populations, agree that males earning potential is not significantly penalized for being overweight or obese this is not the case for women. A study utilizing the National Longitudinal Survey of Youth data, which began in 1979 and has continued through 2008, found that there was a reduction in earnings of 0.8-1.0% per unit increase in BMI (Sabia, 2012). This would mean that there could be up to a 5% decrease in wage earning capacity per year for a white woman who had a BMI of 35 compared to a woman with a BMI of 30. The same study also reviewed wage earnings for Hispanic and Black female populations with a 0.4% and 0.5% decrease in wage earning per unit increase in BMI respectively.

Most of the published studies focus on short-term disabilities, which can last up to 6 months and cause a reduction in the amount of work that an individual can accomplish. One study by Arena et al. identified that overweight employees were 26% more likely to sustain a short-term disability when compared to an individual in the normal weight category (2006). Similarly, the same study identified a 76% increase in risk of short-term disabilities for obese workers when compared to those in the normal category (Arena et al., 2006). There is also an increase in work-related limitations and long-term disabilities for individuals who are overweight and obese. A 2006 study calculated the increased probability of reporting worker limitations was 1% for each point of increase in BMI (Burkhauser and Cawley). Researchers have even looked at the differences in life expectancy with regard to obesity in international and U.S. populations. Preston and Stokes looked at population-based data and identified that if obesity could be eliminated the life expectancy in the U.S. would be projected to increase between 25-40%, when compared to our Canadian and English counterparts (2011). Calculations based on the data presented by Fontaine et al. identified that the life expectancy for a morbidly obese white male is reduced by 5.2 years and white females are reduced by 4.3 years when compared to their overweight counterparts (Dor et al., 2010). These decreases in productive and healthy working years and costs can greatly affect the individual and the workforce as a whole.

1.3 Causes of Obesity

Depending on who you ask, obesity can be caused by a variety of things including genetics, family history, diet, activity levels and socioeconomic factors (Gray et al. 2018). The most commonly accepted clinical definition is that obesity and overweight are caused by an excess amount of body fat that impacts an individual's health (Cakmur, 2017). The rational obesity model accounts for the types of food that are consumed, their calories and the amount of activity that each individual engages in and its resulting energy expenditure, with a net balance of positive calories resulting in weight gain over time (Tomer, 2011). However, not all professionals can agree that this model accurately represents the causes of obesity especially in light of the substantial increase in obesity rates. A recent article highlighted six different fields and how they "viewed" the cause of obesity. Nutritionist often believe that it is due to the over consumption of foods that are too energy dense. Likewise, Economists view the increase in obesity as a result of cheap market prices, especially for foods that are packaged and processed. Architects often associate the increase in obesity with the changes in our built environment. The personal training industry relates the increase to a reduction in the amount of activity and exercise that individuals engage in. Physiologists attribute the increase in obesity to increased levels of appetite hormones that ultimately cause weight gain (Agha and Agaha, 2017). The important thing to remember is that in reality, none of these groups are wrong, there are numerous contributing factors that are associated with the increase in weight and ultimately obesity.

In general, Americans do not get enough physical activity, whether that be at work or recreationally. It could be due to the shift from agricultural, ranching and industrial blue collar occupations to more tech based professional occupations which typically encourage an office environment or it could be a shift in the number of working members in a house-hold and increased obligations that make cooking at home more challenging, but one thing remains the same; the American people do not engage in enough physical activity throughout the week. According to CDC data collected in 2017, 26.6% of adults in the U.S. do not engage in any leisure time activities and 13 states have a percentage that is above the national average (Figure 1.2). The Department of Health and Human Services recently published the 2nd Edition of the

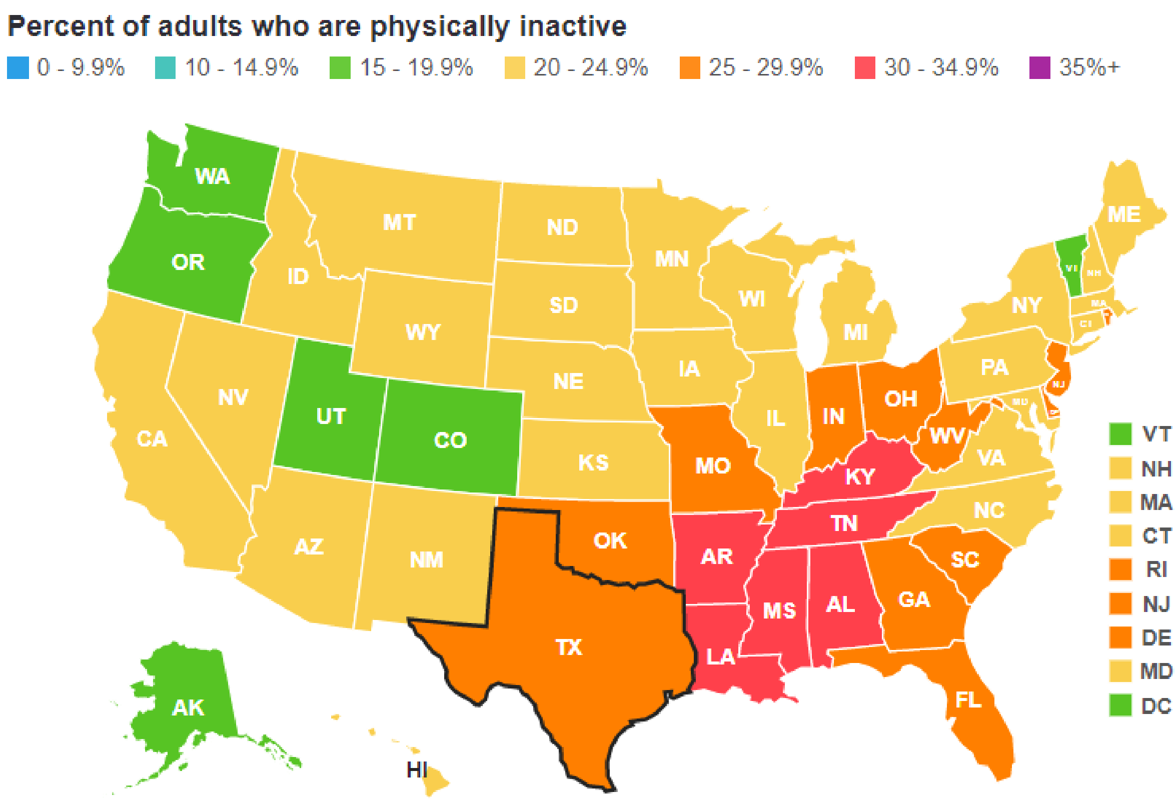

Figure 1.2: Percentage of adults (ages 18 and older) who engage in no leisure time physical activity by answering "no" to the following question: During the past month, other than your regular job, did you participate in any physical activity or exercises? Data Source: Behavioral Risk Factor Surveillance System (BRFSS) Reprinted from: Robert Wood Johnson Foundation, State of Childhood Obesity 2019.

Physical Activity Guidelines stating that "being physically active is one of the most important actions that people of all ages can take to improve their health" (HHS, 2018). The guidance highlights recommendations for pre-school aged children, school age children and adolescents, adults, as well as special populations including adults with chronic health conditions as well as pregnant and post-partum women. Specifically, adults should engage in 150 minutes (30 minutes - 5 days per week) to 300 minutes (60 minutes – 5 days per week) of moderate intensity activities, which are described as brisk walking or dancing, or 75 to 150 minutes of high intensity activities per week (HHS, 2018). Additionally, the guidance recommends inclusion of moderate strength training two or more days per week to increase muscle strength of all major muscle groups. The one thing that really stands out is that while they recommend specific values, any physical activity is better than none and participants can experience health benefits for any amount of moderate activity.

1.4 Health Risks of Increased Sedentary Time

The U.S. population spends a considerable amount of time engaging in sedentary tasks, which have been identified, as those activities that are $\leq$ 1.5 Metabolic Equivalents (METs) (Tremblay, 2012). Several researchers have associated sedentary time with increased risk of obesity, cardiovascular disease, diabetes, all-cause mortality (Katzmarzyk et al., 2009) and cancer (Biswas et al., 2015; Dutta et al., 2015; Neuhaus et al., 2014). Additionally, researchers have identified that musculoskeletal pain, especially in the shoulders, neck and lower back, may be associated with increased sedentary activity or occupational seated time (Healy et al., 2012; Foley et al., 2016; Wilks et al. 2006). Healy and colleagues even suggested that prevalence of musculoskeletal symptoms could be as high as 50% in computer users (2012). A commentary by Marshall and Gyi indicated that poor design and environmental conditions can add additional demands to muscle activity for individuals which can ultimately lead to increased discomfort, pain and even chronic disabilities (2010). A review of the literature also noted significant associations between sitting time and both anxiety and depression (Rebar et al., 2014). It has also been suggested that there is a considerable social impact of chronic musculoskeletal discomfort, absenteeism and health care costs in the industry that may be attributed to a sedentary work environment (Foley, 2016).

1.5 Sedentary Time at Work

Based on data from the 2000 U.S. Census, the percentage of Americans in low activity occupations increased from 23.3% in 1950 to 42.6% in 2000. Similarly, the percentage of individuals in high activity occupations, which remained steady at 30% from 1950-1970, declined to 22.6% in 2000 (Brownson et al., 2005). When you consider the substantial growth in total civilian labor force from 1950 to today, the number of individuals in low activity or sedentary occupations is alarming. A study by Pronk et al. focused on reducing sitting time in individuals who completed desk work including administrative, call center or computer activities as they were most likely to be at risk of being sedentary (2011). A study that reviewed sedentary time specifically in office workers, found that 82% of their work hours and 69% of their non-work hours were spent in sedentary activities (Parry et al., 2013). Another study by Thorp on sedentary time in office workers, customer service and call center employees identified that 6.6 hours or 77% of the participants work hours were spent in sedentary activities (2012). The study also identified that 22% of the participants work hours were spent conducting light activities, together these two categories make up 97% of the average participants work day hours (Thorp et al., 2012). Bantoft and colleagues identified the workplace as the major contributor to the increase in sedentary activities (2016). In light of these findings it seems fitting that an Australian review, focused on creating healthy workplaces, identified office workers as a special population due to the number of hours spent at the computer and the associated occupational sedentary time that they experience (Healey et al., 2012). Several health agencies, including those in the United States, the United Kingdom (Dustan et al., 2012) and Australia, (Healy et al., 2012) have even established proactive programs that target reduced sedentary time to reduce health risk. An Australian report on effective health workplace interventions identified prolonged occupational sitting as one of their five factors that influence health (Healy et al., 2012).

1.6 Use of Computers at work

More and more of our work today is completed within the confines of a brick and mortar office with individuals spending considerable time working in a seated position to accomplish their daily work tasks. Considering that computer work is often associated with occupational tasks, the U.S. Department of Labor, Bureau of Labor Statistics conducted a special supplemental survey on computer and internet use at work in 2003. The survey indicated that as much as 55% of the total civilian labor work force used a computer as part of their job (DOL, 2005), highlighting the top reasons for computer use in the work place which included internet or e-mail use, word processing and spreadsheet or database work. At the time of the survey's publication, this equated to almost 77 million individuals who used a computer in the course of their employment. The study also reported that use of computers for managers and professionals (80%) as well as those in sales positions (67%) were higher than the national average (DOL, 2005).

1.7 Adjustable Workstation Use in Office Settings

In recent years the introduction of adjustable workstations, has given employees an alternative way to work and potentially reduce the overall amount of occupational sedentary time. Karakolis et al. described a sit-stand workstation as one that “allows the user to perform the same tasks from either a seated or standing position” (Karakolis and Callaghan, 2016). One review even went so far as to say that the majority of the current literature on implementation of such systems leads to less reported worker discomfort without a significant reduction in performance (Chau et al., 2016; Karakolis et al., 2014). A study of Finnish university office employees reported that access to sit-stand workstations reduced sitting time significantly (Gao et al., 2016). Researchers also reported that 75% of the participants were satisfied with the workstation and 83.3% felt that the unit had good adjustability. Unfortunately, the study noted that they relied heavily on questionnaires to retrieve the information and lacked any quantitative measures. A recent study of Australian office workers by Mazzotta et al. identified that 65% of participants work hours were spent at their workstation (2018). The study further identified that 94% of their participants were comfortable at their sit-stand workstation identifying reduction in musculoskeletal pain, improved posture as well as improved health as advantages of sit-stand use (Mazzotta et al., 2018). The study utilized several measurement tools including a questionnaire for both participant demographics and workstation use with researchers using an activePAL3 to obtain quantitative data for number of changes per day, total desk time, percent desk time spent sitting, percent desk time spent standing and daily sitting/standing time among others (Mazzotta et al., 2018). One noted drawback of this study is the number of participants. Only 18 participants met the researcher’s eligibility criteria for inclusion in the 7-day study making it difficult to extrapolate the findings to a larger population. A Spanish study identified a population of 557 participants who were office workers at one of four universities to evaluate association of sitting time and physical activity with productivity and mental well-being. While the study utilized the Work Limitations Questionnaire (WLQ) to assess performance and the Warwick-Edinburg Mental wellbeing scale (WEMWBS) to assess mental well-being and happiness, two scales with high validity and reliability, the data are still self-reported data subject to bias (Puig-Ribera et al., 2015). Researchers also noted that the findings were specific to the population of interest, which included a highly educated population of middle age individuals who showed an interest in a workplace physical activity program.

Thorp and colleagues conducted a laboratory-controlled study of simulated office work to identify potential association between work satisfaction, productivity, fatigue and discomfort and workstation type for participants in both a seated and a sit-stand setting (utilizing an electronic height adjustable desk) (2014). The team of researchers utilized the activPAL3™ to ensure participants adhered to the experimental protocol and utilized several questionnaires including the Individual Strength Questionnaire (CIS20-R), the Multidimensional Assessment of Fatigue (MAF) and a modified Nordic questionnaire and the Health and Work Questionnaire (HWQ) to measure productivity, fatigue and discomfort. The team noted that the limitation of study participants to overweight and obese office workers restricts the ability to generalize the findings to a larger population. Additionally, they indicated that since all of the outcomes were self-assessed there is the possibility of bias (Thorp et al., 2014).

A study of call-center employees reported that individuals with a stand-capable workstation sat approximately 73% of the time compared to those with traditional seated workstations who spent 91% of their time seated (Pickens, et al, 2016). A 6-month study of the same population showed that workers with stand capable desks were 46% more productive than their seated counterparts (Garrett et al., 2016). It has been noted by several research teams that future studies need to evaluate economic (i.e. performance and injury/illness costs), mental and health related outcomes for office workers with validated and objective measures when possible (Healy et al, 2012; Ojo et al. 2018; Chau et al, 2010; Karol and Robertson, 2015; van Uffelen et al., 2010). Also, of interest is the need to review long-term sustainability and impact of sit-stand workstations (Graves et al. 2015; Finch et al. 2017; Agarwal et al., 2018).

1.8 Barriers to Continued Use of Alternative Workstations

Employees are often excited to receive a sit-stand workstation but long-term utilization often drops off over time (Karakolis et al., 2016). While many employers are happy to provide these types of accommodations for their employees, long-term utilization and employee compliance have become an issue. Wilks and colleagues identified that the percentage of stable sit-stand users, which includes those that use it at least once per day, is anywhere from 13-21% depending on the age group (2006). This study also identified that one of the main reasons for lack of continued sit-stand use was that the portion of the work surface which was adjustable was too small for the user (2006). A study by Dutta et al. identified a need for work-surface space, making certain sit-stand workstation types less preferred by users than those that offered space to conduct paperwork in addition to computer work (2015). Even more recently an observational study on sit-stand workstations reported that participants identified manual handling risk associated with lifting and lowering the unit and the lack of usable work-surface as limitations of sit-stand workstation use (Mazzotta et al., 2018).

One published review on workplace interventions cited poor study design and lack of long-term follow-up as issues effecting the true determination of the sit-stand workstations effectiveness (Shrestha et al., 2016). An Australian study of office workers that looked at potential barriers to reduced sitting strategies found that while there were feasible and acceptable options available; work demands and organizational norms may still act as barriers (Hadgraft et al., 2017). A study on motivators and barriers to reduction in sedentary behaviors identified poorly adapted environments, fatigue and existing health issues as barriers (Greenwood-Hickman et al., 2016). They further identified personal barriers, which included the lack of incentives and ingrained sitting habits while social barriers included poor social support for reduced sedentary behavior. As part of the Stand @ Work study based on office workers in Australia, Chau et al. reviewed the workers perspectives of sit-stand workstations. Researchers identified that when participants described issues with standing at work they fell into one of two areas: 1) Disruption of others due to the office layout; or 2) Issues with the workstation design (2014). When participants were asked how willing they were to continue utilizing the sit-stand unit many identified a willingness to continue with caveats (Chau et al., 2014). Another study identified foot and knee pain, lack of motivation, small office space and psychological discomfort as barriers to use which could also apply to sit-stand workstations (Cifuentes et al., 2015). While some researchers have shown that use of sit-stand workstations encourages office workers to alter their working positions ultimately leading to less sitting time as well as reduced musculoskeletal discomfort and increased workability (Gao et. al, 2016), the long-term results are mixed.

1.9 Utilization of Stand-Biased Workstation in the Literature

Unfortunately, many researchers lump all alternative workstations into one group, which makes comparing them difficult. A call center study by Pickens et al. defined stand-capable workstations as an all-inclusive term that included all workstations that allowed computer users to work in either a standing or seated position (2016). Based on this definition, stand-capable workstations include counterbalanced workstations, electronic height adjustable workstations, manual height adjustable workstations; desk mounted units as well as stand-biased workstations. This broad category of workstation types is centered on assisting the worker in varying their working posture and reducing sedentary time but the manner in which users interact and ultimately accomplish this is considerably different. For example, the stand-biased workstation has been described as a workstation where the work surface is set to the users standing work height rather than the traditional seated workstation height of 76cm (Pickens et al., 2016). This allows the user to work at the correct standing height every time they choose to work in the standing position and eliminates the need to verify the appropriate workstation height during each posture change. Paired with a drafting chair or stool, workers are also capable of working in a seated position at the workstation. As a result, benefits and barriers to an adjustable desktop unit and a stand-biased workstation are unlikely to be identical due to the inherent nature of the workstation design.

Based on these intrinsic differences in workstation design it is imperative that researchers be very specific about the type of stand-capable workstation that is being investigated. Recently a natural experiment was conducted to look at real world change in sitting time, cardio-metabolic factors as well as productivity but the researchers used height adjustable workstations as opposed to stand-biased workstations and did not use a quantitative measure for productivity (Zhu et al., 2018). Several studies have specifically investigated the benefits of stand-biased workstations in schools with much success, focusing on students in elementary school all the way through high school. Benden and colleagues have focused on stand-biased desks in elementary school populations with a focus on energy expenditure, BMI and discomfort. Data from these studies indicated that the standing population had increased energy expenditure (Benden et al., 2011; Benden et al., 2012) when compared to the students using traditional desks and that discomfort was lower in the group using standing desks (Benden et al., 2013). A 2015 study of elementary school children (2nd-4th grade) found that students in the treatment group, who used stand-biased workstations in the classroom, exhibited increased academic engagement (Dornhecker et al., 2015). Another study reviewed the neurocognitive effects of stand-biased desks in 9th grade students citing an associated improvement in executive functioning and working memory for those students with stand-biased workstations (Mehta et al., 2015). While these studies give us a peek at the possible benefits of stand-biased workstation use in adult populations there are inherent differences in the environment (classroom vs office) as well as the population (child vs adult) of interest.

One pilot study on call center employees utilized a stand-biased comparator group in addition to a sit-stand group following participants for 6 months. The only significant finding noted from the pilot was a reduction in self-reported seated time for those individuals in the stand-biased group when the researchers controlled for sex, race, BMI and time (Pickens et al., 2016). While the authors noted a high dropout rate which may have altered the results of the study, there needs to be additional work in this area as the research on stand-biased workstations specifically in adult populations is limited. Additionally, there is little research published on what factors might encourage office employees to continue their utilization of stand-biased workstations long term and increase their movement throughout the work day, thereby reducing sitting time and health risks in a more sustainable work pattern.

1.10 Purpose of current study

The primary purpose of the current study is to identify differences in computer utilization and bodily discomfort for workers utilizing stand capable workstations compared to those using traditional workstations. The secondary purpose is to determine if there are differences in the various types of stand capable workstations, specifically desktop sit-stand units and stand-biased workstations, with regard to activity levels, sitting time and computer utilization.

This dissertation includes three unique studies. The first study was conducted at a large, multi-disciplinary Northern California company to assess the company's computer utilization and musculoskeletal discomfort. The second study utilized a questionnaire to gather demographic data and collect musculoskeletal discomfort and workstation utilization habits of administrative workers in an academic setting. The study also used accelerometers to measure activity levels and a computer data logging software to collect computer utilization metrics. The final study was a six-year follow-up of stand-biased workstation users to determine current utilization patterns and perceptions of long-term use.

2. RSI-OES SIT-STAND DATA ANALYSIS

2.1 Overview

Many corporations are collecting information and providing workplace wellness programs that are part of a total worker health initiative. According to NIOSH, Total Worker Health® (TWH) is "defined as policies, programs and practices that integrate protection form work-related safety and health hazards with promotion of injury and illness prevention efforts to advance worker well-being" (NIOSH, Dec 2018). Integration of employee health into corporate wellness programs is certainly not a new concept. NIOSH commissioned several papers to be included in the 2004 NIOSH Steps to a Healthier Workforce Conference and they list a driving article published in 1987 about the evolution of workplace health promotion. More recently the organization has focused on "Productive Aging and Work" to provide employers the needed resources to create a productive and safe workplace for all employees during all phases of their career. While not limited to office workers, this initiative can certainly be applied to office and administrative jobs that present unique risk factors due to the sedentary nature of the job.

Numerous researchers have highlighted health risks associated with increased sedentary activity (Katzmarzyk et al., 2009; Biswas et al., 2015; Dutta et al., 2015; Neuhaus et al., 2014), and several others have identified that musculoskeletal pain is associated with sedentary activity and occupational seated time (Healey et al, 2012; Foley et al., 2016; Wilks et al., 2016). Healey and colleagues suggested that the prevalence of musculoskeletal symptoms could be as high as 50% among individuals using computers. While this increase in musculoskeletal discomfort and pain is not solely attributable to workplace activities, some researchers have suggested that poor workplace design and environmental conditions could play a very large role (Marshall & Gyi, 2010). In many situations this includes the increased amount of time that office workers spend in seated positions. Several studies have evaluated the amount of sedentary time that office workers experience and recently researchers have investigated interventions that have the potential to reduce sedentary time and health related risks.

Use of sit-to-stand workstations have been used in many studies as part of workplace interventions in the hopes of modifying health risks. These workstation accommodations allow employees to vary their work postures and have the potential to reduce occupational sedentary time. The results often vary depending on the study parameters, which include the study location as well as the type of variables collected (objective vs. subjective). Like many other studies, the current study collectively groups all stand capable workstations together and compares them to those who use a traditional seated workstation. While the researchers were not able to identify details related to participant's activity and occupational sedentary time, they were able to evaluate associated discomfort and computer use for a large percentage of the organization's office population.

2.2 Methods

2.2.1. Setting

The company that organized data collection is based out of Northern California and employs approximately 24,000 individuals. Primarily an energy company, employees are engaged in a variety of job types including many that utilize a computer as part of their day-to-day activities. Individuals who participated in data collection identified the type of work that they participate in from the following options: Moderate levels of both keyboard and mouse work, Precision mouse work (Graphic Design, Computer-aided Design (CAD) etc.), or Keyboard intensive work (data entry, spreadsheet work etc.). Specific occupations were not collected, but the organization employs, Engineers, Analysts, Business Specialists, IT Experts, Call Routing Analysts, Customer Service Specialists, Human Resource Employee Relations, Accounting Managers, Safety Specialists, Utility Workers, Electricians, Mechanics, Scientists and Metallurgists among many other job titles.

Employees participated in the Remedy Interactive Workplace Injury Prevention Program sponsored by the company between August 2003 and November 2015. Employees were provided an introduction to the program and guided the OES software with a personalized assessment of their body positions and workplace setup. Based on the answers they provided, a personalized email was sent to the individual with recommendations about how to minimize injury risk. Questions included items on general bodily discomfort as well as discomfort in the neck and upper back, the low back, the elbow and forearm, the shoulders, the hands and wrists and eye discomfort in the form of headaches (Figure 2.1). The assessment asked how many hours the employee worked at a computer and how often they conducted non-computer work activities. Following these questions, the assessment asked the employee to select work postures from a few photographic examples that represented their workstation set-up. Included in the assessment was a question on whether the employees used a sit-to-stand desk. At the conclusion of the workstation assessment, the individual was guided through a presentation on basic anatomy, body positions and workstation set-up. The answers to the personalized assessment for each individual were collected in database over the 12-year period of time and provided to Texas

A&M University for analysis in a de-identified format. The company utilized Enviance's Remedy Data Logging Software, RSI Guard™, to collect 1 year of computer utilization measures for each individual in a separate database. Measures were reported as averages for 1 month and 1 year. Both datasets included an anonymous ID that allowed the two datasets to be

Figure 2.1 Remedy Interactive Injury Prevention Program Slides, Reprinted from Remedy Interactive Office Ergonomic Solution software, 2019

connected. Remedy is one of three programs, including Wellnomics and Sit Stand Coach that the research team has utilized to collect computer and workstation utilization measures at both electric and manual sit-stand workstations.

2.2.2 Eligibility

All participants that responded to the sit-to-stand question at days 28 and 364 were considered for inclusion in the study. Researchers limited the participants to those that completed the penultimate questionnaire between 2012 and 2014. In order to minimize any bias introduced by individuals changing their workstation during the study period, only those that maintained their workstation type at both time points were included in the analysis. Individuals that did not have objective computer utilization measures at either 1 month or 1-year time points were excluded. As no demographic data were included in either of these databases, such information could not be used as inclusion or exclusion criteria.

2.2.3 Instrumentation and variables

The questionnaire collected subjective data from the participants on factors including lighting, hours at the computer, breaks, musculoskeletal discomfort, use of correctional lenses and glare. It also asked individuals if they had a secondary home office, if they shared a workstation, if they had adequate space for their keyboard and mouse and how much stress they experienced. Due to the subjective nature of the data collection, the majority of these variables were excluded. The only variables that were included from the subjective portion were the sit-stand status and discomfort. The question on “sit-to-stand” desk (Figure 2.2) was used to

Figure 2.2 Remedy Interactive Sit-to-stand question slide, Reprinted from Remedy Interactive Office Ergonomic Solution software, 2019

categorize participants into the appropriate cohort and frequency of discomfort was reviewed.

Based on the sit-stand status, computer use measurements collected from the RSIGuard® data logging software were compared between the two cohorts for the 1-month average as well as the average for a full year. Variables compared included mouse hours, keyboard hours, total computer hours, words per day, keypresses, typos, total mouse clicks, mouse left clicks, mouse scroll, mouse travel and a calculated typo rate per 500 words typed (Table 2.1). Graphical representations of the variables can be found in Appendix E.

Table 2.1
RSI Guard^{TM} Variables collected

Variable	**Description**
Workstation Type	Traditional or Sit-stand
Employee ID	Unique Identification number assigned to each participant
Hours M*	Mouse usage hours
Hours K *	Keyboard usage hours
Total Hours*	Total hours of computer use per day
Keypresses*	Number of keypresses
Typos*	The number of errors that the user made that were corrected.
Dbl mouse clicks	The number of times the user double clicks the mouse
Left clicks*	The number of times a user clicks the left mouse button.
Middle Clicks	The number of times a user clicks the middle mouse button.
Right Clicks	The number of times a user clicks the right mouse button.
Mouse Clicks*	Total number of mouse clicks
Mouse Scroll	Distance the cursor moves on the screen in meters.
Mouse travel *	Distance the cursor moves on the screen in meters.
Words per day *	Number of words that were typed per day (alpha- numeric combinations followed by a space or return).
Error Rate ⸸	Number of errors per 500 words typed

* Primary Variables ⸸ Calculated Variables

The Office Ergonomic Solution (OES) Software web application completed by participants as part of the Remedy Interactive Injury Prevention Program included several subjective questions including discomfort level. Individuals were asked how often they experienced “work related physical discomfort” with discomfort being defined as “any unpleasant feeling such as soreness, muscle fatigue or eye strain”. The levels of discomfort included; never, infrequently (“less than one day per week”), frequently/periodically (“one to three days per week or flare-ups surrounded by periods of little/no discomfort”) and constant (“four or more days per week”) as seen in the screen capture from the survey in Figure 2.3.

How often do you experience work-related physical discomfort? (Discomfort is defined as any unpleasant feeling such as soreness, muscle fatigue or eye strain.)

- ○ Never
- ○ Infrequently (less than one day per week)
- ○ Frequently / Periodically (one to three days per week OR flare-ups surrounded by periods of little/no discomfort)
- ○ Constantly (four or more days per week)

Figure 2.3 OES Discomfort question, Reprinted from Remedy Interactive Office Ergonomic Solution software, 2019

2.2.4 Study Protocol

This study was a retrospective data analysis of individuals conducting computer work at a large California company. Data were collected in two databases; one for subjective measures including frequency of discomfort and self-selection of sit-to-stand workstation status and another database with objective measures of computer utilization. For the purpose of the study, a stand capable workstation referred to any workstation that allowed the user to work in either a seated or standing position and is the independent variable of interest. Objective data were collected with the Remedy (now Enviance) data logging software package (RSI Guard™) for a variety of variables including computer hours, keypresses, mouse click, typos, mouse distance keyboard errors and words per day (Table 2.1). Data were collected daily and reported as averages at three time points. Participants were also asked to complete a questionnaire prior to and at the end of data collection. This survey included musculoskeletal discomfort as well as their workstation status. Based on the workstation status, a new field to indicate the participant's workstation change over the course of the entire study was generated.

This is what researchers used to determine the participant's cohort. Due to the lack of additional time points, it was assumed that if the participant maintained their selection at both time points that they did not shift back-and-forth during the study period (one year). In total, four unique cohorts were identified: 1) a stand capable; 2) new adopter; 3) revert to seated; and 4) a traditional cohort. Both the stand capable and the traditional cohorts maintained their sit-to-stand workstation selection at a month and one year. The remaining two cohorts include individuals that changed their workstation type during the collection period. Unfortunately, since we were not sure when or why the individuals made the change, it was difficult to determine that all members of these two cohorts were truly similar. As a result, these participants in the *new adopter (n=1695)* and *revert to seated (n=475)* cohorts were excluded for the purpose of this evaluation.

The full RSI Guard™ data set provided by the company consisted of 41,286 records. This included a record for each participant at three time points: Day 28, 91 and 364. The subjective OES dataset included two records for each participant, one that coincided with one month (day 28) and one full year (day 364). As the research team was unable to categorize the sit-stand status at day 91, these records were excluded. Researchers used the anonymous ID and time period to sort the two databases, provided by the company, to match the objective and subjective measures in a Microsoft® Excel database. Prior to data analyses, researchers asked for a review of the study parameters by the Texas A&M University IRB, which was expedited due to the de-identified nature of the data. Once approved, IRB provided the following number for the study: TAMU 2018-0874.

2.2.5 Analysis

Data were analyzed with SAS 9.4® statistical software (Cary, NC). Descriptive statistics were completed for variables, to include mean, standard deviation and frequency, stratified by workstation type. Pearson Chi Square tests were used for categorical variables including discomfort and student's t-tests was be used to compare traditional and sit-stand cohorts with respect to computer usability measures.

2.3 Results

A total of 13,762 individuals participated in at least one part of the data collection provided by the host organization between 2003 and 2015. Of these, 11,438 maintained their workstation type over the course of the collection period. Upon detailed investigation of the data, there were several participants that completed the questionnaire but the data logging software did not collect any computer utilization measures (n=1293). While the data collection period covered 12 years, the majority of data was collected between 2012 and 2015. As a result, the dataset was limited to those participants who completed the first questionnaire between 2012 and 2014, allowing one year for completion of the data collection. The final dataset used for analyses included measures for 10,145 participants. Researchers compared the stand-capable cohort (n=3,404), which included those individuals who answered yes to the question on sit-stand workstations included in the QES and the traditional cohort (n=6,741), which included those that indicated they did not have a sit-stand workstation at both time points.

While reported discomfort for the sit-stand and traditional cohorts were statistically different (Table 2.2) the difference was no more than 5.6% at a month and no more than 2.3% over a year for any level of discomfort. The fact that a greater percentage of the sit-stand group reported never having discomfort at a year compared to 1 month may indicate that the group as a whole had established a workable pattern of use that eliminated work-related discomfort. Additionally, a smaller percentage of sit-stand users reported infrequent or frequent discomfort at

Table 2.2 Discomfort for participants that completed a subjective survey between 2012-2014

	Traditional (n= 6741)	%	Sit-stand (n=3404)	%
Day 28				
Discomfort Level				
Never	2407	35.7%	1024	30.1%
Infrequent	3556	52.8%	1813	53.3%
Frequent	722	10.7%	486	14.3%
Constant	56	0.8%	80	2.4%
No Answer	0	0.0%	1	0.0%
Day 364				
Discomfort Level				
Never	2314	34.3%	1105	32.5%
Infrequent	3595	53.3%	1762	51.8%
Frequent	725	10.8%	447	13.1%
Constant	107	1.6%	90	2.6%
No Answer	0		0	
Change over the collection period				
Never	-90	-1.4%	81	2.4%
Infrequent	36	0.5%	-50	-1.4%
Frequent	3	0.1%	-39	-1.2%
Constant	51	0.8%	9	0.2%
No Answer	0	0.0%	-1	-0.0%

a year as compared to the responses of the same cohort at a month. The percentage of sit-stand users that reported infrequent discomfort dropped 1.5% and frequent discomfort dropped 1.15% over the one-year period of time. The percentage of traditional workstation users that reported infrequent discomfort increased marginally over the year and the percentage of those users that reported no discomfort dropped 1.38% over the year. The percentage of traditional users that reported frequent discomfort held steady but the percent of traditional users that indicated a constant level of discomfort increased from a month to a year as did the percentage of sit-stand users. While the percentages of individuals reporting discomfort are similar, there seems to be more individuals in the sit-stand cohort reporting no discomfort and fewer reporting infrequent and frequent over the yearlong collection period than those reporting in the same categories at a month. Interestingly the reverse is true for the traditional cohort.

The data set was also divided by year to review any differences that might have occurred as a result of the time period that the individual began the program (Table 2.3). This was conducted to ensure that any annual effects were evaluated. The percent of individuals in each category, while not exact, are similar for each year. The majority of participants began the survey in 2014. For this time period more individuals reported never having discomfort at a year than at a month for both cohorts. While those individuals reporting constant discomfort remained the same for the traditional cohort (56) over the course of the study, the sit-stand cohort had three fewer individuals report constant discomfort at a year than at a month.

Table 2.3 Discomfort for participants that completed a subjective survey between 2012-14 (by 1-year time periods)

	2014			2013			2012		
	Traditional (n= 3924)	Sit-stand (n=2931)	p-value	Traditional (n= 1578)	Sit-stand (n=338)	p-value	Traditional (n= 1239)	Sit-stand (n=135)	p-value
Day 28									
Discomfort Level			<0.001*			0.015*			0.065
Never	1360 (34.7%)	887 (30.3%)		611 (38.7%)	103 (30.5%)		436 (35.2%)	34 (25.2%)	
Infrequent	2078 (52.9%)	1537 (52.4%)		803 (50.9%)	192 (56.8%)		675 (54.5%)	84 (62.2%)	
Frequent	430 (10.9%)	426 (14.5%)		164 (10.4%)	43 (12.7%)		128 (10.3%)	17 (12.6%)	
Constant	56 (1.4%)	80 (2.7%)		0 (0%)	0 (0%)		0 (0%)	0 (0%)	
No Answer	0 (0%)	1 (0.1%)		0 (0%)	0 (0%)		0 (0%)	0 (0%)	
Day 364									
Discomfort Level			<0.001*			0.341			0.025*
Never	1395 (35.5%)	974 (33.2%)		521 (33.0%)	102 (30.2%)		398 (32.1%)	29 (21.5%)	
Infrequent	2099 (53.5%)	1510 (51.5%)		823 (52.2%)	173 (51.2%)		673(54.3%)	79 (58.5%)	
Frequent	374 (9.5%)	370 (12.6%)		204 (12.9%)	55 (16.3%)		147 (11.9%)	22 (16.3%)	
Constant	56 (1.4%)	77 (2.6%)		30 (1.9%)	8 (2.4%)		21 (1.7%)	5 (3.7%)	
No Answer	0 (0%)	0 (0%)		0 (0%)	0 (0%)		0 (0%)	0 (0%)	

+, * indicate that samples have statistically different means at alpha = 0.05

The objective data collected from the RSIGuard data logging program between 2012 and 2014 were evaluated to determine computer utilization (Table 2.4). The only measure that was not statistically significant at either time point for the three-year period was mouse scroll. The remaining 10 measures that were compared all showed statistical differences between the

Table 2.4 RSI Continuous variables for participants that completed a subjective survey between 2012-14

	Traditional (n= 6,741)	SD	Sit-stand (n=3,404)	SD	p-value
Day 28 (avg)					
Mouse hours	2.5900	1.1403	3.2549	1.2151	<0.001*
Keyboard hours	0.9506	0.5803	1.1471	0.5901	<0.001*
Total computer hours	2.9341	1.2453	3.5961	1.2563	<0.001*
Words per day	549.4	436.2	634.2	425.8	<0.001*
Keypresses	4993.9	3595.6	5857.4	3518.0	<0.001*
Typos	162.0	135.8	199.1	139.4	<0.001*
Mouse clicks (total)	2159.7	1308.4	2837.7	1464.9	<0.001*
Mouse clicks (left)	2100.6	1248.6	2750.9	1405.4	<0.001*
Mouse scroll	2308.7	2891.0	2344.9	2698.4	0.534
Mouse travel	97954.4	64518.6	141733.0	88126.9	<0.001*
Typo rate per 500 words	161.8	103.1	172.3	96.9	<0.001*
Day 364 (avg)					
Mouse hours	2.5954	1.0868	3.3162	1.1553	<0.001*
Keyboard hours	0.9782	0.5545	1.1851	0.5505	<0.001*
Total computer hours	2.9517	1.1814	3.6668	1.1780	<0.001*
Words per day	563.1	421.8	643.9	400.0	<0.001*
Keypresses	5141.1	3482.3	6005.5	3320.3	<0.001*
Typos	167.1	132.8	203.1	132.6	<0.001*
Mouse clicks (total)	2179.4	1270.2	2868.6	1332.9	<0.001*
Mouse clicks (left)	2115.6	1212.6	2777.9	1276.9	<0.001*
Mouse scroll	2256.5	2581.3	2342.4	2324.7	0.090
Mouse travel	96677.7	59465.0	139182.0	77674.4	<0.001*
Typo rate per 500 words	159.3	79.6	168.5	69.6	<0.001*

* indicates that samples have statistically different means at alpha = 0.05

cohorts. Average total active computer hours for the sit-stand cohort was 3.59 hours as compared to the traditional cohort mean of 2.93 for the first month of data collection. The student's t-test yielded a p value of <0.001 which indicated a high likelihood that the two groups are statistically different, but more important is the practical difference of 0.66 hours between the groups. This translates to approximately 39.6 minutes more of active computer time for sit-stand users compared to traditional users. After a year of data collection, the measures are similar to those that were found after a month with the sit-stand cohort total computer hour mean of 3.66 hours and the traditional mean of 2.95 hours. When compared with the students t the p-value was <0.001 with sit-stand users having 43.2 more minutes of active computer use per day.

Data collection also included mouse and keyboard hours both of which were significant at both time periods. The average daily time mousing for sit-stand users at one month was 3.25 hours compared to 2.59 hours for traditional users. At a year the average daily mousing time increased slightly for both cohorts. Sit-stand users had a mean of 3.32 hours and traditional users had a mean of 2.59 hours. This equated to an increase of active mousing time of 43.2 minutes per day for sit-stand users compared to traditional users over the course of the entire year. When compared to the total computer time, mousing accounts for the majority of all computer activities for both groups and both time points.   This shows that a consistent portion of activities conducted by participants that involved the mouse was similar for both groups over the course of the entire collection period. Based on the data, active keyboard time per day is approximately 1 hour of an individual's computing time. Sit-stand users had on average 1.14 hours of keyboarding per day as compared to traditional users 0.95 hours. While statistically significant the difference equates to 11.4 minutes per day at 1 month and 12.6 minutes per day over the whole year.

While time spent actively using the computer is a critical metric, it is important to also assess the average number of words per day, keypresses, typos or errors and mouse clicks. Sit-stand users had higher mean words per day at both time points when compared to traditional users. Similarly, sit-stand users had higher keypresses per day than traditional users at both time points, with 863.5 more keypresses at 1 month and 864.4 more keypresses at a year. With more keypresses and more words typed per day it's conceivable that there would also be more typos or errors as well. The sit-stand group had a mean of 199.1 errors compared to 162.0 errors for the traditional group, for a difference of 37.1 errors or typos per day after 1 month. Over the course of the entire collection period the sit-stand group had 203.1 typos compared to 167.1 for the traditional. The difference over the course of a year was 36 more errors per day for the sit-stand group when compared to traditional users. On the surface there is nothing striking about having more errors especially if the same group had more words typed per day and more computing time so a typo rate per 500 words was generated to provide a better comparison of production between the two cohorts. Based on the data collected it appears that sit-stand users may be prone to more mistakes than their traditional counterparts. The rate for traditional users per 500 words was 161.8 compared to 172.3 for sit-stand users after 1 month. While the traditional rate for the entire collection period dropped to 159.3 for traditional users the rate for sit-stand users over the year dropped to 168.5.

Similar to the discomfort data, the computer utilization was broken down by year to review any differences that might have occurred due to the time at which the participant began the survey. The data collected in 2014 and 2013 are very similar to the overall data (Table 2.5). The only variable that was not significant in 2014 was the mouse scroll which is consistent with the overall data set. In 2013 the typo rate was also insignificant between the two cohorts at both time periods. The difference in the data occurs in 2012 where words per day, keypresses, typos, mouse scroll and typo rate were not significantly different between the two cohorts at both time points.

Table 2.5 RSI Continuous variables for participants that completed a subjective survey between 2012-14 (by 1-year time periods)

	2014					2013					2012				
	Traditional (n= 3924)	SD	Sit-stand (n=2931)	SD	p-value	Traditional (n= 1578)	SD	Sit-stand (n=338)	SD	p-value	Traditional (n= 1239)	SD	Sit-stand (n=135)	SD	p-value
Day 28															
Mouse hours	2.678	1.132	3.306	1.173	<0.001	2.493	1.135	2.844	1.294	<0.001	2.434	1.145	3.155	1.650	<0.001
Keyboard hours	0.968	0.570	1.152	0.5615	<0.001	0.933	0.594	1.105	0.735	<0.001	0.9157	0.5930	1.135	0.765	0.002
Total computer hours	3.016	1.224	3.642	1.203	<0.001	2.843	1.262	3.227	1.421	<0.001	2.789	1.268	3.514	1.713	<0.001
Words per day	542.1	424.7	634.2	416.6	<0.001	555.3	438.5	654.7	504.3	<0.001	564.9	467.9	582.3	407.3	0.642
Keypresses	4939.9	3470.4	5847.5	3398.7	<0.001	5033.5	3650.9	6043.5	4388.5	<0.001	5114.6	3901.0	5605.5	3625.1	0.140
Typos	160.3	131.9	199.9	138.1	<0.001	165.5	141.1	201.1	151.9	<0.001	162.9	141.0	176.6	134.0	0.263
Mouse clicks (total)	2287.4	1351.8	2903.3	1454.1	<0.001	2021.6	1186.6	2408.2	1407.1	<0.001	1931.1	1233.6	2488.9	1614.0	0.001
Mouse clicks (left)	2216.8	1284.4	2812.4	1392.9	<0.001	1973.6	1153.9	2343.9	1363.0	<0.001	1894.2	1207.3	2434.6	1569.8	<0.001
Mouse scroll	2473.4	3106.4	2365.2	2698.5	0.124	2161.6	2578.5	2292.2	2598.2	0.402	1974.2	2495.7	2034.5	2934.5	0.818
Mouse travel	103734	66465	145522	84777	<0.001	92748	62783	115813	75019	<0.001	86281	58017	124351	153654	0.005
Typo rate per 500 words	161.8	100.8	174.2	100.3	<0.001	162.6	95.1	166.7	69.8	0.366	158.7	115.3	159.0	63.8	0.954
Day 364															
Mouse hours	2.6927	1.076	3.375	1..125	<0.001	2.494	1.100	2.862	1.184	<0.001	2.416	1.069	3.166	1.446	<0.001
Keyboard hours	0.9969	0.542	1.1937	0.5387	<0.001	0.9618	0.572	1.1316	0.614	<0.001	0.9395	0.5674	1.134	0.623	0.001
Total computer hours	3.042	1.155	3.721	1.144	<0.001	2.856	1.216	3.256	1.252	<0.001	2.785	1.192	3.518	1.466	<0.001
Words per day	553.8	402.2	643.5	395.6	<0.001	570.1	426.7	669.9	445.7	<0.001	583.9	472.6	588.4	370.3	0.897
Keypresses	5069.6	3300.3	6004.6	3266.1	<0.001	5190.1	3551.8	6156.7	3789.5	<0.001	5305.1	3922.9	5646.7	3229.2	0.255
Typos	164.8	127.5	203.6	132.3	<0.001	171.5	164.7	206.9	192.2	<0.001	168.9	141.4	181.7	124.8	0.269
Mouse clicks (total)	2311.1	1312.2	2938.2	1323.0	<0.001	2043.1	1169.5	242.1	1283.6	<0.001	1936.2	1203.2	2478.9	1390.6	0.01
Mouse clicks (left)	2235.0	1239.2	2843.2	1265.5	<0.001	1992.1	1137.5	2353.1	1239.6	<0.001	1894.9	1173.6	2423.6	1360.3	<0.001
Mouse scroll	2453.7	2798.1	2359.7	2320.5	0.129	2078.7	2296.3	2260.8	2259.3	0.181	1858.1	2103.8	2171.6	2571.4	0.173
Mouse travel	102559	60865	143124	77095	<0.001	91851	59504	113788	66595	<0.001	84197	52027	117176	98231	<0.001
Typo rate per 500 words	161.6	81.6	169.5	70.1	<0.001	158.8	73.3	163.6	65.2	0.227	154.5	79.8	160.5	66.4	0.333

2.4 Discussion

This study utilized data collected form a California corporation as part of a company workplace wellness initiative. It included over 10,000 participants, which increased the power of the study. However, this study did not include any demographics, which made the information hard to relate to other populations of interest. The research team worked diligently to obtain this information, but was unable to do so at the time of this publication. It will be important for future researchers to ensure that some type of demographics are included in the data use agreement. While the data set included a multitude of computer utilization variables, it did not include any measures of occupational workstation utilization. Future studies need to be able to quantify that participants not only have access to a sit-stand but how often they use it to establish a dose response relationship.

Results from the OES-RSI data analysis showed that all but one variable reviewed during the entire study period was statistically significant. The only measure that was not significantly different was mouse scroll. This measure is defined by Enviance as the “number of pointer scroll clicks” and was similar for both the sit-stand and traditional users at both time points. Based on this definition there is a possibility that those individuals that utilize laptops and computers that use a trackpad as well as some specialty “mice” as opposed to a traditional mouse may not register pointer scroll clicks. This may severely limit the ability to utilize this measurement to compare mouse utilization between the two groups.

The most notable finding focused on active minutes utilizing the computer. Overall, active computing time of sit-stand users was almost 45 minutes more per day than their traditional counterparts. Both mousing and keyboarding showed the same trends with those having a sit-stand workstation out performing their traditional counterparts. Another result of note was that between 87-90% of all active computing time was registered as active mousing as opposed to typing. This could be a result of the types of occupations that are represented in each cohort or it could be a modification of the type of work (mousing vs typing) being asked of certain occupations. Ultimately, based on the data collected, individuals who have access to sit-stand workstations have increased computer usability measures when compared to those who utilize a traditional workstation. To quantify the difference in computer utilization, a cost savings estimate was calculated to indicate the additional productivity that could be realized by providing those individuals who used a traditional workstation with a sit-to stand workstation. Based on OPM standards for work days per year and the increase in time spent actively utilizing the computer for sit-stand workstations users determined from the current data, it is estimated that each sit-stand user, on average, works 171.5 more active hours per year than their traditional seated counterparts without any additional salary costs. If you consider the average U.S. hourly rate of $25 per hour (BLS, 2019) the potential cost savings per year is $4,287.50. This would easily pay for the cost of an electric height adjustable workstation (at approximately $2200) in 6.1 months.

During the first month of data collection, the percentage of participants who indicated that they never experienced discomfort was approximately 5% higher in the traditional group compared to the sit-stand group. Over the course of a year this difference dropped to under 2%. Additionally, the difference in all four categories did not differ by more than 3% for any one group. Thus, while stratification of discomfort between the two time periods is significant the practical difference may be negligible by industry standards. This difference in discomfort could be due to individuals who were experiencing discomfort prior to the 1-year collection period.

Some of these individuals may have requested a change from a traditional workstation to a sit-stand workstation as part of a medical accommodation. In this situation, individuals might have been experiencing increased discomfort due to a health issue and the discomfort may not have resolved until after the 1-month collection period was concluded. The differences in reported discomfort could also be due to confusion about each category's definition and potential issue with recall for a 1-year period of time. Since the question defined discomfort categories by number of days per week experiencing symptoms, a weekly discomfort might have been more appropriate. This way participants should have little discomfort classifying their discomfort and the company can address any situations that result in frequent or constant discomfort for more than three consecutive periods.

2.4.1 Limitations

Data provided for analysis did not include any demographics, which made it impossible to characterize the sample comprising the study group. As a result, it is difficult to determine how the sample compared to the entire company population or how it compared to a sample of the California general population. This limits the ability to generalize the data to a certain subset of the population. It is unknown if the traditional group is older or younger or included predominantly more males verses females than those included in the sit-stand group. This also eliminated the possibility of evaluating the data once cofounders had been accounted for.

Several questions about how and why the company initiated the program and collected the data remain unknown. In private industry, individuals are often provided sit-stand workstations as part of an accommodation to reduce stressors caused by injury or illness. The data provided did not include any injury reports or indicators of the circumstances that might have precipitated provision of a sit-stand workstation. It is also important to note that there is no indicator of how long the participant had access to their workstation prior to the beginning of the collection period. Another issue was that the data were not specific about what type of sit-to stand device each participant had access to. While the picture included in the survey (Figure 2.2) shows what appears to be a height adjustable workstation, there is no definition of what is considered a sit-stand workstation and no indication of exactly which type of sit-to-stand workstations participants used. As a result, the cohort of sit-to-stand users may be a conglomeration of users that have height adjustable workstations, desktop sit-stand units, and

Figure 2.2 Remedy Interactive Sit-to-stand question slide, Reprinted from Remedy Interactive Office Ergonomic Solution software, 2019

stand-biased workstations. While the survey specifically asks “Do you use a sit-to-stand desk?” there is no follow-up question to quantify the amount of time spent in sitting or standing postures or how many transitions from standing to seated work are accomplished throughout the work day. This limits the ability to equate use of sit-stand workstations to computer usability measures and productivity as there is no way to quantify use of the sit-to-stand desk. Collection of transitions per day or time standing to work would provide researchers a measure to assess workstation utilization.

Without the demographics, it is difficult to group the population by type of work. While all of the participants complete computer work there is a wide variety of occupations that could be included in this category. Certain occupations may travel more often or might work collaboratively which could alter the data. There is also not a question to characterize utilization of anti-fatigue mats or footrests in the Remedy Interactive OES web application. This limits the ability of the researchers to factor in these when reviewing reported discomfort.

Quite possibly the biggest limitation is that the data are reported as averages for both time points for each individual as opposed to daily values. This limits the ability of the research team to assess seasonality or exclude periods where the individuals might have been out of the office. With over 10,000 participants this would have been a huge data set if all 365 days were included for each participant but the data could have been subdivided to account for these differences.

2.4.2 Strengths

This study is one of the very first to compare more than 10,000 traditional and sit-stand workstation users in a workplace setting, with daily data collection. The data cover a one-year period of time, which allows the research team to compare the values at a year for all participants no matter when the individual participant entered study. As a result, the research team did not have to consider changes in seasonal workload or holidays schedules as every participant contributed an entire year's worth of data. Additionally, with a study population this large, it is highly likely that the sample is representative of the company population.

The company also used RSIGuard® to quantify computer utilization measures rather than have participants estimate time spent at the computer. This allows a comparison of real time that participants spend using the mouse, the keyboard or total computer use during the first month and over the course of the yearlong collection period. As a result, this study is the first to utilize objective data collected over a 1-year period to compare traditional workstation users and those that had a sit-stand unit at their primary workstation.

2.5 Conclusion

This study is the first of its kind to evaluate computer utilization and discomfort over a 1-year period in association with workstation type in a real-world setting. While there are several questions that remain unanswered with respect to the population demographics, the fact that over 10,000 individuals were included in the data analysis suggests that the majority of the company's office population did in fact participate in some form of data collection over the course of the study period. Results from the study strongly support use of sit-stand workstations as alternative workstations with those individuals who had access to a sit-stand workstation for the 1-year study period spending 43 more active computing minutes than their counterparts. This combined with minimal changes in percent of participants reporting discomfort suggest that organization and individuals will benefit greatly from utilization of alternative workstation designs in the workplace.

3. HEALTH SCIENCE CENTER WORKSTATION STUDY

3.1 Overview

With the shift from a predominantly blue-collar to a largely white-collar working population the amount of time individuals sit over the course of the day, especially the workday, has increased. The U.S. Census reported that the percentage of individuals in low activity occupations, which was 23.3% in 1950, had increased to 42.6% in 2000. Americans spend time sitting at the office, on the couch watching television, eating meals and during their daily commute among other sedentary tasks. Researchers have associated sitting time, that specifically occurs at work, with increased musculoskeletal pain and discomfort especially in the shoulders, neck and lower back (Healy, 2012; Foley, 2016 and Wilks, 2006). Additionally, sedentary time has been associated with increased risk of several diseases including obesity, diabetes, cancers, cardiovascular disease and all-cause mortality (Biswas, 2015; Dutta, 2015; Neuhaus, 2014 and Katzmarzyk, 2009). One study even identified the workplace as a major contributor to the increase in sedentary activities (Bantoft, 2016).

In many cases office work consists of telephone calls, filing, data processing and paperwork. In 2003, a special survey was conducted by DOL to characterize the amount of computer and internet utilization at work. The survey identified that 55% of the civilian workforce utilized a computer at work. Due to the overwhelming amount of information tying sedentary activity to increase health risks, many employers have begun implementing workplace wellness programs and alternative work environments. As a result, several researchers have investigated if the introduction of sit-stand workstations have actually modified occupational sitting time. A review of the published literature yielded mixed results but further investigation indicated that the reason may be because a variety of workstation types have been lumped together as “sit-to-stand” workstations. The study by Dutta et al. highlighted the fact that not all sit-to-stand workstations offer the same benefits. For example, they found that certain sit-stand workstations were less preferred due to the need for additional workspace (2015). Another study found that in addition to needing more work surface space, manual handling risk was a deterrent to sit-stand use for some individuals (Mazzotta, 2018).

The current study investigated the differences in workstation types and their effects on measures of computer utilization, discomfort and identified barriers to continued use. Participants included in the study all completed administrative duties at the Texas A&M Health Science Center (HSC). Participants were categorized according to their workstation type, with individuals utilizing a traditional seated workstation being assigned to the control group. The remaining participants who were able to alter their posture throughout the workday, to include a combination of seated and standing work, were considered to have a stand-capable workstation no matter the specific type of unit they utilized. Because there are a variety of stand-capable workstations throughout the Health Science Center, researchers sub-divided the exposed group into stand-biased workstation users and sit-stand workstation users. Stand-biased workstations were considered those that had a fixed work surface located at approximately standing elbow rest height and utilized a drafting stool or chair with an extended cylinder. For the purpose of this study, sit-stand workstations included desktop units as well as those that had a fully height adjustable work surface and used a traditional office chair.

3.2 Methods

3.2.1 Setting

The study was conducted at Texas A&M University Health Science Center. All participants worked for the university at either the main campus or a satellite campus location. All participants were required to work in their university office during the study period, and those that were student workers were excluded. Those individuals who were scheduled to be out of the office for extended periods of time during the study period were offered later appointments during study collection or excluded. All participants were required to utilize a university pc computer due to the software needs during the study. There were no limitations on style of office workstation set-up or type of office chair.

3.2.2 Recruitment

Once IRB approval was received from the Texas A&M University IRB (TAMU IRB 2018-0617D), potential participants were contacted by email. Researchers utilized the HSC mail groups to reach the population of interest, which included employees in the Bryan-College Station, Dallas, Corpus Christi, McAllen, Houston, Round Rock, Lake Jackson and Victoria campus locations. The IRB approved email message (Appendix A), included the informed consent document (Appendix B) and invited potential participants to email one of two study protocol directors to receive more information about the study or to schedule an enrollment appointment. In total 3,013 individuals were sent the original recruitment email and three reminder emails were sent to potential participants from an HSC email account. IRB limited the number of participants for HSC portions of the study to 100 participants, to be assigned to one of three cohorts based on the individual's workstation type at the time of enrollment in the study.

The recruitment emails were sent out at the beginning of April 2019, and the first participants were enrolled the last week of April. The final participants were enrolled the week of July 22-26th and finished data collection by August 5th 2019.

3.2.3 Participants

Individuals were eligible to participate in the study if they were age 18 years or older, worked in an office related occupation, and were available to schedule the 1-week ActivPAL™ assessment during the chosen collection period. While 79 individuals completed at least one component of the study, only 64 participants completed all three components. The breakdown of study recruitment and enrollment can be found in Figure 3.1 below.

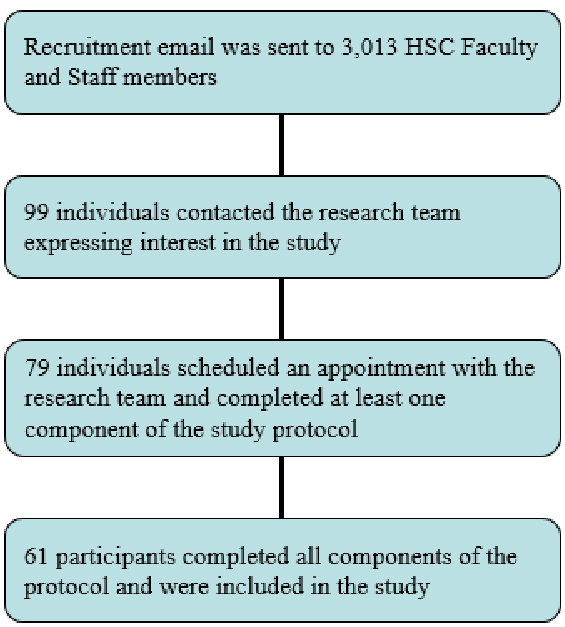

Figure 3.1 Study recruitment and participation diagram

All participants that scheduled the initial appointment were assigned a unique identification number and those that completed at least one component of the study provided a signed consent form to be included in the study. Unique identification numbers were utilized to protect participants but also indicated the type of workstation that the individuals used and the participant's cohort. Participants were asked to provide demographic data including age, height, weight and gender, which can be found in Table 3.1.

Table 3.1 HSC Study Demographics

	Overall n=66	Stand-biased n=21	Sit-Stand n=20	Traditional n=25
Mean (SD) age (yrs.)	41.7 (10.9)	40.8 (10.8)	42.7 (10.2)	42.1 (11.8)
% Female (n)	78.8 (52)	71.4(15)	80.0(16)	84.0(21)
Mean (SD) height (in)	65.5 (4.3)	65.8 (5.1)	65.2 (4.6)	65.6 (3.5)
Mean (SD) weight (lbs.)	178.9 (43.4)	167.4 (40.6)	189.5 (42.7)	180.1 (45.6)
Mean (SD) BMI	29.4 (7.3)	27.6 (8.0)	31.7 (7.8)	29.1 (6.2)
BMI Categories				
% Normal	29.0 (18)	47.4(9)	10.5(2)	29.2(7)
% Overweight	27.4 (17)	26.3(5)	26.3(5)	29.2(7)
% Obese	43.5 (27)	26.3(5)	63.2(12)	41.7(10)
Race				
Asian	1.5 (1)	0.0(0)	0.0(0)	4.0(1)
Black or African American	10.8 (7)	25.0(5)	0.0(0)	8.0(2)
White or Caucasian	63.1 (41)	45.0(9)	65.0(13)	76.0(19)
Multi-racial	3.1 (2)	10.0(2)	0.0(0)	0.0(0)
Pacific Islander	1.5 (1)	0.0 (0)	0.0(0)	4.0(1)
Hispanic	20.0 (13)	20.0(4)	35.0(7)	8.0(2)
Education				
High School	22.7(15)	14.3(3)	30.0(6)	24.0(6)
Undergraduate	37.8 (25)	33.3(7)	35.0(7)	44.0(11)
Post graduate	33.3 (22)	42.9(9)	30.0(6)	28.0(7)
Prefer not to answer	6.1 (4)	9.2(2)	5.0(1)	4.0(1)
Income				
$10-20K	1.5 (1)	0.0(0)	5.0(1)	0.0(0)
$20-50K	19.7 (13)	19.1(4)	20.0(4)	20.0(5)
$50-100K	28.8 (19)	19.1(4)	25.0(5)	40.0(10)
$100-150K	21.2 (14)	19.1(4)	20.0(4)	24.0(6)
$150-200K	10.6 (7)	4.8(1)	15.0(3)	12.0(3)
$200K +	9.1 (6)	19.1(4)	10.0(2)	0.0(0)
Prefer not to answer	9.1 (6)	19.1(4)	5.0(1)	4.0(1)

66 participants completed the demographic questions, 65 provided age and height and 64 provided weight

3.2.4 Instrumentation and Variables

Participants were asked to complete a multi-page questionnaire that targeted the office environment. The approved questionnaire asked participants if they utilized a footrest, monitor arm, keyboard tray or an anti-fatigue mat at their workstation. Additionally, the questionnaire asked if they spent time standing at their workstation and if they utilized a sit-stand or stand-biased workstation. The questionnaire (Appendix D) was included as part of an original pilot study to assess demographics, and included hours seated and standing, number of position changes, reason for requesting the stand-biased workstation, and possible barriers to continued use. To address any musculoskeletal discomfort, researchers utilized the previously validated Nordic Musculoskeletal Questionnaire (NMQ) (Kuorinka et al., 1987). The NMQ was included in the questionnaire provided to all participants. This included participants who were not able to complete RSI Guard™ or activPAL™ data collections for one reason or another.

Additionally, participants had their computer utilization habits monitored by objective measures using Enviance computer software (RSI Guard™). The data logging software provided a quantifiable measure of the participant's computer utilization. The software package was installed on HSC computers in silent mode to minimize interruption of work at the workstation and prevent participants from working to achieve certain utilization measures. Variables collected by the program are included in Table 3.2.

Table 3.2 RSI Guard™ Variables collected

Variable	Description
Workstation Type	Traditional, Sit-stand, or Stand-biased
Employee ID	Unique Identification number assigned to each participant
Keyclicks*	Number of keypresses
Ptr Clicks	Number of mouse/pointer clicks of any type
Ptr Kbd Switch	Number of times the user switches from the keyboard to the mouse.
Errors*	Number of errors that the user made that were corrected.
Dbl mouse clicks	Number of times the user double clicks the mouse
Left clicks	Number of times a user clicks the left mouse button.
Middle Clicks	Number of times a user clicks the middle mouse button.
Right Clicks	Number of times a user clicks the right mouse button.
Total Mouse distance	Distance the cursor moves on the screen in meters.
Manual Drag Drop	Number of times the user drags and drops items.
Word Count*	Number of words that are typed (alpha- numeric combinations followed by a space or return).
Mins Active*	Number of minutes during which there was at least 1 sec of keyboard or mouse activity
Kbd Shortcuts	Number of key control shortcuts that were used.
Start of Day	Start time is the moment RSI Guard™ first starts up for the day, or, if RSI Guard™ is left running overnight, the moment the user first uses the keyboard or the mouse.
End of Day	End time is the last time during the day that the user uses the keyboard or mouse.
Error Rate ⸸	Number of errors per 500 words typed

* Primary Variables ⸸ Calculated Variables

The final instrument utilized as part of the study was the activPAL accelerometer. All participants were provided an activePAL™ activity sensor during the face-to-face appointment. The sensor was pre-programed utilizing the proprietary PAL software (activPAL V 7.2.38, PAL Technologies LTD, Glasgow, UK) and set to run for 1 week during the study period to quantify standing time, sitting time, activity level, and sit\stand changes per day (Table 3.3). The default sampling frequency of 20 Hz and minimum hold time of 10 seconds was used for all participants in the study. Once programed, the sensor was waterproofed using a latex free finger cot and wrapped in a 3M ^{TM} Tegaderm surgical dressing. Participants were asked to wear the sensor on the anterior midline of the thigh, midway between the hip and knee.

Table 3.3 ActivPAL^{TM} Variables collected

Variable	Description
Employee ID	Unique number given to participants
WS Type	Workstation type (traditional, stand-biased, or sit-stand)
Energy Expenditure	Reported in METs per hour
Step Count	Steps per day
Sitting Time (h)	Hours of time sitting per day
Standing Time (h)	Hours of standing time per day
Step Time (h)	Hours of stepping time per day
Sit to stand Transitions	Number of times the individual changes posture

3.2.5 Study Protocol

The approved study protocol included all three components. Participants scheduled their face-to-face appointment with the research team at a time that was convenient in their schedule. Individuals were asked what type of workstation they utilized and a preliminary participant code was created. This included a three digit number paired with three a letter code which represented workstation type. Once an individual requested to be included in the study, a unique identification number was generated and confirmed when the study team visited the individual during initial set-up.

Participants were able to schedule software installation and equipment drop-off on a Friday or Monday during one of 12 weeks to account for summer vacations, conferences and other engagements. During the face-to-face appointment, participants were asked if they had any questions about the study and were then asked to sign the informed consent if they had not done so previously (Appendix B). Once consent had been obtained, the researchers installed the data collection software on the individual's office computer. The software ran in the background of the participants computers for up to 6 weeks; to collect a minimum of 10 occupational days of data. RSI Guard™ collected computer utilization measurements in the background for all participants. Due to scheduling and computer issues several participants had more than 10 days of computer utilization data. To ensure that no one individual skewed the data due to contribution of additional days of data, the research team ran analysis on the full data set as well as a revised data set that was limited to no more than 10 days of RSI Guard™ data per participant.

Participants were provided their unique identification number to put on all study materials at this time. All participants were provided the questionnaire with this number already at the top and asked to complete the form at their convenience. Participants were also provided an activePAL™ activity sensor during the face-to-face appointment, which was pre-programed utilizing the proprietary PAL software to include the participant's identification number. The sensor was marked with the unique identification number and waterproofed to allow participants to engage in activities of normal daily living. Participants were asked to wear or change into shorts to aid in correct sensor placement; however, not all individuals were able to comply. Researchers demonstrated correct placement of the sensor during the first appointment and an information sheet was provided (Appendix C) for any individuals who needed additional information about the activPAL™ and or its placement. Additional Tegadem™ dressings were provided for participants who indicated that they took baths or went swimming as the dressing is not 100% waterproofed when submerged for extended periods of time. All participants were asked to wear the activity sensor for the entire week for which they were scheduled. Upon investigation of the data files, some of the sensors may not have been recording accurately for the duration of the study. To address this issue the full dataset was revised and those participants whose records showed 1.25 METs per hour for the entire day and less than 100 steps total were excluded from the dataset. The focus of the study was occupational activity; however, the sensors were set to record activity continuously for the entire week. To address this both the 24-hour data and the data collected from 8am to 5pm were evaluated.

3.2.6 Analysis

Descriptive statistics were calculated for all continuous variables, to include mean, and standard deviation. Proportions were calculated for all categorical variables, stratified by workstation type. Pearson Chi Square tests were utilized to assess discomfort and the ANOVA tests was used to compare traditional, stand-capable and stand-biased cohorts with respect to computer usability measures, sitting time, standing time and changes per day. The Scheffe post-hoc test was used to determine which cohorts were statistically different at alpha =0.01.

3.3 Results

A total of 61 individuals completed the entire study, with 63 participants participating in computer utilization portions of the study. Some individuals, who responded to the recruitment email, were not able to participate in the RSI Guard™ data collection due to enhanced security protocols and sensitive data that was handled by their office. Additionally, there were five potential participants who utilized an Apple® as their primary office computer and the research team was unable to procure the MAC version of the collection software from Enviance. In total

21 individuals were assigned to the stand-biased group, 22 were assigned to the sit-stand group and 20 were assigned to the traditional group for computer utilization.

3.3.1 HSC Questionnaire

All participants were required to complete the questionnaire to be included in the study. The stand-biased group had 65% of individuals who had a footrest compared to 28.6% of sit-stand users. Additionally, the sit-stand group had more individuals reporting antifatigue mats (47.6%) compared to the 29.7% of the stand-biased group that had anti-fatigue mats (Table 3.4). While not all stand-biased workstation users reported spending time standing to work (90%), they had more than either the sit-stand (65%) or traditional group (26%). It is also important to note that 60% of the sit-stand group believed that they currently utilized a stand-biased workstation, as did just over 8% of the traditional group.

Table 3.4 Workstation Use and Accessories

	Overall	Stand-biased	Sit-Stand	Traditional
Office Accessories				
% Footrest (n)	35.94 (23)	65.0 (13)	28.57 (6)	17.39 (4)
% Monitor arm (n)	4.69 (3)	0 (0)	9.52 (2)	4.35 (1)
% keyboard tray (n)	12.5 (8)	10.0 (2)	19.05 (4)	8.70 (2)
% anti-fatigue mat (n)	29.69 (19)	35.0 (7)	47.62 (10)	8.70 (2)
% spend time standing at workstation (n)	58.73 (37)	90.0 (18)	65.0 (13)	26.09 (6)
% have utilized a sit-stand workstation (n)	61.9 (39)	63.16 (12)	95.24 (20)	30.43 (7)
% currently utilizing a stand-biased workstation (n)	50.79 (32)	90.0 (18)	60.0 (12)	8.70 (2)

66 participants completed this portion of the survey.

The NMQ specifically asks individuals if they have experienced any issues, including aches, pain and discomfort, during the past 12 months. Surprisingly while 65% of participants reported having neck discomfort, the only region that had a significantly different proportion of individuals reporting discomfort was the lower back. The traditional group had 80% of the participants report discomfort of the lower back while the stand-biased group reported only 51.7%. While not significant, the sit-stand group had a higher percentage of participants reporting upper back, wrist and hand and hip discomfort than either the stand-biased or the traditional group (Table 3.5).

Table 3.5 Nordic Musculoskeletal Discomfort Questionnaire (NMQ)

	Overall count (%)	**Stand-biased**	**Sit-Stand**	**Traditional**	**Overall, p-value**
Neck (%)	50 (65.79)	18 (62.1)	14 (63.6)	18 (72.0)	0.72
Upper Back (%)	34 (44.74)	11 (37.9)	13 (59.1)	10 (40.0)	0.27
Lower Back (%)	52 (68.42)	15 (51.7)	17 (77.3)	20 (80.0)	0.04*
Shoulder (%)	45 (59.21)	17(58.62)	12 (54.55)	16 (64.00)	0.80
Wrist & Hand (%)	30 (39.47)	9 (31.0)	11 (50.0)	10 (40.0)	0.39
Hips (%)	29 (38.16)	10 (34.5)	10 (45.5)	9 (36.0)	0.70
Knees (%)	25 (32.59)	7 (24.1)	8 (36.4)	10 (40.0)	0.43
Ankles & Feet (%)	19 (25.0)	7 (24.1)	8 (36.4)	4 (16.0)	0.28

Stand-biased group n=29 the Sit-stand group n=22 and the Traditional group n=25
* Indicates that the sample means are statistically difference at alpha =0.05
Note: Includes individuals who did not complete the ActivPAL™ or RSI Guard™ components of the study.

3.3.2 RSI Guard computer utilization data

The data from RSI Guard™ were collected and aggregated into one large file. As previously mentioned, some participants did not have 10 full days of occupational and some had more than the desired 10 days. As a result, the data were assessed with all available days of data (Table 3.6) and with the dataset restricted to a maximum of 10 occupational days per participant (Table 3.7). When all available data were included there was a statistical difference in the mean number of keyclicks for the stand-biased and traditional groups, with the stand-biased group having an average of 2,103.23 more keyclicks per day. There was also a statistical difference in the mean number of daily keyboard errors between the stand-biased and traditional group as well as between the sit-stand and traditional group. Similar to the study in Chapter 2, the stand-capable (including both the stand-biased and sit-stand) groups had higher reported errors or typos than the traditional group. There was also a significant difference in the mean daily word count, with the stand-biased group being statistically different from both the sit-stand and traditional groups. Thus, while the stand-biased group had more errors, they also typed more words per day. To ensure that a more equitable measure was used, the research team calculated an error rate (number of errors/typos per 500 words). This rate was not significantly different between any of the groups.

Table 3.6 RSI Guard™ Variables (all data)

	Overall Study mean (SD)	**Biased**	**Sit-Stand**	**Traditional**	**Overall p-value**
Key clicks	6306.27 (5318.3)	7485.12*	6257.19	5381.89*	<0.01
Pointer Clicks	2073.17 (2073.2)	2247.89	2013.68	1977.64	0.06
Pointer Keyboard Switches	566.64 (433.72)	613.68	539.81	549.58	0.06
Keyboard Errors	214.53 (204.61)	264.03*	221.01+	168.77*+	<0.01
Double Mouse Clicks	152.97 (148.38)	178.22*	133.57*	147.83	<0.01
Left Mouse clicks	2028.83 (204.61)	2199.91	1968.16	1937.25	0.06
Middle Mouse Clicks	0.1248 (0.628)	0.1132	0.2186*	0.0593*	<0.01
Right Mouse Clicks	44.38 (55.55)	48.44	45.30	40.033	0.15
Total Mouse Distance	152115.4 (114205.7)	156926.9	152405.1	147939.6	0.58
Manual Drag & Drop	149.69 (151.83)	146.07	164.10	141.11	0.12
Word Count	693.79 (621.75)	843.51*+	672.71*	587.99+	<0.01
Active Computer Minutes	213.45 (109.23)	209.73	215.35	214.98	0.76
Keyboard Shortcuts	51.20 (74.97)	50.94	66.08*	39.48*	<0.01
Error Rate per 1000	352.68 (275.46)	356.93	356.27	346.27	0.85

Stand-biased group n=318, the Sit-stand group n=311 and the Traditional group n=388
+, * indicate that samples have statistically different means at alpha = 0.01

To ensure that the data collection was more balanced, the number of days of RSI Guard™ data were limited to 10 and statistics were recomputed (Table 3.7). The revised data showed that there was no significant difference in the number of keyclicks between the three groups; however, there was still a significant difference between the stand-biased and traditional groups with respect to errors. While the stand-biased group had an average of 74 more errors per day, the calculated error rate showed no difference among the groups. This could be in part due to the statistical difference in average daily word count between the stand-biased and traditional groups.

There were a couple of interesting differences identified in the data. In both datasets the sit-stand group used statistically more keyboard-shortcuts and middle mouse clicks. Also, of note is that the stand-biased group had statistically more double mouse clicks than the sit-stand group. While it is un-clear how these variables could play into an organization's definition of productivity, they are an interesting finding.

Table 3.7 RSI Guard™ Variables (first 10 days/participant)

	Entire Study mean (SD)	**Stand-biased**	**Sit-Stand**	**Traditional**	**Overall p-value**
Key clicks	6327.41 (5207.15)	7032.55	6319.34	5788.86	0.05
Pointer Clicks	2046.56 (1465.68)	2198.67	1907.42	2042.96	0.15
Pointer Keyboard Switches	575.26 (446.47)	620.02	528.04	579.35	0.13
Keyboard Errors	211.04 (186.30)	247.59+	223.28	172.76+	<0.01
Double Mouse Clicks	151.10 (137.14)	175.02*	127.87*	151.65	<0.01
Left Mouse clicks	2002.44 (1430.35)	2152.71	1860.83	2002.29	0.14
Middle Mouse Clicks	0.13 (0.58)	0.11	0.24+	0.05+	<0.01
Right Mouse Clicks	43.99 (53.61)	45.84	46.35	40.62	0.46
Total Mouse Distance	145771.73 (102366.47)	154574.1	150410.4	135165.8	0.12
Manual Drag & Drop	142.75 (131.61)	152.89	142.58	135.05	0.39
Word Count	697.07 (612.21)	794.65*	677.32	637.81*	0.03
Active Computer Minutes	213.28 (109.37)	207.77	214.74	216.36	0.70
Keyboard Shortcuts	57.45 (82.20)	56.36	70.44*	47.64*	0.02
Error Rate per 500 words typed	180.22 (164.89)	191.59	180.85	170.81	0.44

Stand-biased group n=183, the Sit-stand group n=195 and the Traditional group n=238
+ indicate that samples have statistically different means at alpha = 0.01
* indicate that samples have statistically different means at alpha = 0.05

3.3.3 activPAL activity measures

The activPAL™ sensors were used to quantify activity levels for participants. The researchers were specifically interested in occupational activity so the data was limited to activity collected between the hours of 8am to 5pm (Table 3.8). The stand-biased and sit-stand groups had more standing time and less sitting time than the traditional group but were not significantly different from one another. Interestingly the stand-biased and sit-stand groups had fewer transitions per hour than the traditional group. Even though the traditional group transitioned from seated to standing postures more often, the stand-biased group expended more energy (METs/hr.) than the traditional group. While not statistically significant, the stand-biased group reported on average 492.5 more steps per day than their traditional counterparts.

Table 3.8 ActivPAL™ Variables (8am-5pm)

	Entire Study mean (SD)	**Stand-biased**	**Sit-Stand**	**Traditional**	**Overall p-value**
Sitting time (min/hr.)	37.89 (17.54)	34.04^	35.42+	42.69+^	<0.0001*
Standing time (min/hr.)	17.93 (16.15)	21.52^	20.12+	13.52+^	<0.0001*
Stepping time (min/hr.)	4.15 (4.44)	4.44	4.37	3.78	0.0292
Step count/ hr.	358.09 (389.81)	383.00	358.78	337.23	0.1583
Transitions/ hr.	3.34 (2.65)	2.75^	3.14+	3.95+^	<0.001*
Energy Expenditure METs/hr.	1.43 (0.177)	1.45^	1.43	1.41^	0.0017

Stand-biased group n=486, the Sit-stand group n=397 and the Traditional group n=594
+, ^ indicates that samples have statistically different means at alpha = 0.01
* Indicates overall significance at alpha =0.01

It was also important to review the full 24-hour activity data to see if any of the groups were compensating for occupational activity levels (Table 3.9). The stand-biased group still showed a decreased amount of sitting/lying time (1042.61 minutes/day) and increased standing time (303.67 minutes/day) when compared to the traditional group. Similar to the workday data, the number of transitions were significantly increased for the traditional group and the sit-stand groups when compared to the stand-biased group. The full day data showed no differences in energy expenditure, step count or step time.

Table 3.9 ActivPAL^{TM} Variables (entire 24 hr. day)

	Entire Study mean (SD)	**Stand-biased**	**Sit-Stand**	**Traditional**	**Overall p-value**
Sitting/lying time (min)	1089.97 (157.56)	1042.61+	1079.65	1133.63+	<0.01*
Standing time (min)	265.62 (140.01)	303.67^	267.23	234.83^	0.03*
Stepping time (min)	73.98 (38.39)	77.24	73.75	71.56	0.72
Step count/day	6039.58 (2367.54)	6432.78	5712.68	5940.32	0.47
Transitions/day	51.43 (20.85)	43.63+^	48.36^	59.48+	<0.01*
Energy Expenditure (METs)	32.81 (1.97)	32.94	32.51	32.91	0.50

Stand-biased group n=54 the Sit-stand group n=44 and the Traditional group n=69
+ indicates that samples have statistically different means at alpha = 0.01
^ indicates that samples have statistically different means at alpha = 0.05
* indicates overall significance at alpha =0.05

3.4 Discussion

The demographic data showed similar average age, height and weight distribution in all three of the workstation groups. The sit-stand group had a higher percentage of individuals in the obese category than either the traditional or stand-biased groups. The percentage of individuals who were overweight was almost equal for all three groups at 26.3-29.2%. Additionally, the stand-biased group had more individuals that were categorized as normal or underweight than either or the two remaining groups. This distribution could be purely coincidental or it could be due to the additional time spent standing. The fact that the desktop sit-to stand group had more individuals that were obese and less individuals that were in the normal category than the stand-biased group may indicate that there is a reason behind why individuals choose certain workstations and the proportions are a result of that choice. Individuals who are obese may not feel like they are capable of utilizing a stand-biased desk as they do not realize that they are not required to stand the entire day. As a result, many of them may opt for a workstation type that offers increased health benefits but also allows the user to sit or stand. In the case of the current study participants, the choice seems to be desktop sit-stand units. The selection could be a result of limited options offered by individual departments or funding constraints as opposed to the user's choice or the desktop unit could truly be the participants preferred selection. Unfortunately, the questionnaire did not ask any questions that would help the researchers identify the reason behind the current workstation selection if they utilized a sit-stand.

The questionnaire did ask participants how many of them had utilized a sit-stand workstation. Only 95% of the individuals that were classified by the researchers as current sit-stand workstation users identified that they used a sit-stand workstation. Additionally, only 90% of the individuals classified by the research team as a stand-biased user identified themselves as currently utilizing a stand-biased workstation. Similarly, 60% of sit-stand users and 8.7% of traditional users indicated that they were currently utilizing a stand-biased workstation. While the researchers classified participants based on observation of the workstation rather than the individuals self-selected workstation type, it brings up the fact that the general public many not fully understand the differences between the three workstation types. Researchers need to do a better job educating the public about the different types of workstations that are considered stand capable include the desktop sit-stand unit, stand-biased and height adjustable workstations.

Surprisingly the neck, upper back, and wrist and hands did not show any significant differences in percent of individuals reporting pain with in the last 12 months. The percentages were slightly higher in these areas for both the sit-stand and traditional groups. This may indicate that they have difficulty finding a neutral working posture when they change their working postures. The fact that participants utilizing a stand-biased workstation are not required to re-adjust their workstation settings with each transition may translate to less discomfort for this group as a whole. The low back was the only area of the NMQ that showed a statistical difference amongst the three groups. The stand-biased group had the lowest percent of individuals reporting low back discomfort with approximately 52% while 80% of the traditional group and 77% of the sit-stand group reported low back discomfort. This reduction in low back discomfort for the stand-biased group could be due to the increased percent of individuals who have footrests, which assist in increasing postural changes throughout the day. While 65% of the stand-biased group had a footrest, less than 30% of the sit-stand group had one available for their use, which could play a part in the number of participants reporting low back discomfort.

Of the computer utilization measures collected there were several that were significantly different between the respective groups. One area that was not significantly different was the amount of active computer minutes per day. This means that the three groups spent similar amounts of time actively utilizing the computer. The stand-biased group had statistically more keyboard errors but when compared utilizing the error rate the three groups were not significantly different. The stand–biased group also had a higher word count their traditional counter parts. The sit-stand group used statistically more keyboard-shortcuts and middle mouse clicks than the traditional group while the stand-biased group had statistically more double mouse clicks than the sit-stand group. Unfortunately, it is unclear if these differences are truly related to the workstation type or are a result of the type of activities completed during the collection period. One way to potentially identify true differences in the three groups is to increase the collection period to one month. The other option is to limit data collection to the 9-month period of time when all faculty and staff are in their offices.

The activPAL™ sensors were used to quantify occupational activity levels for participants. Since participants were asked to wear the sensor 24 hours a day, the research team had to partition out the occupational time. The stand-biased group had less sitting time and more standing time per hour than either of the two remaining groups. The stand-biased group spent approximately 35% of their day standing while the sit-stand group spend approximately 33% and the traditional group spent 23%. The stand-biased group had significantly more energy expenditure (METs) than the traditional group and while not statistically significant, the stand-biased group reported on average 492.5 more steps per day than their traditional counterparts. Over the course of a workweek this approaches an additional mile (2500 steps) taken for the stand-biased users. This could play a role in improving health and getting people moving.

It was important to review the full 24-hour activity data to see if any of the groups were compensating for occupational activity levels. The full day data showed no differences in energy expenditure, step count or step time. This hints at a possible overall increase in non-occupational activity for the traditional group as daily stepping time and step count are similar for the traditional, sit-stand and stand-biased groups.

3.4.1 Limitations

All participants in the study were employed at an institute of higher education and most of them were already aware of the potential benefits of increasing occupational activity. While the research team tried to minimize the possibility that participants increased activity during the study period by having the RSI Guard^{TM} software run in the background, there is always the possibility that some of them increased their activity levels in response to the study.

Just over 70% of the participants were college educated with at least an undergraduate degree. Additionally, approximately 80% of the population was female and 60% was Caucasian. With primarily a white, female, and college educated study population it may be difficult to generalize this group to other populations of interest.

The research team was restricted in the variables that could be evaluated due to the type of RSI Guard^{TM} data files available. Some participant's computers saved an exportable RSI file that included a multitude of variables; however, other participants only had a rich text file. This file was converted from a tab delimited text file to a comma separated excel document. Once it was saved as a Microsoft ® Excel file, it was then aggregated from hourly to daily totals. When compiling the data from each participant into a complete file it was identified that the variables in the two files were different. As a result, the team was limited in the metrics that could be compared due to the two different file types not being 100% comparable in content.

The study started late in the spring semester, which presented challenges as many of the staff had planned to take time off or were attending conferences and seminars during early summer. Additionally, there were a limited number of activPAL^{TM} activity sensors, which required the study team to limit the number of participants that could enter the study each week.

These issues extended the collection period well into August, and through the majority of the summer semester. As a result, data collection was spread over several months as opposed to being collected during one 10-day cycle.

Due to the limited number of activity sensors, the protocol was written to include one work week of activPAL™ data collection. As the sensors were primarily distributed on Mondays and collected from participants on Fridays, this limited the number of full collection days to three per participant. Several of the older sensors were unable to hold a charge for more than five days and some died prior to the research team collecting them. As a result, not every participant has activPAL™ data to quantify standing time, seated time, sit to stand transitions or energy expenditure (METs).

3.4.2 Strengths

This study enrolled 76 participants, 61 of which completed all three components of the study. Participants were recruited with a blanket email and once enrolled, were assigned to a group based on their workstation set-up. The researchers did not preselect or target individuals with specific workstations types, however the groups turned out to be reasonably balanced. The stand-biased group had 18 participants, the sit-stand group had 19 and the traditional group had 24 participants with full data. This equated to an 80% study completion rate of those who completed all portions of the study.

This study utilized the activPAL™ to collect objective quantifiable measures to assess workstation utilization in the form of sitting time, standing time, sit to stand transitions and energy expenditure (METs) rather than a subjective questionnaire. This allowed the research team to assess participants true activity levels as opposed to how much participants thought they moved. Additionally, the study utilized objective measures to determine how much active computing time each participant engaged in daily. While certainly not a perfect or complete estimate of daily productivity for administrative jobs, it is definitely a component worth considering.

Musculoskeletal discomfort was evaluated utilizing the previously validated Nordic Musculoskeletal Questionnaire (NMQ) rather than creating a tool specifically for this study. The NMQ was found to be repeatable, sufficiently sensitive and suitable as screening tool (Ohlsson et al, 1994 and Palmer et al., 1999). It has also been previously used to evaluate musculoskeletal discomfort for administrative workers using computers and in call centers (Bergqvist et al, 1995 and Cook et al, 2000). Utilizing a standardized format will allow future work to be compared to the current data collected during this study with minimal difficulty.

The current study utilized a questionnaire to collect demographic data. The questionnaire, which was previously used in another study on stand capable workstations, also included targeted questions on office accessories and the amount of time each participant used their specific workstation. The information will allow researchers to better characterize the types of office accessories that are used and if workers truly know the difference between the different stand-capable workstation types.

3.5 Conclusion

Results from this study indicate that there may be some significant differences in computer utilization when comparing stand-biased, sit-stand and traditional workstation users.

Stand-biased users type more words per day and make more errors than their traditional counterparts but there does not seem to be a difference in the error rate, meaning that the increases are likely proportional. As anticipated, due to the design of the stand-biased workstation, these users have decreased sitting time and increased standing time when compared to traditional users. Additionally, the stand-biased group reported a higher occupational average hourly MET (1.45) when compared to traditional users at 1.41 METs. When the data were reviewed for the full 24-hour period there was no difference in energy expenditure between any of the groups, which may indicate that the traditional group increases their non-occupational activity to compensate for using a traditional workstation. The results of the NMQ indicated that the only area where the percentage of individuals reporting discomfort was statistically different was the low back with the stand-biased group reporting 28.3% less discomfort than the traditional group and 25.6% less than the sit-stand group. As a result, the data collected as part of this study supports the use of stand-biased workstations as a viable alternative to desktop sit-stand and traditional workstations to increase occupational activity, with minimal changes to computer utilization and overall discomfort of workers.

4. HEALTH SCIENCE CENTER STAND-BIASED SIX YEAR FOLLOW-UP WORKSTATION STUDY

4.1 Overview

The introduction of alternative workstations is certainly not a new concept. Researchers have described studies on sit-stand workstations as early as the late 80's. While they have become more mainstream, with many employers providing them to employees as workplace accommodations there are very few studies that focus solely on the benefits of stand-biased workstation utilization. A stand-biased workstation is one where the work surface is set to approximately the individuals standing elbow rest height (40-42 inches) rather than the traditional height of 30 inches and thus encourages individuals to stand to work rather than sit for the entire 8-hour workday (Gurr et al., 1998, Hjelm et al., 2000, and Pickens et al., 2016). A tall or drafting type chair is provided so that the user may sit at the workstation when desired without adjusting the desk height, thereby improving comfort (Kress et al., 2014).

Many of the studies that have utilized a stand-biased workstation focused on discomfort or measures of attentiveness as opposed to activity and computer utilization (Benden et al., 2011; Benden et al., 2012; Mehta et al., 2015 and Dornhecker et al., 2015). This study was designed to review long-term data from stand-biased users in a 6-year follow-up including self-reported measures of activity, workstation utilization, and barriers to continued use. Additionally, quantifiable measures of workstation utilization (including sitting time, standing time, and changes per day), and productivity (including active minutes, key clicks. word counts, and total mouse distance) were assessed.

4.2 Methods

4.2.1 Setting

Prior to 2013 several individuals at the Health Science Center elected to shift from a traditional office workstation to a stand-biased workstation. For many of these individuals this included retrofitting the workstation by raising the working surface to an appropriate standing work height and utilizing a stool with an 8 or 10” cylinder. Many of these participants chose to make the shift due to increased research in the area of sit to stand workstations and the health effects associated with sedentary time. The original study, conducted in 2013, invited office workers at the Health Science Center to participate in a study investigating the amount of time that individuals had utilized a stand-biased workstation, the time to full transition and the reasons for requesting a stand-biased workstation. Participants in the current follow-up were all employed by the Texas A&M University System. As a result, all of the individuals maintained an office location on campus; however, not all participants in the follow-up were required to currently have a stand-biased workstation.

4.2.2 Recruitment

Participants for the current study were recruited from individuals that participated in the stand-biased workstation study at the Texas A&M Health Science Center in 2013. To be included in the original study individuals were required to have been employed by the University for a minimum of 3 months and worked in administrative, research or teaching occupations. Additionally, all participants had converted to a stand-biased workstation prior to enrollment in the study of their own choice. In total 25 participants were included in the original study. Researchers attempted to contact all 25 participants included in the 2013 study, requesting their participation in a follow-up study to determine long-term utilization of stand-biased workstations. When the list was reviewed, three potential participants were excluded due to their participation in the study development. Additionally, one individual was excluded as the individual had retired from the university. Remaining potential follow-up participants were contacted individually by email, which included a short introduction and recap of the previous study. A diagram outlining the recruitment process can be found in Figure 4.1. Researchers achieved a response rate of 76% with 16 of 21 individuals contacted responding to the invitation. Additionally, 14 out of 16 individuals who responded to the invitation and began a portion of the study, submitted the questionnaire resulting in a questionnaire completion rate of 88%. Six individuals completed all portions of the study, including the elective components, which resulted in an overall completion rate of 38%. Researchers received approval for the study protocol by the Texas A&M University IRB. TAMU IRB 2018-0617D.

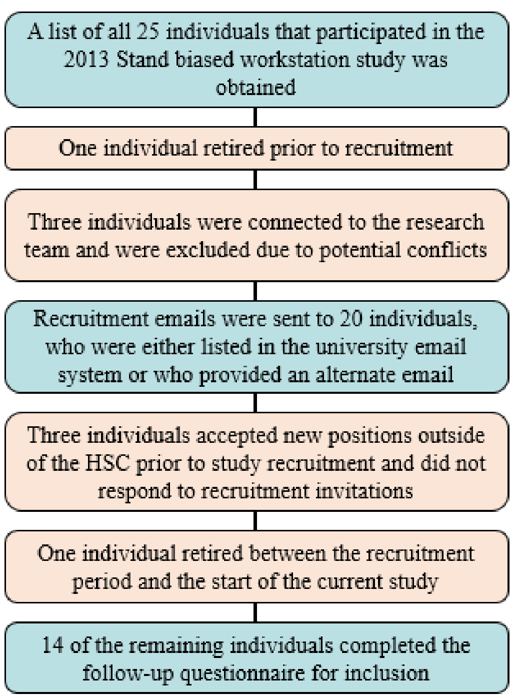

Figure 4.1 Study Recruitment and Participant diagram

4.2.3 Participants

Potential study participants were encouraged to join the comprehensive HSC workstation study described in chapter 3 if possible, but were not required. In total, 14 individuals responded to emails or personal invitations to join the follow-up study, 6 of which participated in the full comprehensive study and 8 which completed only the questionnaire. Participants were asked to answer a variety of questions on demographics but allowed to decline if they felt it necessary. Questions included age, height, weight, gender, race, highest education level, annual household income and occupation. A summary of the demographics can be found in Table 4.1.

Table 4.1 Follow-up Study Demographics		**Stand-biased**	**Sit-stand**	**Traditional**
		n=10	n=3	n=1
Mean (SD) age (yrs)	47.14 (11.43)	47.7 (13.09)	49.0 (3.00)	36.0
% Female (n)	92.86 (13)	90.0 (9)	100 (3)	100 (1)
Mean (SD) height (in)	65.07 (3.54)	64.7 (4.00)	67.0 (1.00)	63.0
Mean (SD) weight (lbs)	163.00 (43.65)	160.5 (46.22)	177.3 (47.71)	145.0
Mean (SD) BMI	26.73 (4.62)	26.56 (4.55)	27.63 (6.61)	25.69
BMI Categories				
% Normal	42.86 (6)	50.0 (5)	33.3 (1)	0 (0)
% Overweight	28.57 (4)	20.0 (2)	33.3 (1)	100 (1)
% Obese	28.57 (4)	30.0 (3)	33.3 (1)	0 (0)
Race				
Asian	7.14 (1)	0 (0)	33.3 (1)	0(0)
Black or African American	7.14 (1)	10.0 (1)	0 (0)	0(0)
White or Caucasian	78.57 (11)	80.0 (8)	66.6 (2)	100 (1)
Hispanic	7.14 (1)	10.0 (1)	0(0)	0(0)
Education				
Undergraduate	35.71 (5)	40.0 (4)	0 (0)	100 (1)
Post graduate	64.29 (9)	60.0 (6)	100 (3)	0 (0)
Prefer not to answer	0 (0)	0 (0)	0 (0)	0 (0)
Income				
$50-100K	7.14 (1)	10.0 (1)	0 (0)	0 (0)
$100-150K	21.43 (3)	20.0 (2)	0 (0)	100(1)
$150-200K	21.43 (3)	20.0 (2)	33.3 (1)	0 (0)
$200K +	21.43 (3)	20.0 (2)	33.3 (1)	0 (0)
Prefer not to answer	28.57 (4)	30.0 (3)	33.3(1)	0 (0)

14 of the original 25 participants completed the follow-up survey. While all participants provided height and weight at follow-up, two did not provide this data during the original study.

4.2.4 Instrumentation and Variables

Participants were asked to complete a multi-page questionnaire that targeted the office environment. The approved questionnaire asked participants if they utilized a footrest, monitor arm, keyboard tray or an anti-fatigue mat at their workstation. Additionally, the questionnaire asked if they spent time standing at their workstation and if they utilized a sit-stand or stand-biased workstation. The questionnaire (Appendix D) was included as part of an original pilot study to assess demographics, and included hours seated and standing, number of position changes, reason for requesting the stand-biased workstation, and possible barriers to continued use. The questionnaire was provided to all participants including participants who were not able to complete RSI Guard™ or activPAL™ data collections for one reason or another.

Additionally, participants that agreed to participate in the full study had their computer utilization habits monitored by objective measures using Enviance computer software (RSI Guard™). The data logging software provided a quantifiable measure of the participant's computer utilization. The software package was installed on HSC computers in silent mode to minimize interruption of work at the workstation and prevent participants from working to achieve certain utilization measures. Variables collected by the program are included in Table 4.2.

Table 4.2 RSI Guard™ Variables collected

Variable	Description
Workstation Type	Traditional, Sit-stand, or Stand-biased
Employee ID	Unique Identification number assigned to each participant
Keyclicks*	Number of keypresses
Ptr Clicks	Number of mouse/pointer clicks of any type
Ptr Kbd Switch	Number of times the user switches from the keyboard to the mouse.
Errors*	Number of errors that the user made that were corrected.
Dbl mouse clicks	Number of times the user double clicks the mouse
Left clicks	Number of times a user clicks the left mouse button.
Middle Clicks	Number of times a user clicks the middle mouse button.
Right Clicks	Number of times a user clicks the right mouse button.
Total Mouse distance	Distance the cursor moves on the screen in meters.
Manual Drag Drop	Number of times the user drags and drops items.
Word Count*	Number of words that are typed (alpha- numeric combinations followed by a space or return).
Mins Active*	Number of minutes during which there was at least 1 sec of keyboard or mouse activity
Kbd Shortcuts	Number of key control shortcuts that were used.
Start of Day	Start time is the moment RSI Guard™ first starts up for the day, or, if RSI Guard™ is left running overnight, the moment the user first uses the keyboard or the mouse.
End of Day	End time is the last time during the day that the user uses the keyboard or mouse.
Error Rate ⸸	Number of errors per 500 words typed

* Primary Variables ⸸ Calculated Variables

The final instrument utilized as part of the study was the activPAL accelerometer. All participants were provided an activePAL™ activity sensor during the face-to-face appointment. The sensor was pre-programed utilizing the proprietary PAL software (activPAL V 7.2.38, PAL Technologies LTD, Glasgow, UK) and set to run for 1 week during the study period to quantify standing time, sitting time, activity level, and sit\stand changes per day (Table 3.3). The default sampling frequency of 20 Hz and minimum hold time of 10 seconds was used for all participants in the study. Once programed, the sensor was waterproofed using a latex free finger cot and wrapped in a 3M ™ Tegaderm surgical dressing. Participants were asked to wear the sensor on the anterior midline of the thigh, midway between the hip and knee.

Table 4.3 ActivPAL™ Variables collected

Variable	Description
Employee ID	Unique number given to participants
WS Type	Workstation type (traditional, Stand-biased, or sit-stand)
Energy Expenditure	Reported in METs per hour
Step Count	Steps per day
Sitting Time (h)	Hours of time sitting per day
Standing Time (h)	Hours of standing time per day
Step Time (h)	Hours of stepping time per day
Sit to stand Transitions	Number of times the individual changes posture

4.2.5 Study Protocol

Once participants contacted the research team to indicate their willingness to participate or requested additional information, a face-to-face appointment was scheduled. The research team utilized a questionnaire that mirrored the interview questions approved by TAMU IRB and used in the original study. A questionnaire was selected over the interview process due to the timing of the study. Final IRB approval for the study was received in May and the majority of HSC faculty members were on 9-month appointments, making it difficult for some individuals to schedule an in-person appointment. Those individuals who chose not to participate in the comprehensive HSC study were provided the questionnaire in person or via HSC email.

After participants scheduled their appointment, the research team assigned each individual a unique identification number to protect the participant's identity. For those individuals who chose to be included in the comprehensive HSC study, the first appointment included installation of Remedy computer software (RSI Guard™), provision and guidance on the activPAL^{TM} activity sensor and the questionnaire which included demographic questions. Individuals who were unable to complete the comprehensive study, due to other obligations, were asked to complete only the questionnaire. In addition to demographics, the questionnaire included questions on the work environment, non-work environment and musculoskeletal discomfort as categorized by the previously validated NORDIC Musculoskeletal Questionnaire (NMQ) and can be found in Appendix D. Questions covered the amount of time each individual spent sitting and standing at the workstation, and if they currently utilized a sit-stand or stand-biased workstation. Participants were also asked how many days in a typical week they participated in high intensity, moderate intensity and recreational walking per week. Additionally, participants were asked to estimate the amount of time that they spent sitting during a typical day, to include time spent sitting at work, traveling, or watching television but not including time spent sleeping.

Once participants had completed the questionnaire, the research team entered the data into a Microsoft ® Excel spreadsheet, which was saved on a secure drive. Data were imported into SAS 9.4® statistical software (Cary, NC) for analysis.

4.2.6 Analysis

Descriptive statistics were calculated for continuous variables, to include mean, standard deviation of participant's age, height, weight, BMI, and number of months utilizing a stand-biased workstation. Proportions were calculated for all categorical variables including BMI category, race, education, income and access to office accessories. A paired t-test was used to determine any differences in self-reported values of workstation utilization for those participants who were included in the original study and the current 6-year follow-up. Additionally, the objective measures from the activPAL activity sensor and RSIGuard computer utilization collected during the follow-up were assessed using ANOVA with a Scheffe post-hoc test to determine, which groups were statistically different at p=0.05.

4.3 Results

The research team was able to enroll 14 of the original 25 participants. Of these, only 6 consented to be included in the larger HSC study described in chapter 3, leaving 8 that participated in only the questionnaire portions of the study.

4.3.1 Workstation Characterization via Questionnaire

The data from the original 2013 study asked participants if they utilized a footrest, monitor arm, keyboard tray or an anti-fatigue mat. All of the participants in the original study were utilizing stand-biased workstations; however, over the 6-year period several individuals had moved offices locations or requested to change workstations types. Of the 14 participants, only four reported changing their workstation. One participant indicated that they switched offices and the new location had a traditional workstation. Another participant indicated that the height of the workstation was set up incorrectly and that they have not been able to fix it. As a result, the individual sits almost 100% of the time at their stand-biased workstation. One participant reported that the risers, which were used to raise their worksurface, gave of an offensive odor and as a result, they changed the workstation to a desktop sit-stand unit. The final individual moved to a new office and requested a height adjustable workstation. The general workstation characteristics for the study participants by year can be found in table 4.4 below.

Table 4.4 Workstation Characteristics

	2013	2019
Workstation Type		
% Stand biased (n)	100 (14)	71.4 (10)
% Sit-stand (n)	0 (0)	21.4 (3)
% Traditional (n)	0 (0)	7.14 (1)
Office Accessories		
% Footrest (n)	100 (14)	50.0 (7)
% Monitor arm (n)	7.14 (1)	7.14 (1)
% keyboard tray (n)	42.8 (6)	0.0 (0)
% anti-fatigue mat (n)	14.3 (2)	35.7 (5)
% spend time standing at workstation (n)	100(14)	85.71 (12)
% have utilized a sit-stand workstation (n)	---	71.43 (10)
% currently utilizing a stand-biased workstation (n)	100 (14)	71.43 (10)
Self-reported average time (months) utilizing a stand-biased workstation (SD)	11.96 (8.71)	60.77 (37.10)

-- This was a new question asked in 2019 only

As all of the participants completed the questionnaire in 2013 and 2019, several self-reported measures were compared longitudinally. Table 4.5 includes the mean number of hours that individuals participated in vigorous or moderate activities as well as the number of days per week that they walked for at least 10 minutes at a time and the number of hours spent sitting or reclining in a typical day for all 14 participants who completed the follow-up. Results from the self-reported data collected from the questionnaire showed no significant difference in the number of days that the participants reported vigorous moderate activities. The only significantly different self-reported measure of activity was the number of days per week individuals walked a minimum of 10 minutes per day. In 2019 participants reported a mean of 5.15 days per week which was up from the 2013 reported mean of 2.83. This may indicate that participants have increased the number of days that they walk in place of adding additional vigorous or moderate activities.

Table 4.5 Self-reported Activity Measures

	2013 Mean (SD; CV)	**2019** Mean (SD; CV)	**p-value**
Days per week participating in vigorous activity^	2.21 (1.57; 0.71)	1.69 (1.84; 1.09)	0.1794
Days per week participating in moderate activity +	2.28 (1.98; 0.87)	3.08 (1.67; 0.54)	0.0515
Days per week that the individual walks at least 10 minutes at a time	2.83 (2.59; 0.92)	5.15 (1.91; 0.37)	0.0177 *
Hours spent sitting or reclining during a typical day	6.64 (4.08; 0.61)	5.42 (3.35; 0.62)	0.1711

^ Vigorous activity was described as those that caused large increases in heart rate or breathing and may include activities like football, aerobic or running.
+ Moderate activity was described as those that caused small increases in heart rate or breathing and may include cycling, swimming, volleyball or a brisk walk.
* Indicates that the sample means are statistically difference at alpha =0.05

Participants also indicated how many hours they worked at their primary workstation per day as well as the number of hours they spent seated and standing, which are listed below in Table 4.6. While the hours spent per day at the workstation and the hours spent seated to work were not significantly different, the data showed that the group spent significantly less time standing in 2019 with 2.21 hours as opposed to 3.62 hours in 2013. This is likely because four individuals shifted from stand-biased workstations to either a sit-stand or traditional workstation reducing the overall amount of time spent standing.

Table 4.6 Self-reported Occupational time at the workstation

	2013 Mean (SD)	**2019** Mean (SD)	**p-value**
Hours per day at the primary workstation	6.42 (1.60)	5.64 (1.69)	0.151
Hours spent seated	3.08 (1.87)	3.36 (1.86)	0.254
Hours spent standing	3.62 (2.10)	2.21 (1.76)	0.006 *

* Indicates that the sample means are statistically difference at alpha =0.05

4.3.2 activPAL Measures

Participants that consented to be enrolled in the full HSC study were asked to complete objective data collection with the activPAL and RSIGuard software. These components were not included in the original 2013 study on stand-biased workers and as a result only the data collected in 2019 are shown. While only six participants completed the activPAL data collection, the data were reported in the hopes of validating the self-reported data. While the overall standing time was different in 2019, none of the three groups activity measures were significantly different from one another. It is important to note that while not significant, the amount of time that the stand-biased group spent standing and seated at the workstations measured by the AP were higher than the self-reported values for the same time period. This may indicate that individuals spend more time at their workstation both in seated and standing postures than they estimate.

A few participants changed workstation types between 2013 and 2019, hence the data in Table 4.7 are stratified by workstation type. Only six individuals completed these portions of the study and as a result no p-values were reported. It is interesting to note that participants who utilized a stand-biased workstation and consented to wear the activPAL spent slightly more than 50% of the workday standing (4.6 hours) and spent 3.8 hours per day seated with the remaining 35 minutes spent walking. The participant who utilized a sit-stand workstation and wore the activPAL spent approximately two thirds of their day sitting (5.8 hours) and 2.8 hours standing with the remaining 20 minutes walking per day. The traditional workstation user who consented to wear the activPAL spent approximately 80% of the day sitting (7.1 hours) and 1.3 hours per day standing with the remaining 34 minutes walking. While the amount of time spent in seated or standing positions varies amongst the different workstation groups, the amount of time walking per day tends to stay between 20-35 minutes no matter the workstation type. These numbers also follow the trend often seen in studies comparing stand-biased and traditional workstations with stand-biased users spending more time standing, less time sitting but no appreciable difference in occupational walking time.

Table 4.7 2019 activPAL occupational activity measures (8am-5 pm)

	Stand-biased Mean (SD)	Sit-stand Mean (SD)	Traditional Mean (SD)
Hours sitting /day	4.64 (2.05)	5.80 (0.59)	7.09 (0.54)
Hours standing /day	3.76 (1.84)	2.85 (0.79)	1.32 (0.32)
Hours stepping /day	0.59 (0.24)	0.34 (0.19)	0.57 (0.21)
Step count / day	3188.2 (1411.5)	1751.33 (986.1)	3330.67 (1168.4)
Energy Expenditure (METs/day)	13.06 (0.78)	12.36 (0. 26)	12.74 (0.49)
Transitions /day	26.5 (17.26)	19.0 (14.0)	43.3 (4.5)

* Due to the small number of participants in each cohort no measures of significance are reported

One important area to consider is the number of transitions per day by group. The activPAL registers a transition when the individual changes and holds the new posture for a minimum of 10 seconds. The stand-biased group, which is likely already standing, had 26.5 transitions from sitting to a standing position or vice versa per day. The traditional group, which likely starts a transition from the seated position, had 43.3 transitions per day and the sit-stand group had 19.0 transitions per day. While it is plausible for the traditional group to have twice as many transitions as the stand-biased group due to the workstation height, and the need to return to a seated position to return to work, the sit-stand transitions are intriguing. With only 19 transitions per day, this could mean that the individual is not raising and lowering the desktop unit and therefore not experiencing as many transitions as their counterparts due to some undetermined factor. Unfortunately, the questionnaire did not ask any questions about utilization deterrents that individuals experienced and as a result, we are unable to determine why there is such a difference in the desktop sit-stand workstation users' number of daily transitions.

4.3.4 RSIGuard Measures

Each participant contributed 10 occupational working days, however only six participants were included in the data collection. It is difficult to identify any trends amongst the data with such small participant numbers. The one thing to consider is the fact that the number of active computing minutes per day amongst the three groups varies by less than 17 minutes. This means that all of the included participants spent approximately the same amount of time actively utilizing the computer over the course of the collection period. The values for keyclicks, errors, error rate, mouse clicks and distance all vary amongst the three workstation groups. Table 4.8 shows mean computer utilization measures by day for individuals who consented to have the RSIGuard software installed on their computer.

Table 4.8 2019 RSIGuard Computer utilization measures per work day

	Stand-biased	**Sit-stand**	**Traditional**
	Mean (SD)	Mean (SD)	Mean (SD)
Keyclicks	6440.8 (2984.2)	13737.1 (12518.2)	2163.3 (1178.4)
Errors	232.3 (150.5)	494.2 (436.1)	75.4 (48.1)
Words	754.7 (361.9)	1349.4 (1209.3)	178.4 (113.5)
Double mouse clicks	162.5 (122.6)	146.9 (105.1)	178.0 (74.8)
Left Mouse clicks	2014.5 (1216.8)	1884.1 (1329.2)	2063.5 (846.3)
Total mouse distance	136291 (94837.8)	322497 (298200.0)	236572 (116764.7)
Active computing minutes	217.7 (100.8)	222.4 (168.3)	234.4 (104.2)
Error rate (errors/500 words)	153.7 (58.7)	267.0(202.0)	216.4(38.6)

Due to the small number of participants in each cohort no measures of significance are reported

4.4 Discussion

While the number of participants for the follow-up was small, only 28.5% of them changed workstation type during the 6 years since the original study was conducted. During this time, the organization experienced several moves at which point individuals could have changed their workstation with little difficulty. In 2019, 85.7% of the stand-biased users were still spending time standing to work at their workstation. When participant's responses were compared longitudinally, the only two measures that were significant included the number of days per week that participants spending walking at least 10 minutes and the number of hours spent standing. The group currently spends more days walking than they did in 2013 and less time standing to work at the workstation. This may be attributable to a maturation effect due to the increase in age of the group in 2019 that is consistent with a follow-up. It could also be because the group has realized over the 6-year period that you do not have to stand 100% of the time at a stand–biased workstation to see benefits.

While the questionnaire did not specifically ask participants to answer questions that would indicate they understood the differences between stand-biased, sit-stand and traditional workstations, all participants had a stand-biased workstation in 2013 in order to be included in the study. Participants were categorized by the research team as opposed to the answers provided by the participant to minimize classification error. While 12 of 14 participants indicated that they spent time standing at the workstation, which seems to be in alignment with the comments they provided, 10 of them also indicated that they had used a sit-stand workstation. Only three of the participants were classified by the research team as sit-stand users at the time of data collection, which means that seven individuals indicated they used a sit-stand workstation which cannot be verified. This discrepancy in workstation identification by the participants indicates that the individuals may not have been fully aware of the differences in workstation types. Ten individuals indicated that they utilized a stand-biased workstation, which fits with the researcher's classification.

While objective computer utilization data and occupational activity were collected, only six individuals consented to participate in objective data collection with activPAL and RSIGuard. More participants are needed in each group to allow between group comparisons of the data. Additionally, while every effort was made to minimize classification and recall bias in this study, the time between the original study and follow-up may be too long. While the data collected is certainly informative, shortening the follow-up period and conducting several follow-up iterations may be a better way to collect the needed data to characterize long-term computer utilization and workstation use.

Of the individuals who participated in objective data collection, one individual utilized a sit-stand workstation, one individual utilized a traditional workstation and the remaining four individuals utilized stand-biased workstations. With only one individual in two of the three groups, comparing the objective data is difficult. The activPAL data trends were consistent with previous data collected in the HSC study with respect to sitting and standing time. Over the 10-day collection period, stand-biased users spent more time standing and less time sitting than either of the remaining groups. The data for transitions by workstation type were interesting with the traditional group having more transitions than either the stand-biased or sit-stand group. While most of the RSIGuard data are difficult to interpret due to the small and unequal number of participants in each of the groups, one thing to note is that the average number of active computing minutes varies by less than 17 minutes amongst the three groups. This indicates that the individuals who agreed to wear the activPAL spent similar amounts of time actively working at the computer. With more individuals in each group, the data could have been evaluated to determine if there were any differences in typing vs mousing to more fully characterize computer utilization.

4.4.1 Limitations

The sample size of the current study is extremely small. This may increase the possibility that small changes in computer utilization or physical activity could be reported as significantly different. Of the original 2013 study population, two participants had retired and three had taken new positions outside of the university and were unable to participate in the follow-up. Only 14 of the original 25 participants consented to be included in the follow-up study. This equates to a 44% loss to follow-up. Due to the extended time period between the original study in 2013 and the current data collection, the chance of recall bias increases considerably. The average number of months participants had used a stand-biased workstation was 60.7 months, which equates to slightly more than 5 years. This takes into account the average number of months of use in 2013 which was 11.9 months as well as the fact that four individuals no longer utilized a stand-biased workstation and as a result did would not have contributed to this average. Additionally, 92.8% of the study population was female making it difficult to extrapolate the results to the male population.

Only 42% of the current study population consented to complete the activPAL and RSIGuard components of the study. This could introduce selection bias, due to some individuals choosing to participate in all three components of the study as opposed to just completing the questionnaire. With all three types of workstations represented, it was difficult to compare computer utilization measures collected from RSIGuard with any significant power.

4.4.2 Strengths

This study is currently the first to conduct a 6-year follow-up of stand-biased workers in any setting. The researchers were able to utilize the same questionnaire at both time points to increase the ability to compare measures longitudinally. In addition, several individuals consented to participate in objective data collection with the activity sensors and computer data logging software. These measures help quantify actual time spent standing and sitting at the workstation and the specific computer utilization variables.

4.5 Conclusion

This study suggests that the majority of individuals who choose to use a stand-biased workstation maintain their selection over time. The fact that none of those individuals who changed workstation types during the 6 years between studies reported discomfort as the reason for the switch is encouraging. Additionally, only one individual in the follow-up group chose to return to a traditional workstation. While participants in 2019 reported less standing time than they did in 2013 they still managed to spend more than 2 hours per day standing. This combined with the fact that 85% of the study population was still spending time standing to work 6 years after implementation, suggests that stand-biased workstations have been accepted as a suitable alternative to traditional workstations in the academic setting.

5. CONCLUSIONS

5.1 Findings form Dissertation Studies

The three studies included in this dissertation all evaluate computer utilization and discomfort of workers utilizing sit-stand or stand capable workstations, with all three utilizing Enviance's RSI Guard™ as the software package used to track computer utilization measures. Additionally, the participants in all three studies were assigned to a cohort based on their workstation type at the time of enrollment in the study. Table 5.1 shows a comparison of several notable RSI Guard™ measures for both the RSI-OES study and the HSC Study. While

Table 5.1 Comparison of RSI Guard™ variables for participants in RSI-OES study and the HSC Study at the conclusion of each study

	RSI-OES Traditional (n= 6,741)	HSC Study Traditional (n=20)	RSI-OES Sit-stand (n=3,404)	HSC Study Sit-stand (n= 22)	HSC Study Stand-biased (n=21)
Mouse hours	2.5954	---	3.3162	---	---
Keyboard hours	0.9782	---	1.1851	---	---
Total computer minutes	177.10	216.4	220.01	214.7	207.8
Words per day	563.1	637.8	643.9	677.3	794.7
Keypresses	5141.1	5788.9	6005.5	6319.3	7032.5
Typos	167.1	172.7	203.1	223.3	247.6
Mouse clicks (left)	2115.6	2002.3	2777.9	1860.8	2152.7
Mouse travel	96677.7	135165.8	139182.0	150410.4	154574.1
Typo rate per 500 words	159.3	170.8	168.5	180.8	191.6

--- Indicates there is no comparison measurement available

the circumstances under which the studies were conducted varied, the outcomes are similar to one another for each variable. The data for the RSI-OES Data Analysis study was collected as part of a wellness initiative at a large California corporation. The organization currently employs individuals in a variety of occupations, leading the researchers to believe that while the participants all completed administrative work they are likely from multiple different occupations throughout the company. The HSC and Follow-up studies were conducted at an institute of higher education with an emphasis on public health. These participants were very much aware of the potential health benefits of occupational activity and some even participate in walking groups to increase their activity levels throughout the day.

Results from the RSI-OES data analysis showed that all but one variable reviewed during the study was statistically significant. The most notable finding focused on active minutes utilizing the computer. Overall, active computing time of sit-stand users was almost 45 minutes more per day than the traditional counterparts. Both mousing and keyboarding showed the same trends with those having a sit-stand workstation out performing their traditional counterparts. Another result of note was that the majority of all active computing time was registered as active mousing as opposed to typing.

The HSC study was considerably smaller in population size than the previous study but the protocol included objective measures of activity in addition to objective computer utilization measures. The participants were divided into one of three cohorts, as opposed to two, based on a more stringent definition of stand-capable workstation types. The data showed that the stand-biased cohort had statistically higher word count and more errors than the traditional group, but not the sit-stand group. It did however show that the calculated error rate, which was within 20 per 500 errors, was not statistically different among all three groups. This means that while stand-biased users produce more words per day, their error rate is not appreciably different than their traditional or sit-stand counterparts. The activPAL™ sensors are designed to track 24-hour activity, but the focus of the current dissertation was on occupational activity so the data were limited to data collected between 8 am and 5 pm. Step count and stepping time was not significantly different among the groups but the sitting time was significantly more for the traditional group than either the stand-biased or the sit-stand groups. Similarly, the time standing was significantly less in the traditional group than for either the stand-biased or the sit-stand group. While the stand-biased group reported the highest minutes per hour standing at 21.5 it was not statistically different than the sit-stand group, which reported 20.1. An interesting finding was identified in the number of transitions per hour. Individuals in the traditional group had statistically more transitions per hour when compared to both the stand-biased and sit-stand groups; however, the stand-biased and sit-stand groups had more energy expenditure (METs) than the traditional group. This may be due to the traditional group compensating for the sedentary nature of their workstation type by adding occupational activity. While subjective in nature the study also reported percent of individuals who spent time standing at the workstation with 90% of stand-biased users indicating that they stand to work at their workstation. Only 65% of sit-stand users indicated that they stand to work and a surprising 26% of traditional workstation users indicated that they stand to work. One question that yielded surprising results was the one which asked if participants were currently utilizing a stand-biased workstation. While 90% of true stand-biased users indicated that they used a stand-biased workstation, 60% of sit-stand users and 8.7% of traditional users indicated that they were currently utilizing a stand-biased workstation. This confirms the fact that most participants were not clear on the different workstation types as each participant was categorized by the research team based on observation of workstation at the time of enrollment rather than based on the participants answer to this question. Another interesting finding was that the only area that showed a significant difference on the NMQ was low back with 80% of traditional users indicating some discomfort over the last 12 months as compared to 51.7% of stand-biased users indicating some pain over the last year.

While the number of participants for the follow-up was small, only 28.5% of them changed workstation type during the 6 years since the original study was conducted. During this time the organization experienced several moves at which point individuals could have changed their workstation with little difficulty. Similar to the HSC study, 85.7% of the stand-biased users were still spending time standing to work at their workstation. When participant's responses were compared longitudinally, the only two measures that were significant were the number of days per week that they spending walking at least 10 minutes and the number of hours spent standing. The group spends more days walking than they did in 2013 and less time standing to work at the workstation. This may be attributable to the increase in age or the realization that you do not have to stand 100% of the time at a stand–biased workstation to see benefits. Only six of the 14 consented to participate in objective data collection with the activPAL™ and RSI Guard™ but similar to the HSC study, the active computing minutes were not significantly different among the groups. While the RSI Guard™ data were reported with only one participant in the sit-stand and traditional group it is difficult to extrapolate these values to a larger group of individuals.

5.2 Implications for Future Research

5.2.1 RSI-OES California Study

This study utilized data collected form a California corporation as part of a company workplace wellness initiative. It included over 10,000 participants which increased the power of the study. However, this study did not include any demographics which made the information hard to relate to other populations of interest. The research team worked diligently to obtain this information, but was unable to do so at the time of this publication. It will be important for future researchers to ensure that some type of demographics are included in the data use agreement. While the data set included a multitude of computer utilization variables, it did not include any measures on occupational workstation activity or sit-stand use. Future studies need to be able to quantify that participants not only have access to a sit-stand but how often they use it to establish a dose response relationship

5.2.2 HSC Workstation Study

Several issues presented themselves over the course of this study. It is important for researchers to ensure that their population of interest is available during the study collection period. Use of quantifiable measures is key to any good research study. However, it is important to ensure that all of the computer operating systems collect all of the same data across the board at the onset of the study. This way future studies will not be limited to those variables that are consistent in the collected file types. Additionally, it is important to test and re-test your programable sensors factoring in the needed time to distribute them to the participants. Future studies would benefit from a full 2 weeks of occupational activity collection, but this will take planning and coordination. Some participants indicated that they had concerns about how some of the questions were worded. While the current research team worked diligently with the IRB to make sure that the questionnaire was written clearly, there was still confusion. Allocating the additional time to administer the questionnaire in person could prevent confusion for future researchers.

5.2.3 Follow-up Stand-biased study

The data collected indicate that self-reported data may not accurately reflect the true amount of time an individual spends at their workstation. As a result, future research needs to focus on utilizing objective measures of data collection to objectively quantify the measures of interest. Additionally, it would be highly beneficial if another study could be conducted which included a larger sample size. While the current data are interesting, 14 participants is not enough to generalize workstation use.

5.3 Final Conclusions

All three of the studies included in this dissertation focus on evaluation of computer utilization and discomfort of administrative workers in real world settings. While they vary in duration and number of participants, there are several common themes that can be found in the data. Both the RSI-OES and HSC Study showed that stand-capable users (including stand-biased and sit-stand users) type more words per day than their traditional counterparts. When considering the number of keystrokes, the stand-capable groups had anywhere from 864 - 1,243 more keys pressed per day. While not significant between the groups in each individual study, the error rate per 500 words typed varied by less than 10% when both studies were considered side by side. Based on these key pieces of information, users of stand capable workstations are more likely to type more words per day with more keystrokes per day and a comparable error rate. This combined with the statistical increase in METs and stand time during the workday; indicate that stand-capable workstations are beneficial for not only the user's health and wellbeing but also the employer's bottom line.

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APPENDIX A: RECRUITMENT EMAIL

Subject: Recruiting Participants for a Workstation Productivity Study at HSC

Content

Howdy,

The department of Environmental and Occupational Health is interested in understanding work behaviors, long-term utilization, and productivity patterns of individuals with various workstation types. We are looking for individuals that currently have a stand-biased workstation as well as those that have a traditional seated workstation.

In this study, participants will be asked to download an ergonomic software on their primary work computer with the assistance of HSC information technology. The software will run in the background for four (4) weeks. Participants will also be asked to wear a physical activity tracker for five workdays. There will also be a 15-20 minute questionnaire that includes demographic data, environmental assessments, and discomfort levels. Participants will be offered a $100.00 VISA Gift Card for completion of the study.

We hope you will consider being a participant. Please take a few minutes to review the attached information sheet and let us know if you have any questions. If you are willing to participate please send an email indicating your availability to either of the Protocol directors listed below. This study has been reviewed and approved by the Texas A&M Institutional Review Board (IRB 2018_0617D).

We look forward to working with you!

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APPENDIX B: CONSENT FORM

Texas A&M Health Science Center Workstation Study
CONSENT FORM

Introduction

The purpose of this form is to give you information that will help you decide if you want to participate in a workstation study. If you decide to participate in this study, this form will be used to document your consent.

The purpose of the study is to identify the benefits of stand-biased desks compared to traditional workstations as well as analyze the ideal office environment. The study will evaluate the use of stand-biased workstations body discomfort, computer usage, productivity, and reductions in sitting time. This study is being sponsored/funded by Texas A&M University.

Definitions:

Traditional office: an assigned office in a commercial building that is regularly maintained by

the owner

Home office: a designated space to work within a primary residence

Traditional workstation: a fixed height workstation set up for seated work and a normal chair.

Stand-biased workstation: a raised desk and a tall chair that allows both sitting and standing without changing the desk height.

What will I be asked to do?

Screening Visit (visit #1): Once you schedule a meeting with the research team, a researcher will visit your workplace to explain the study and answer your questions. Once you give consent, the team will make sure that the data collection software is installed on your computer. The team will provide you with a unique identification number so that all of your data will remain confidential. This visit should take between 20-30 minutes.

If the time between your screening visit and the first day of your study period is longer than 3 weeks, the research team may visit you to make sure the software is working properly before "day 1" of the study. The study will run silently on your computer for up to four weeks.

Day 1: The software will begin to collect productivity data on day 1 and continue through the end of your study period. This will include time using the keyboard, time using the mouse, typos, words per minute, and total computer time. You will not be required to do anything special for this part of the data collection. Software will be removed at the conclusion of the study.

You will be asked to answer a questionnaire including questions on your height, weight, gender, race, physical work environment, non-work environment, and discomfort. You will also estimate the amount of time that you spend at your workstation. You will be asked to estimate how long it took to get used to working at your desk. You will also answer questions on amount of time participating in sports, walking and watching TV. You will also be asked about the presence of certain items in your workspace, such as dehumidifiers and candles. The questionnaire should take approximately 15-20 minutes to complete.

A sub-sample of participants will be asked if air quality samples can be collected from the office space. If you agree to participate, the air quality monitor will be set up in a representative location that is not in the way of your daily tasks. The monitor will run continuously throughout the week and is not expected to distract or displace you in any way.

Researchers will visit **(visit #2)** your work area to place the activPAL^{TM} sensor on your leg on the afternoon of day 1. The activPAL^{TM} sensor will be used to collect data including time sitting, time standing, steps and time stepping, number of sit to stand transfers and energy expenditures measured in METs. The sensor will have a latex free waterproof covering and be secured to the leg with 3M^{TM} Tegaderm^{TM} transparent film dressing (commonly used to cover IVs). To protect your privacy, you should be prepared to wear or change into shorts to allow the researchers to place the sensor on your leg. The sensor will be in place for 5 days. You will be able to complete normal activities including exercising, doing yard work and showering while wearing the sensor. We ask that you refrain from taking baths and swimming or aggressively rubbing the dressing area. You will be able to wear any clothing, as long it is not restrictive on the leg area. The covering can pull hair and you may want to shave the area first. This should take approximately 5 minutes.

Additionally, if selected to participate in office air monitoring, the researcher will set up the air monitor in a non-intrusive location. He or she will explain how the monitor works and who you should contact if anything should happen to the machine. For example, if the machine is accidentally knocked off of a surface, you can contact the researcher to address the issue.

Day 5: Researchers will return **(visit #3)** to your work area to remove the sensor and air monitoring equipment. We ask that you wear or change into shorts to allow for sensor removal. This will take approximately 3-5 minutes.

Day 26: This is the final day of data collection. At the end of the day, you will be visited **(visit #4)** by the research team and asked to complete the questionnaire noting any areas of discomfort. This will take you approximately 5-10 minutes.

At the end of the study, researchers will visit you one final time **(visit #5)** to remove the software from your workstation. This will take approximately 10 minutes.

Information collected as part of this study will not be shared with your supervisor or the Texas A&M System Human Resources Department.

What are the risks involved in this study?
The risks linked with this study are minimal. The research team has made plans to use latex free products to minimize any risk due to a latex allergy. There is a possibility that the covering may pull hair when removed and as a result we suggest that you shave the area prior to sensor placement to minimize this. Please understand that participation in this study is not a substitute for consultation with a physician for any medical issues you may have.

What are the possible benefits of this study?
You will not receive a direct benefit from participating in this study; but information collected will help guide workstation changes to help reduce sedentary time and improve health.

Do I have to participate?
No, you do not have to participate in this study. Your participation is voluntary and is not a condition of your employment at Texas A&M. There is no penalty for choosing not to participate, and you can withdraw from any part of the study at any time.

Is there compensation for participation?
If you choose to participate in the study, you will receive a $100 gift card when the researchers pick up the workstation questionnaire. You will receive this compensation in person.

Who will know about my participation in this research?
The data collected in this study will be kept confidential to the extent allowed by law. No personal information linking you to this study will be used in any published documents. Data will be stored securely and only Texas A&M Researchers and members of the Human Research Protection Program will have access to the information.

Who do I contact with questions about the research?
If you have questions about this study, you may contact the Principle Investigator, Dr. Mark Benden at mbenden@sph.tamhsc.edu, Ms. Tricia Salzar at (281) 386-8801 tsalzar@sph.tamhsc.edu, or Ms. Kamrie Sarnosky at (931) 551-5023.

Who do I contact about my rights as a research participant?
This study has been reviewed and approved by the Human Research Protection Program and the Institutional Review Board at Texas A&M University. For problems or questions regarding your rights as a participant, you can contact the offices at (979) 458-4067 or irb@tamu.edu.

Signature
Be sure you have read the information above and have received answers to all your questions. By signing below, you consent to participate in this study for the 4-week collection period. You will be given a copy of the signed consent form for your records.

Signature:____ Date:______________

Printed Name:

____

Type of workstation you will be using:

☐Traditional ☐Stand-biased ☐Sit-stand ☐Unsure

Location of your primary work place:

☐Office Building ☐Home Office

Future Studies:
The researcher may contact me in the future to see if I am interested in participating in other research studies by the principle investigator of this study

I agree ______________ I disagree ___________________

Signature of Person Obtaining Consent: ___________________________________

Printed Name of Person:________________________________ Date: ___________

APPENDIX C: ActivPAL^{3}™ Information Sheet

The activPAL™ is an activity monitor that provides a measures of your activity. It has been used in numerous studies and publications on sedentary time and activity levels. The current study will be utilizing the monitor to provide quantitative data on participants' activity levels. This information sheet will give you some details on what you can expect to see when the research team places the activPAL™.

All participants will wear the activPAL for 5 days. The monitor may be one of two types, an activPAL™ 3or an activPAL™ micro (both are seen in Figure C-1).

Figure C-1 activPAL™ 3c and activPAL™ micro, Reprinted from PAL Technologies, 2020

The research team will water proof the activPAL™ so that it can be used with normal daily activities including exercising, bathing and showering. A non-latex finger cot and Tegaderm surgical bandage will be used to seal the monitor from accidental water intrusion and the top of the activPAL™ with be indicated with an arrow (seen in image 2 below). Participants should refrain from swimming or bathing during the 5 days when wearing the activPAL™.

Figure C-2 Waterproofed activPAL™

Figure C-3 Placement of the activPAL™

The research team will assist with the placement of the monitor on the anterior thigh as seen in image 3 if needed. Participants are encouraged to wear or change into shorts for the monitor placement. A sterile dressing (3M Tegaderm^{TM}) will be used to secure the monitor to the thigh. The dressing will allow participants to go about their normal daily activities without worrying about the monitor being dislodged.

Figure C-4 Tegaderm Covering

Figure C-5 activPAL^{TM} secured to the thigh

On the 5th day, a member of the research team will return to the participant's location to collect the activPAL^{TM}. The monitors will then be downloaded and associated with the participants assigned unique identification number to protect the participant's privacy.

Video on ActivePAL3 use:

https://www.youtube.com/watch?v=BuaRHz_BOA4

https://www.youtube.com/watch?v=cgGqHrawpKw

APPENDIX D: HSC WORKSTATION INTERVIEW/QUESTIONNAIRE

Participant ID:________________

Section 1: Demographics (optional)

1. How tall are you?
2. How much do you weigh?
3. What is your age?
4. Do you identify yourself as Hispanic or Latino?
5. What is your race?
    a. American Indian or Alaskan Native
    b. Asian
    c. Black or African American
    d. Native Hawaiian or Pacific Islander
    e. White or Caucasian
    f. Multiracial or more than one race
6. What is your gender?
7. What is the highest education you have completed?
    a. Less than high school
    b. High school degree
    c. Undergraduate degree
    d. Postgraduate degree
    e. Prefer not to answer
8. What is your current occupation?
9. What is your annual household income?
    a. $10,000-20,000
    b. $20,000-50,000
    c. $50,000-75,000
    d. $100,000-150,000
    e. $150,000-200,000
    f. >$200,000
    g. Prefer not to answer

Section 2: Work Environment

10. How many hours a day do you estimate that you are at your primary workstation during a typical 8-hour work day? ________________________

11. Of those hours- how many hours do you believe are spent in the following postures:
    a. seated ______________
    b. standing ______________

12. Do you possess any of the following items at your workstation?
    a. Footrest
    b. Monitor arm

c. Adjustable keyboard tray
d. Standing pad/anti-fatigue mat
e. None of the above
f. Other (please specify):

13. Do you spend time standing at your primary workstation throughout a traditional workday?
    a. Yes
    b. No

14. Have you ever used a sit-stand workstation?
    a. Yes
    b. No

15. Do you currently have a standing biased workstation?
    a. No, Why?____
    b. Yes, How long have you had it: ____

16. Do you have live plants in your office?
    a. Yes
    b. No

17. Are there room deodorizers (such as a wall plug-in, essential oil diffusers) in the area(s) in which you work?
    a. Yes
    b. No
    c. Unsure
        i. Have you used these items in the past week?
            a. Yes
            b. No
            c. Unsure

18. Are there air purifiers in the area(s) in which you work?
    a. Yes
    b. No
    c. Unsure
        i. Have you used these items in the past week?
            a. Yes
            b. No
            c. Unsure

19. Do you use aromatic candles in the area(s) in which you work?
    a. Yes
    b. No
    c. Unsure
        i. Have you used these items in the past week?

1. Yes
2. No
3. Unsure

20. Do you use a space heater in your office space?
    a. Yes
    b. No
    c. Unsure

21. Is there an area rug in your office space?
    a. Yes
    b. No

22. Is there carpet in your office space?
    a. Yes
    b. No

Section 3: Non-work Environment (The following questions will cover your physical activity and habits outside of the work environment).

23. In a typical week, on how many days do you participate in vigorous-intensity sports, fitness or recreational activities that cause large increases in heart rate or breathing (may include activities like football, aerobics or running) ________________________

24. How much time do you spend doing vigorous-intensity activities on a typical day?
____

25. In a typical week, on how many days do you participate in moderate-intensity sports, fitness or recreational activities that cause small increases in heart rate or breathing (may include activities like brisk walking, cycling, swimming or volleyball)__________

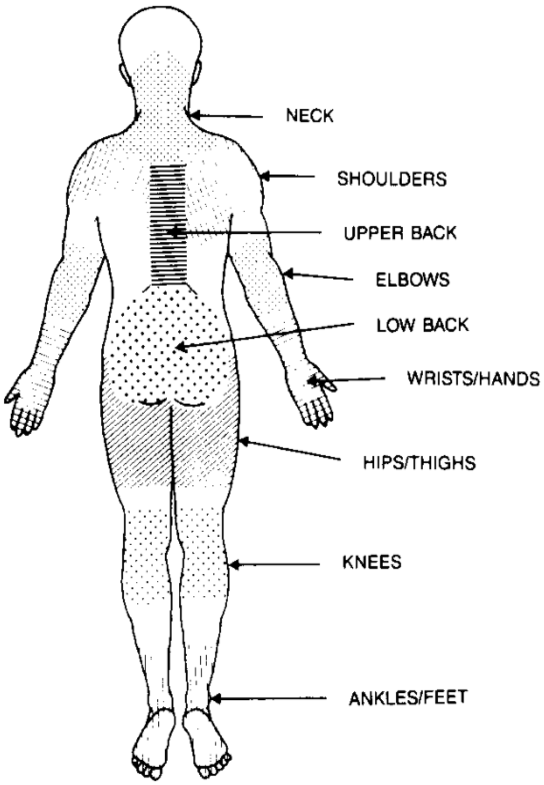
26. How much time do you spend doing moderate-intensity activities on a typical day?
____

27. In a typical week, on how many days do you walk for at least 10 minutes at a time? This includes walking at work, walking at home, walking for travel from place to place and any other walking that you do completely for recreation or leisure. _______________

28. How much time do you spend walking for recreation or leisure on a typical day?
____

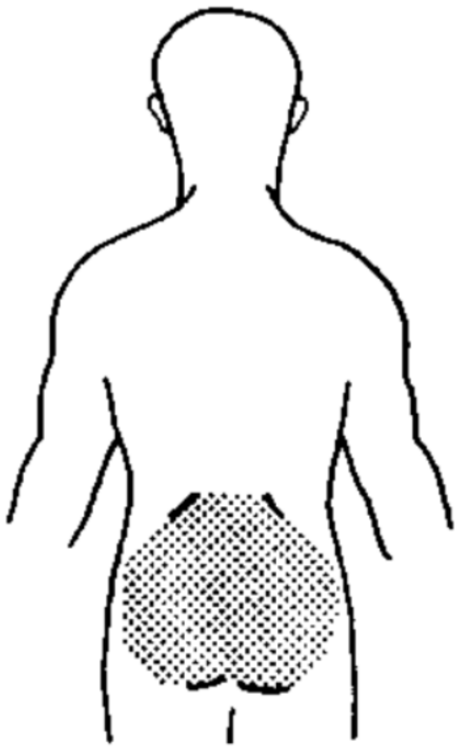
29. How much time do you typically spend sitting or reclining on a typical day? (this includes all sitting time to include time spent at a desk, sitting with friends, travelling by bus, car or train, reading, playing cards or watching television but not including time spent sleeping)? ____

Section 4: Musculoskeletal Discomfort based on the NORDIC Questionnaire (*Applied Ergonomics* 1987, 18.3, 233-237)

Locomotive Organs:	**Have you at any time within the last 12 months had trouble (ache, pain or discomfort) in:**	**To be answered only by those experiencing trouble.**	
Please answer by placing a check in the appropriate box for each question. You may be in doubt as to how to answer but please do you best anyway. Please answer every question, even if you never have any trouble in any part of your body.		Have you at any time during the last 12 months been prevented from doing your normal work because of trouble?	Have you had trouble with in the last 7 days?
	Neck: □ No □ Yes	□ No □ Yes	□ No □ Yes
	Shoulders: □ No Yes, in the right shoulder Yes, in the left shoulder Yes, in both shoulders	□ No □ Yes	□ No □ Yes
	Elbows: □ No □ Yes, in the right elbow □ Yes, in the left elbow □ Yes, in both elbows	□ No □ Yes	□ No □ Yes
	Wrist/Hands: □ No □ Yes, in the right wrist/hand □ Yes, in the left wrist/hand □ Yes, in both wrists/hands	□ No □ Yes	□ No □ Yes
	Upper Back: □ No □ Yes	□ No □ Yes	□ No □ Yes
	Lower Back (small of the back): □ No □ Yes	□ No □ Yes	□ No □ Yes
	One or both hips: □ No □ Yes	□ No □ Yes	□ No □ Yes
	One or both Knees: □ No □ Yes	□ No □ Yes	□ No □ Yes
In this diagram, you can see the approximate position of the parts of the body referred to in the questions. Limits are not sharply defined and may overlap. You should decide for yourself which part you have or have had your trouble.	One or Both ankles/feet: □ No □ Yes	□ No □ Yes	□ No □ Yes

Low Back:

In the picture below you can see the approximate position of the part of the body that is referred to in the questions. BY low back trouble is meant ache, pain, or discomfort in the shaded area whether or not it extends from there to one or both legs (sciatica).



Please place a check in the appropriate box (one per question). You may be in doubt as to how to answer, but please do you best.

1. Have you ever had low back trouble (ache, pain or discomfort)?
   □ No □ Yes

If you answered NO to question 1, do not answer questions 2-8.

2. Have you ever been hospitalized because of low back trouble?
   □ No □ Yes

3. Have you ever had to change jobs or duties due to low back trouble?
   □ No □ Ye

4. What is the total length of time that you have had low back trouble during the last 12 months?
   - □ 0 days
   - □ 1-7 days
   - □ 8-30 days
   - □ More than 30 days, but not every day
   - □ Every day

5. Has low back trouble caused you to reduce your activity during the last 12 months?
   a. work activities (at home or away from home)
   □ No □ Yes
   b. leisure activities
   □ No □ Yes

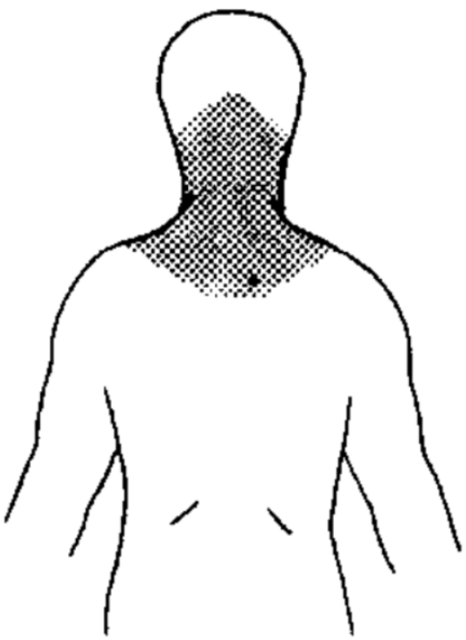
6. What is the total length of time that low back trouble has prevented you from doing your normal work during the last 12 months?
   - □ 0 days
   - □ 1-7 days
   - □ 8-30 days
   - □ More than 30 days, but not every day
   - □ Every day

7. Have you been seen by a doctor, physical therapist, chiropractor or other such person because of low back trouble in the past 12 months?
   □ No □ Yes

8. Have you had any low back trouble in the past 7 days?
   □ No □ Yes

Neck:

In the picture below you can see the approximate position of the part of the body that is referred to in the questions. By neck trouble is meant ache, pain, or discomfort in the shaded area. Please concentrate on this area ignoring any trouble you have in adjacent areas of the body.



Please place a check in the appropriate box (one per question). You may be in doubt as to how to answer, but please do you best.

1. Have you ever had neck trouble (ache, pain or discomfort)?
   □ No □ Yes

If you answered NO to question 1, do not answer questions 2-8.

2. Have you ever hurt your neck in an accident?
   □ No □ Yes

3. Have you ever had to change jobs or duties due to neck trouble?
   □ No □ Ye

4. What is the total length of time that you have had neck trouble during the last 12 months?
   □ 0 days □ 1-7 days
   □ 8-30 days □ More than 30 days, but not every day
   □ Every day

If you answered 0 days in question 4, do not answer questions 5-8

5. Has neck trouble caused you to reduce your activity during the last 12 months?
   a. work activities (at home or away from home)
   □ No □ Yes
   b. leisure activities
   □ No □ Yes

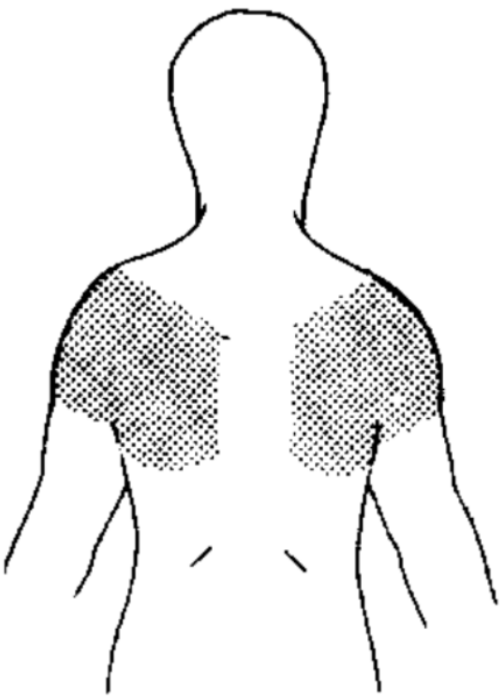
6. What is the total length of time that neck trouble has prevented you from doing your normal work during the last 12 months?
   □ 0 days □ 1-7 days
   □ 8-30 days □ More than 30 days, but not every day
   □ Every day

7. Have you been seen by a doctor, physical therapist, chiropractor or other such person because of neck trouble in the past 12 months?
   □ No □ Yes

8. Have you had any neck trouble in the past 7 days?
   □ No □ Yes

Shoulder:

In the picture below you can see the approximate position of the part of the body that is referred to in the questions. By shoulder trouble is meant ache, pain, or discomfort in the shaded area. Please concentrate on this area, ignoring any trouble you many have in adjacent parts of the body.



Please place a check in the appropriate box (one per question). You may be in doubt as to how to answer, but please do you best.

1. Have you ever had shoulder trouble (ache, pain or discomfort)?
□ No □ Yes

If you answered NO to question 1, do not answer questions 2-8.

2. Have you ever hurt your shoulder in an accident?
□ No □ Yes, my right shoulder □ Yes, both shoulders
□ Yes, my left shoulder

3. Have you ever had to change jobs or duties due to shoulder trouble?
□ No □ Yes

4. Have you had shoulder trouble in the last 12 months?
□ No □ Yes, my right shoulder □ Yes, both shoulders
□ Yes, my left shoulder

If you answered NO to question 4, do not answer questions 5-9

5. What is the total length of time that you have had shoulder trouble the last 12 months?
□ 1-7 days □ 8-30 days
□ More than 30 days, but not every day
□ Every day

6. Has shoulder trouble caused you to reduce your activity during the last 12 months?
a. work activities (at home or away from home) □ No □ Yes
b. leisure activities □ No □ Yes

7. What is the total length of time that shoulder trouble has prevented you from doing your normal work during the last 12 months?
□ 0 days □ 1-7 days
□ 8-30 days □ More than 30 days

8. Have you been seen by a doctor, physical therapist, chiropractor or other such person because of shoulder trouble in the past 12 months?
□ No □ Yes

9. Have you had any shoulder trouble in the past 7days?
□ No □ Yes, my right shoulder □ Yes, both shoulders
□ Yes, my left shoulder

APPENDIX E: RSI-OES SIT-STAND STUDY GRAPHS

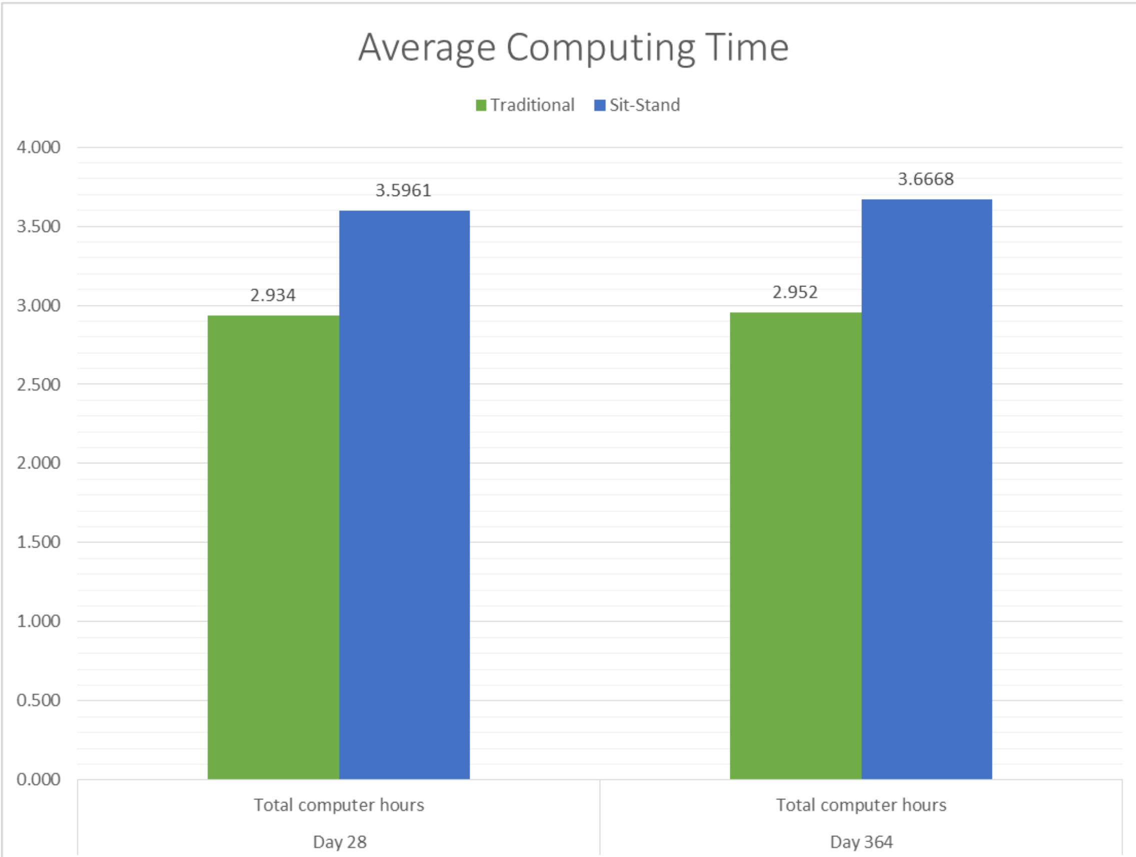


Figure E1 Average number of hours spent actively computing per day at both time points stratified by workstation type

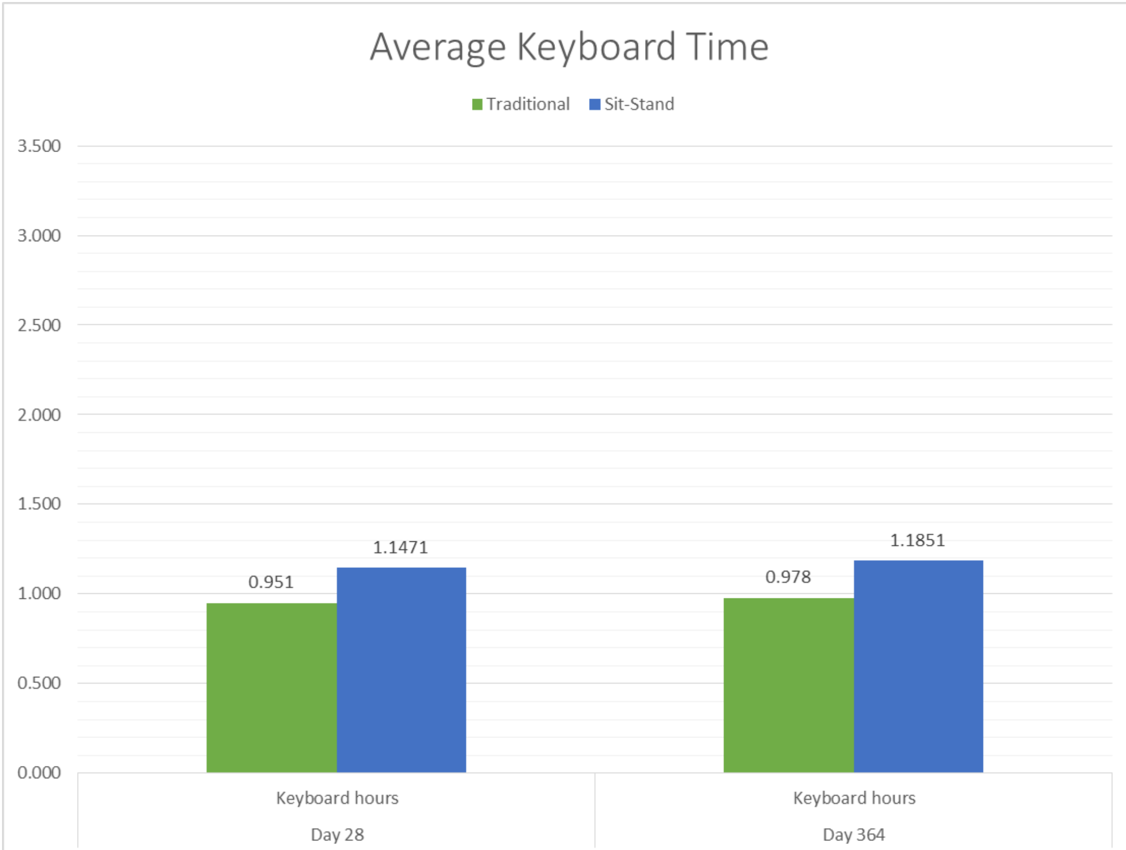


Figure E2 Average number of hours spent actively keyboarding per day at both time points stratified by workstation type

Figure E3 Average number of hours spent actively mousing per day at both time points stratified by workstation type

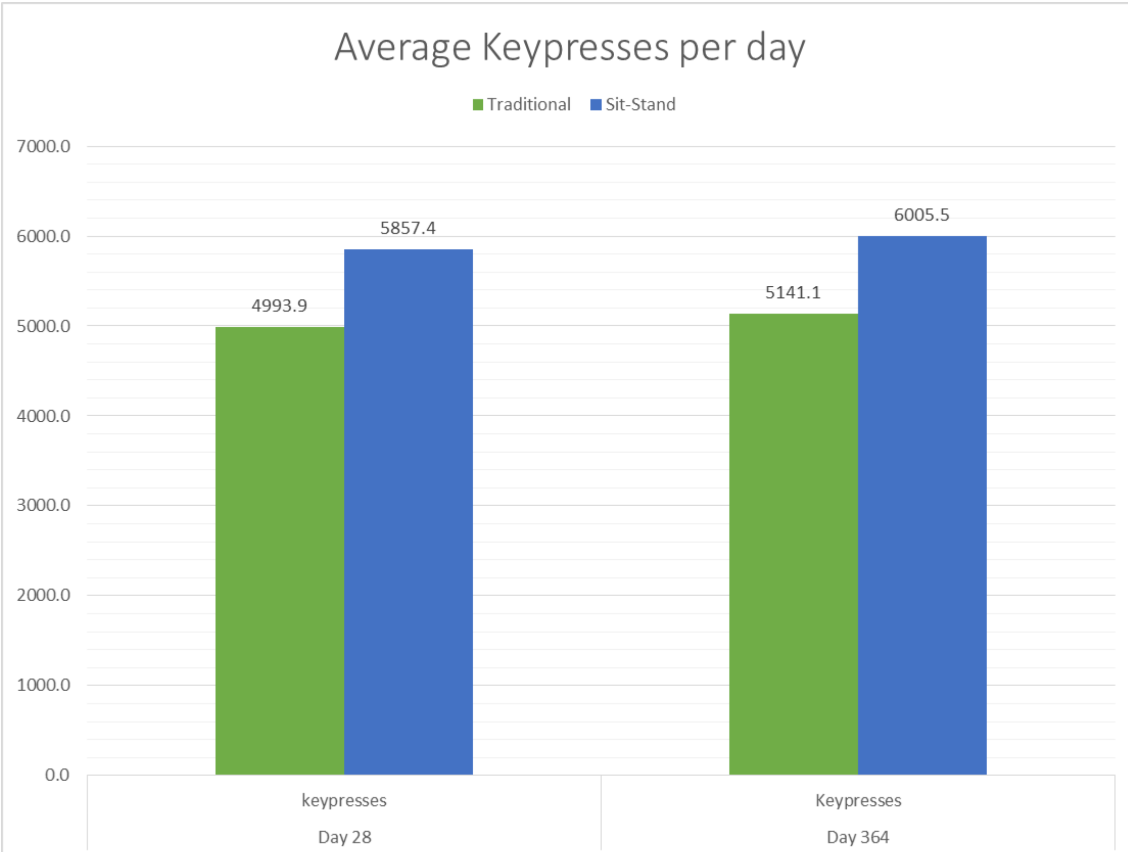


Figure E4 Average number of keys pressed per day at both time points stratified by workstation type

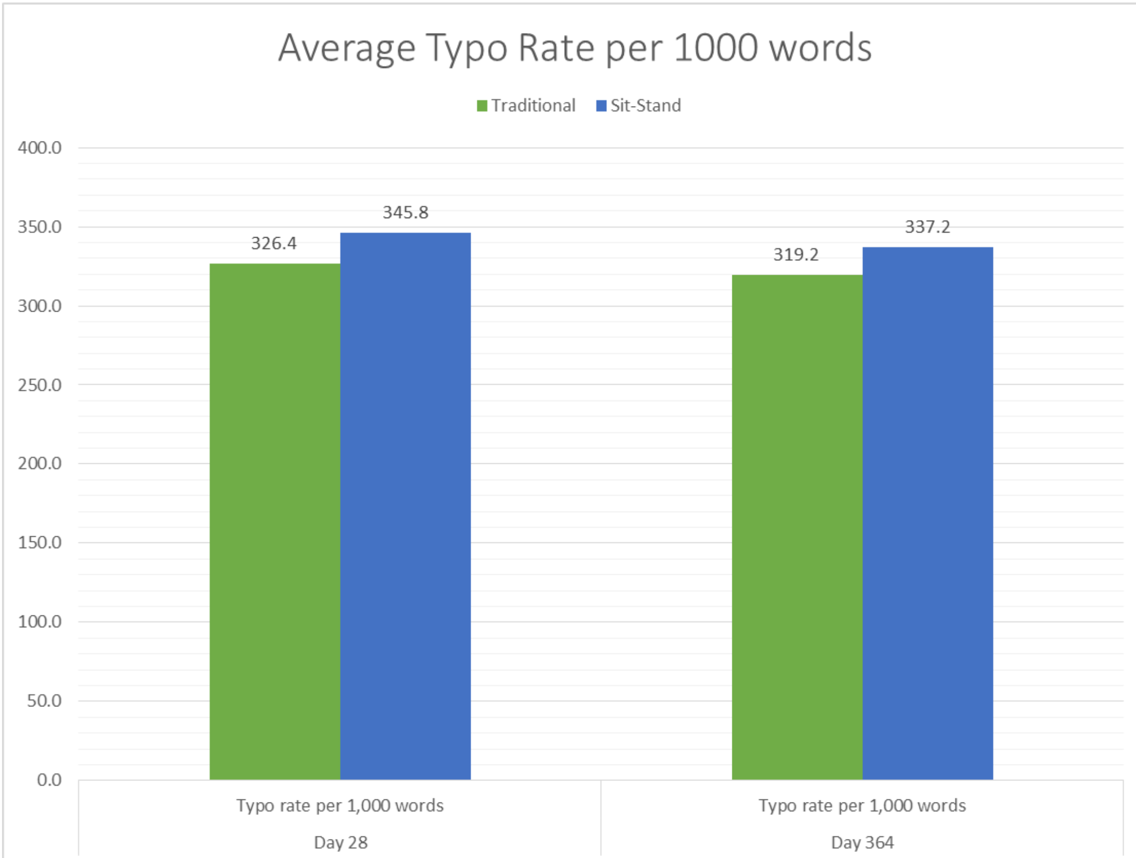


Figure E5 Average typo rate per 1000 words typed per day at both time points stratified by workstation type

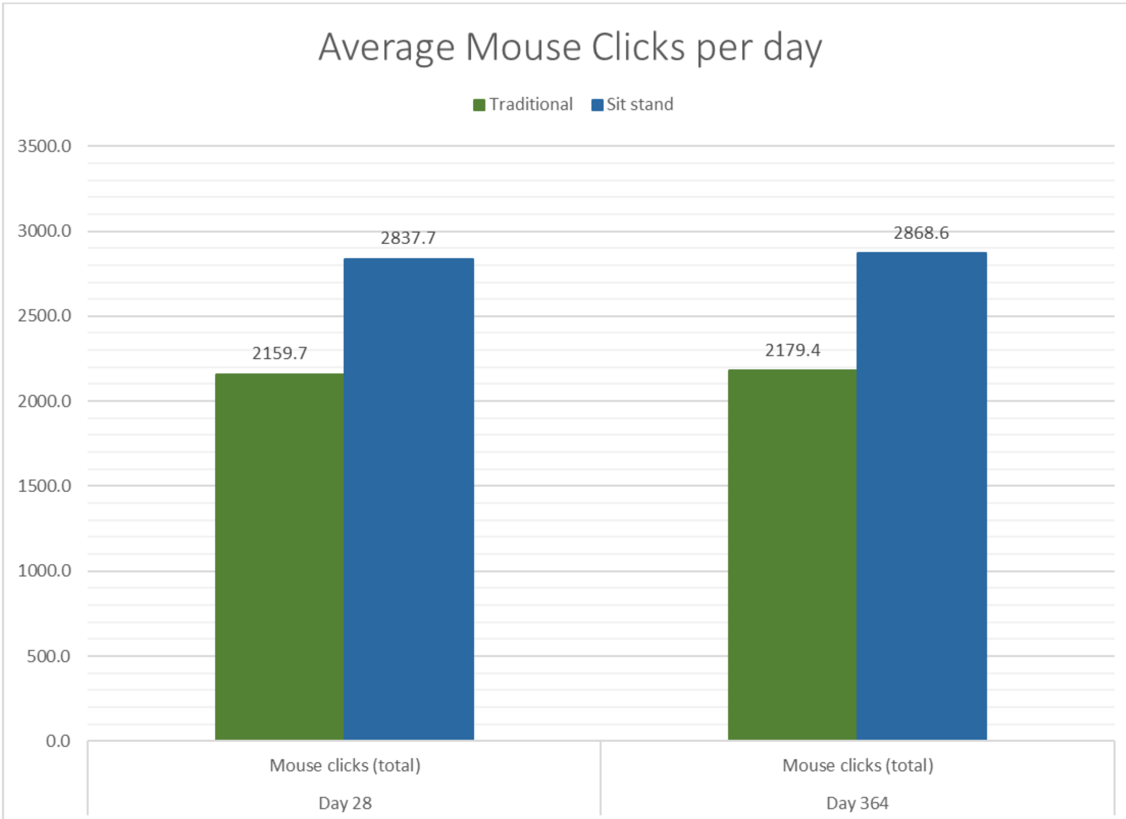


Figure E6 Average number of mouse clicks per day at both time points stratified by workstation type

Figure E7 Average number of pixels that the mouse travels per day at both time points stratified by workstation type

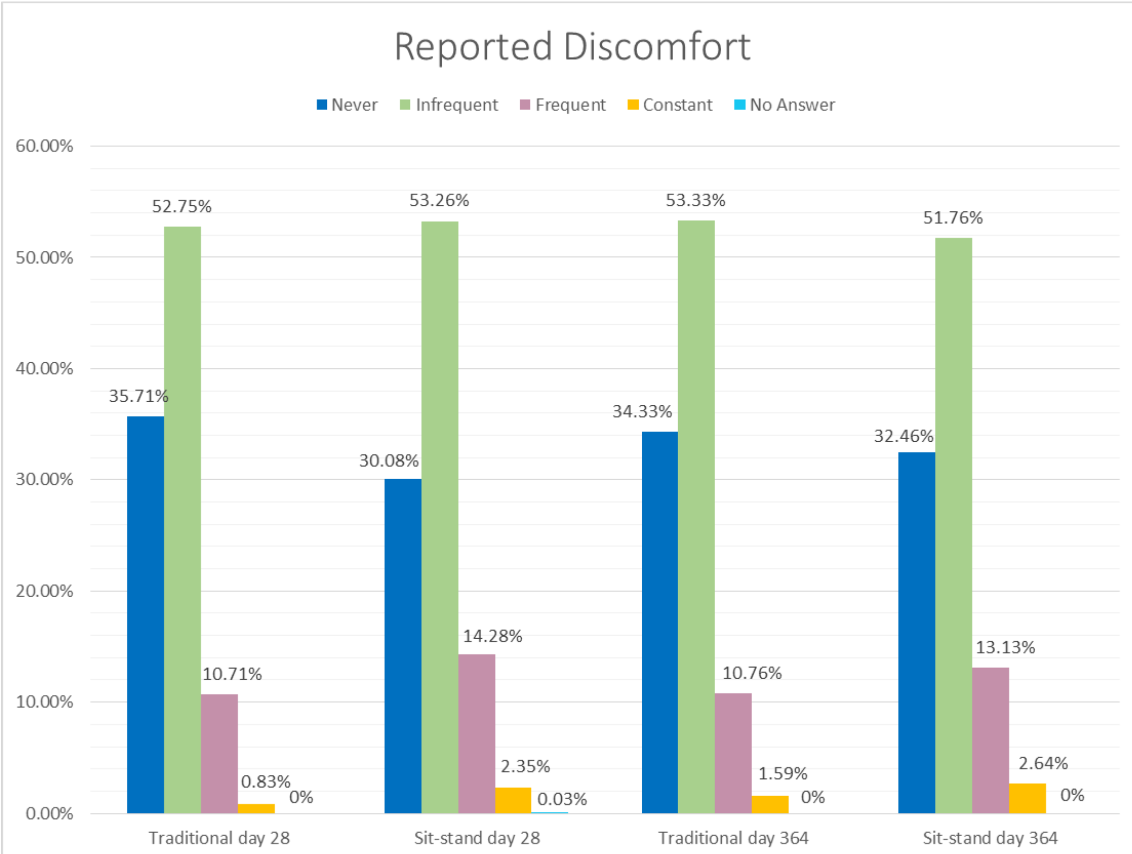


Figure E.8 Percent of individuals reporting musculoskeletal discomfort stratified by workstation type and time period

APPENDIX F: HSC WORKSTATION STUDY GRAPHICS

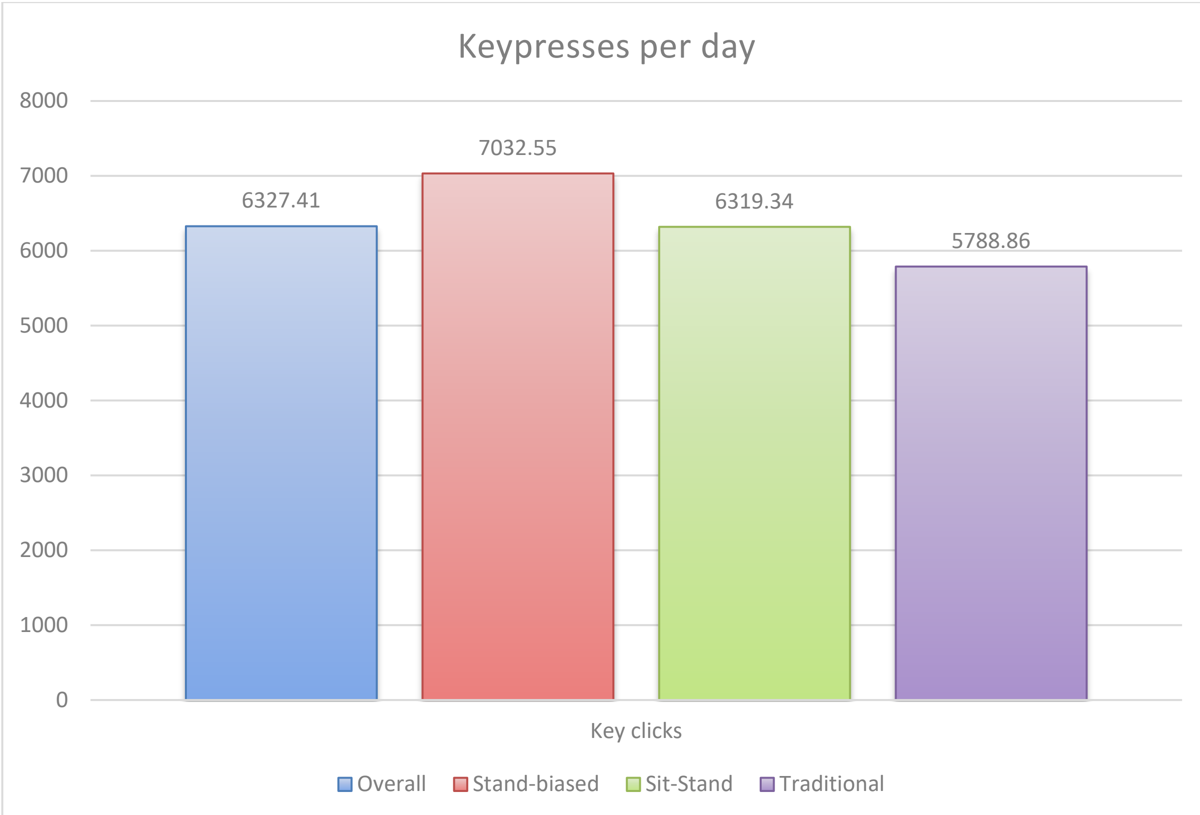


Figure F.1 Number of keypresses per day stratified by workstation type

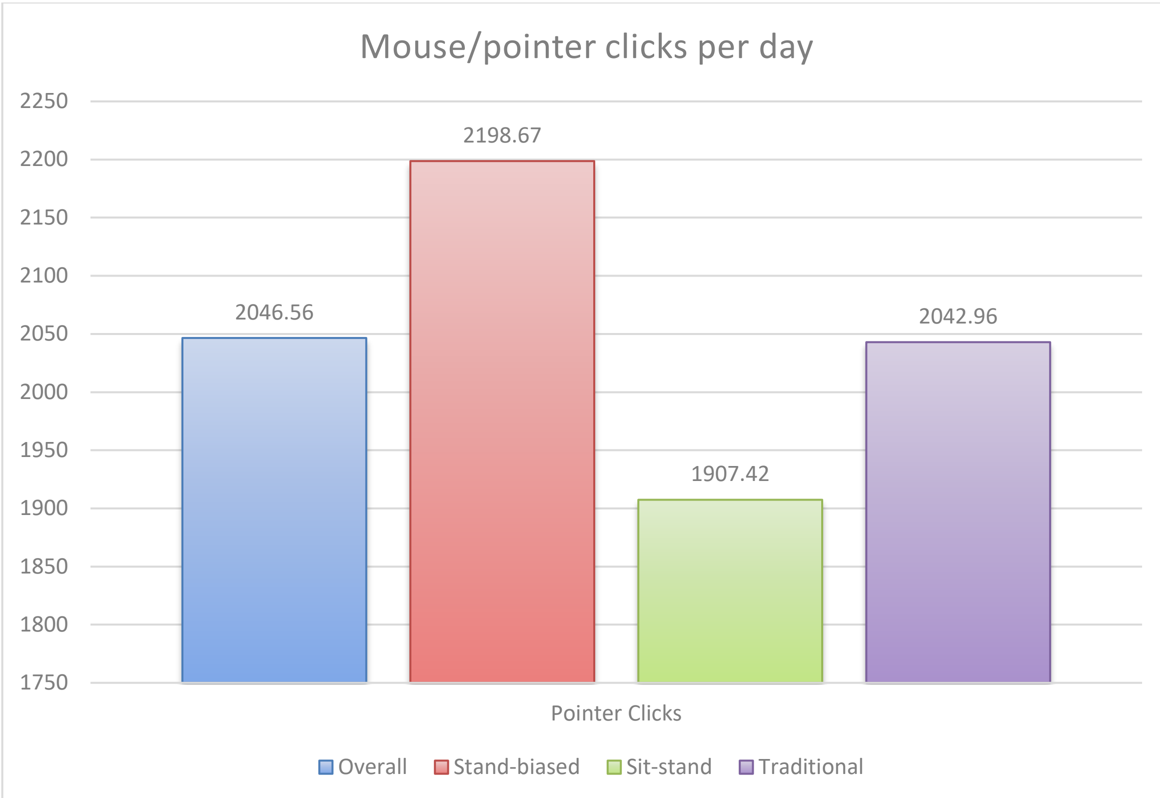


Figure F.2 Mouse or pointer clicks per day stratified by workstation type

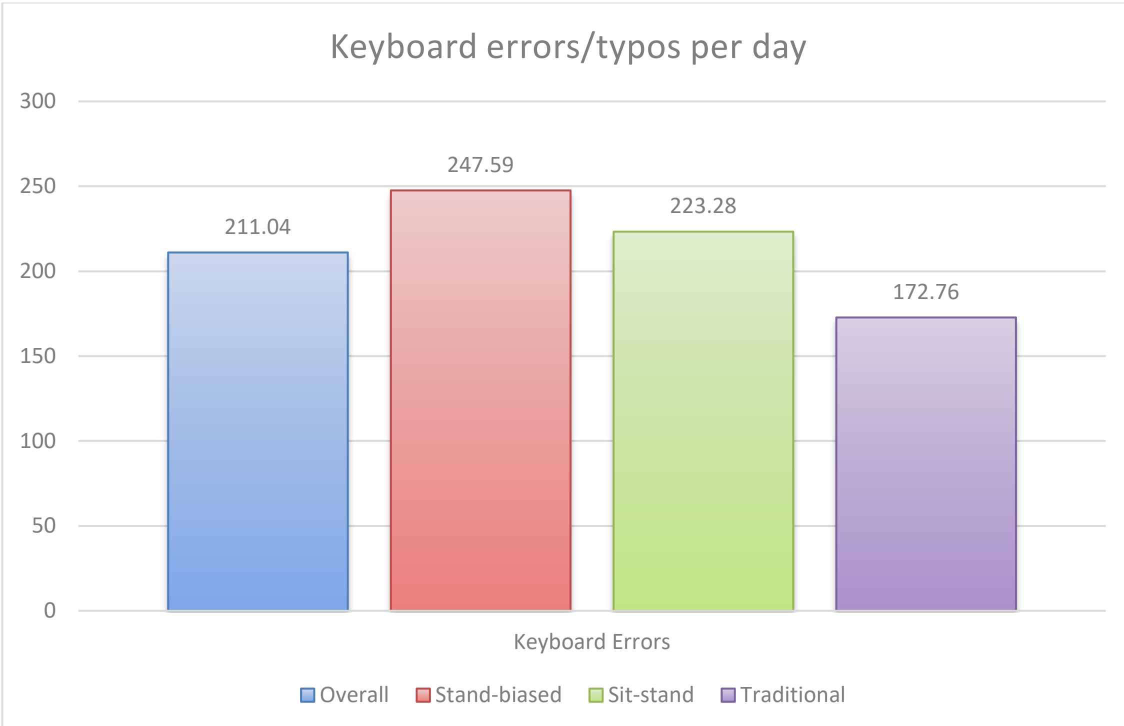


Figure F.3 Number of keyboard errors or typos per day stratified by workstation type

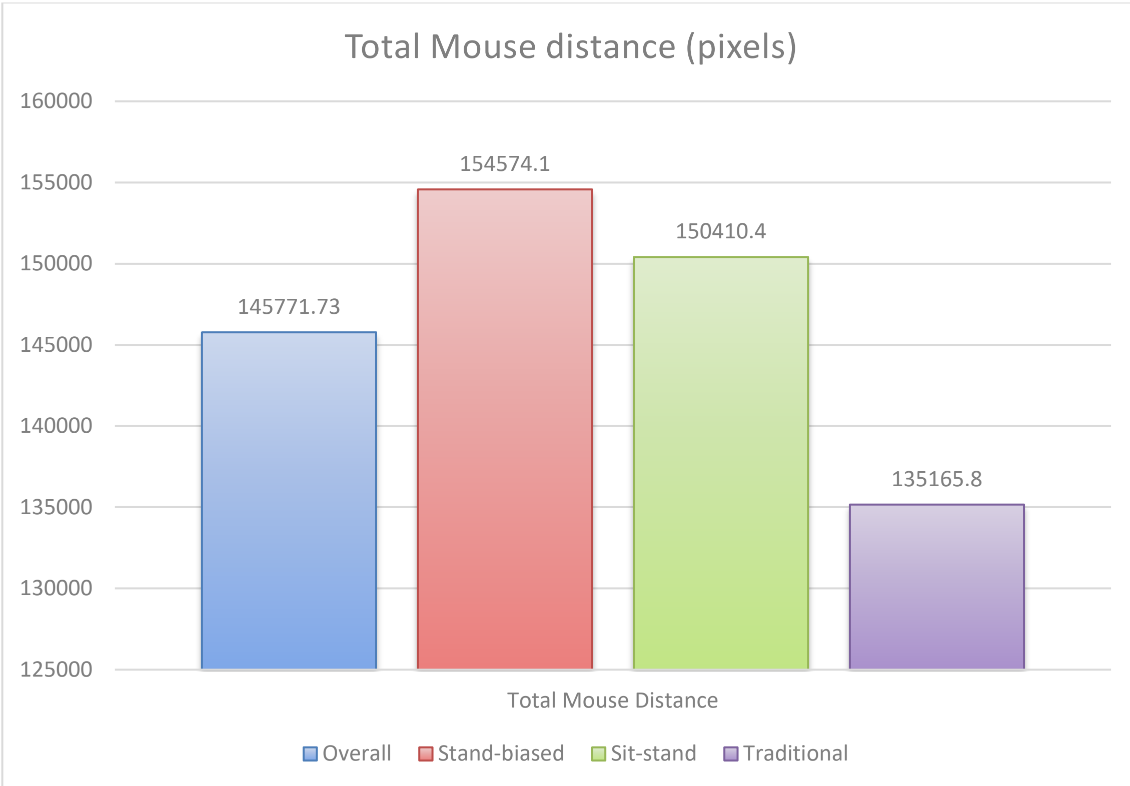


Figure F.4 Average mouse distance per day stratified by workstation type

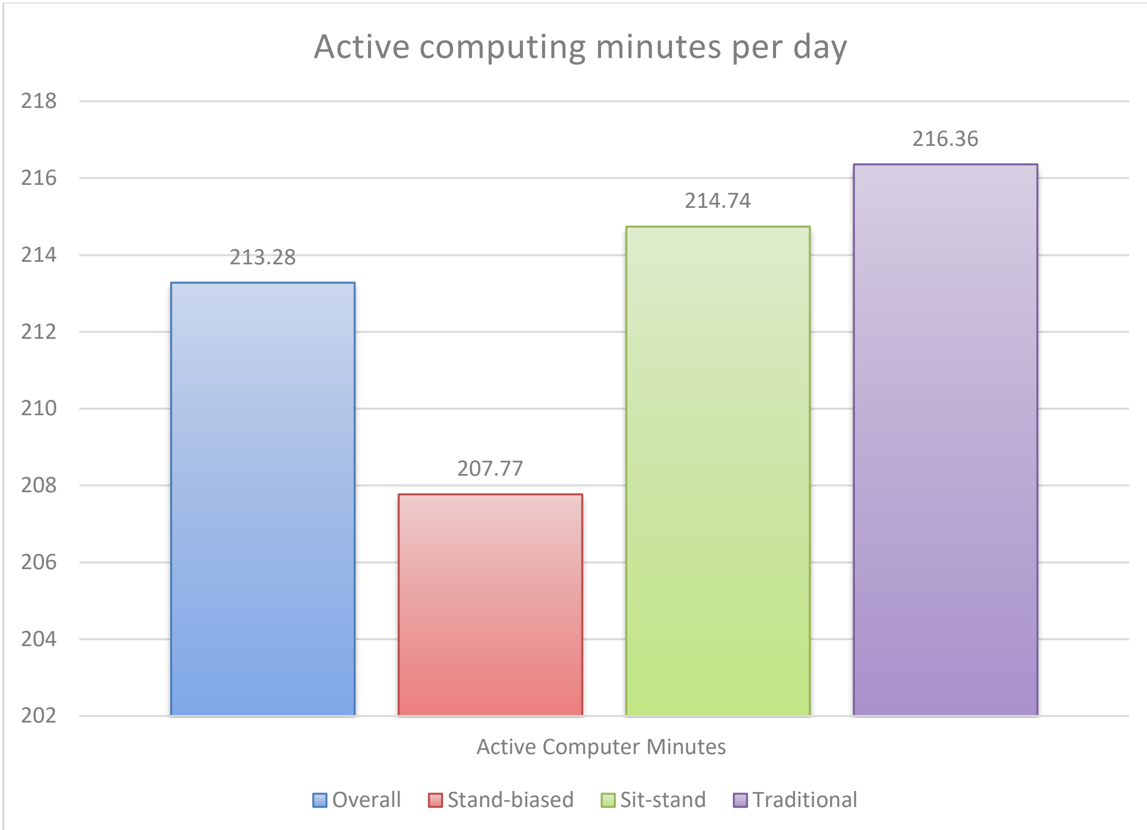


Figure F.5 Average active computing minutes per day stratified by workstation type

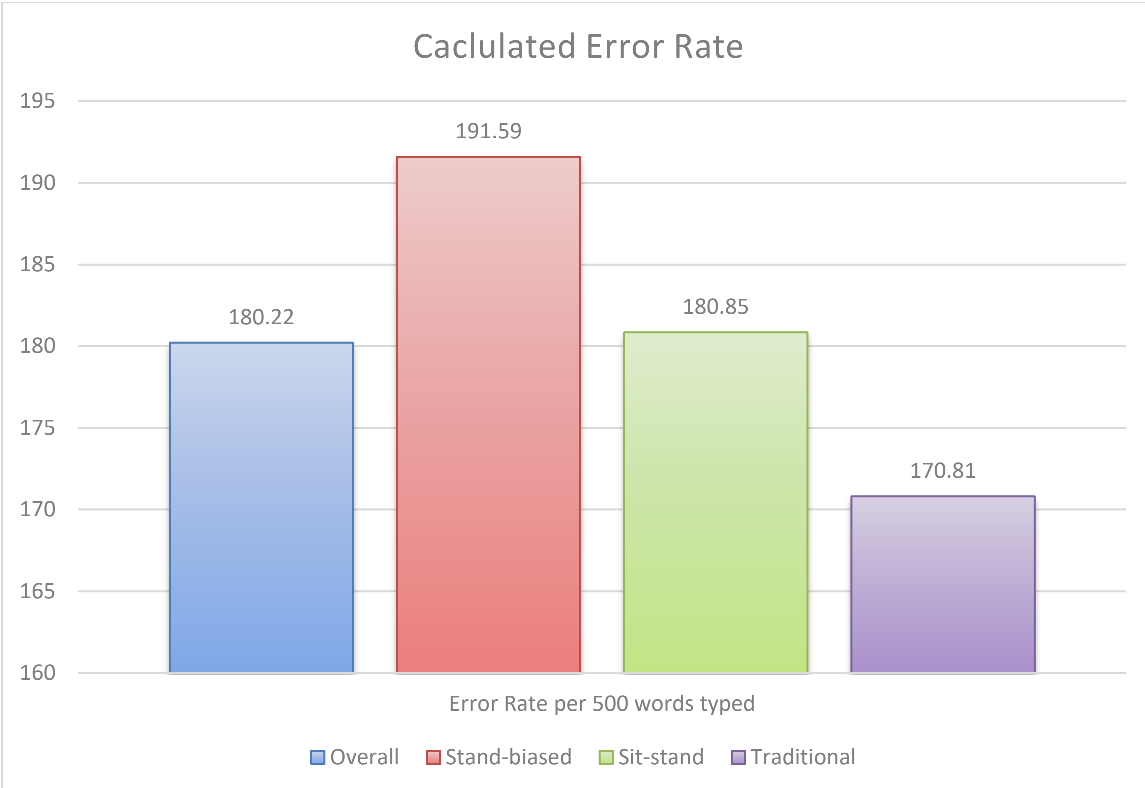


Figure F.6 Calculated average daily error rate (errors per 500 words typed) stratified by workstation type

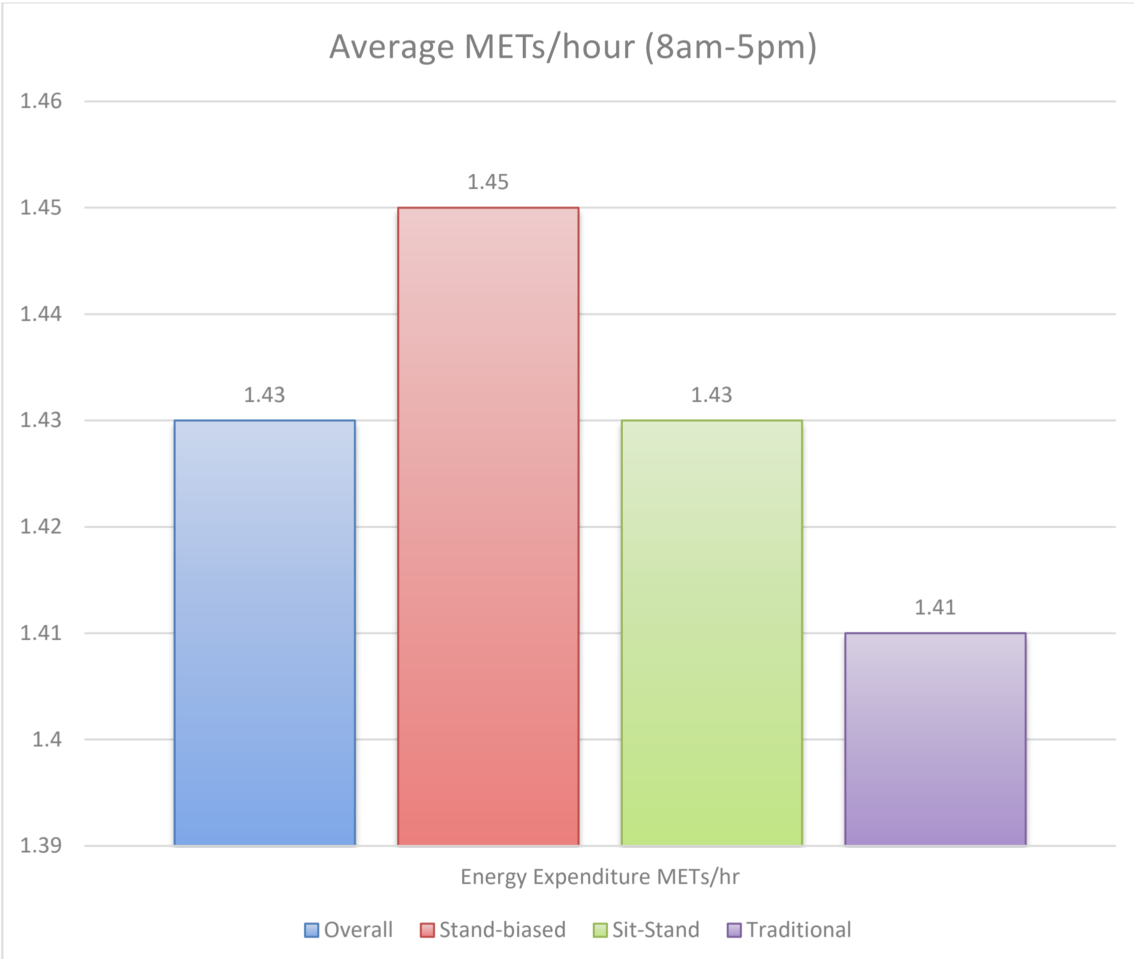


Figure F.7 Average hourly energy expenditure in METs stratified by workstation type

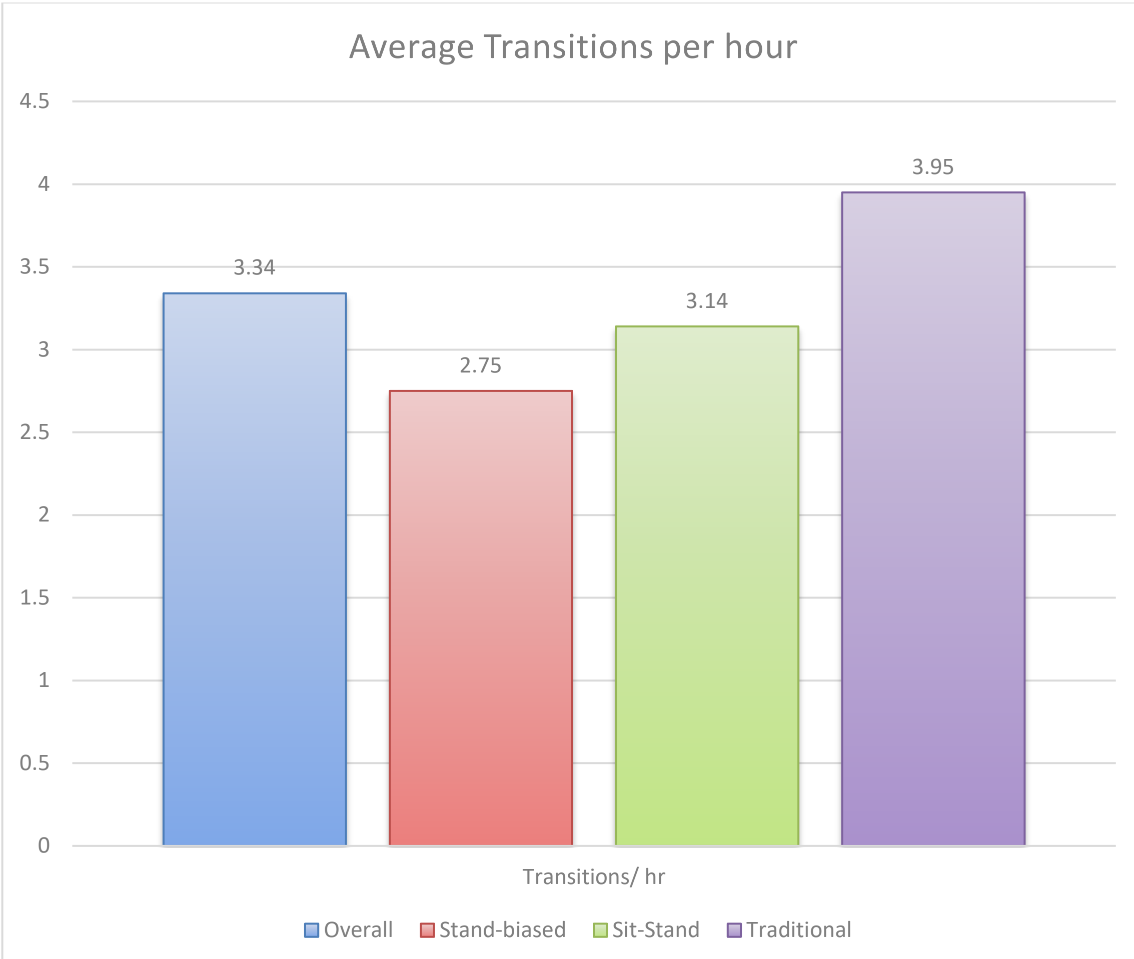


Figure F.8 Average number of transitions per hour stratified by workstation type

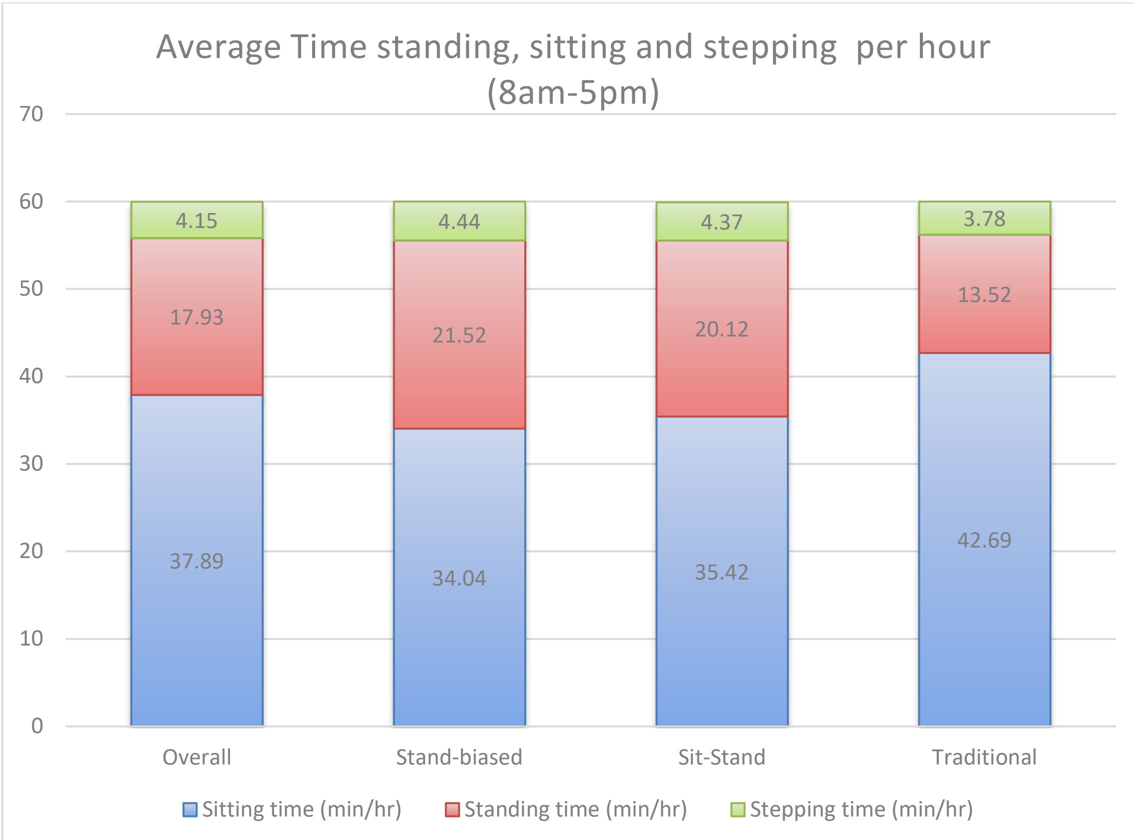


Figure F.9 Average time spent sitting, standing and stepping per hour during the workday stratified by workstation type

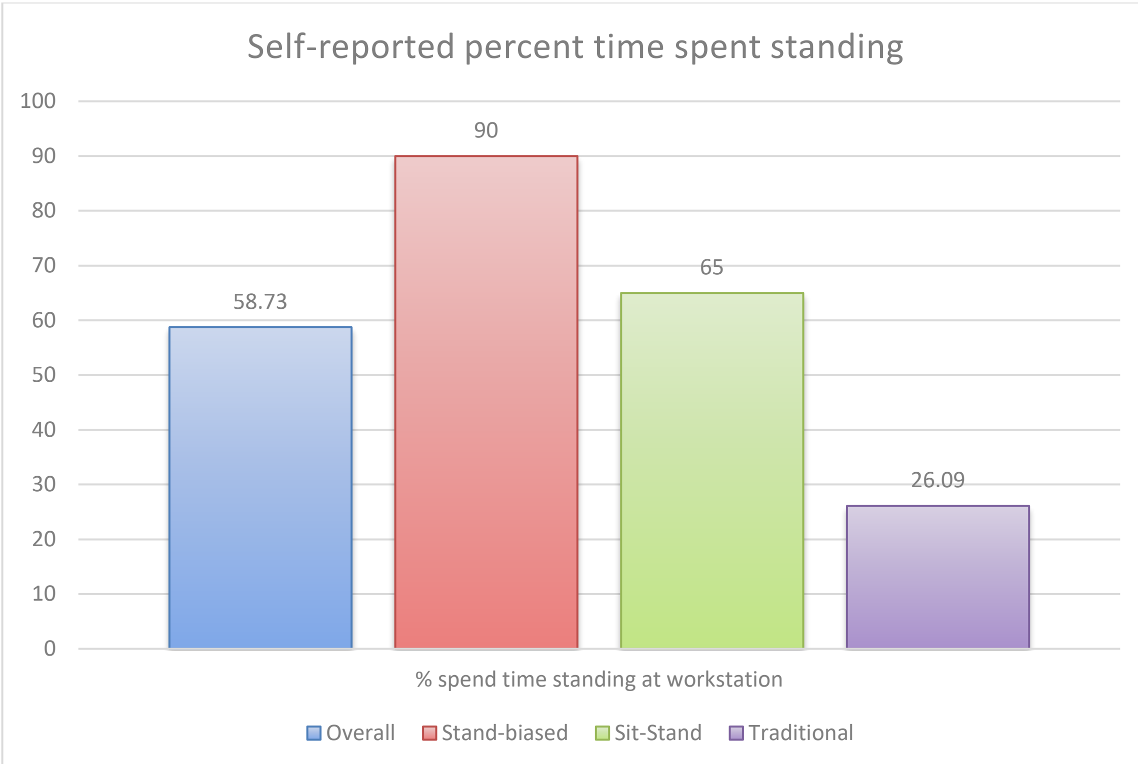


Figure F.10 Percent of participants indicating that they spent time standing to work stratified by workstation type

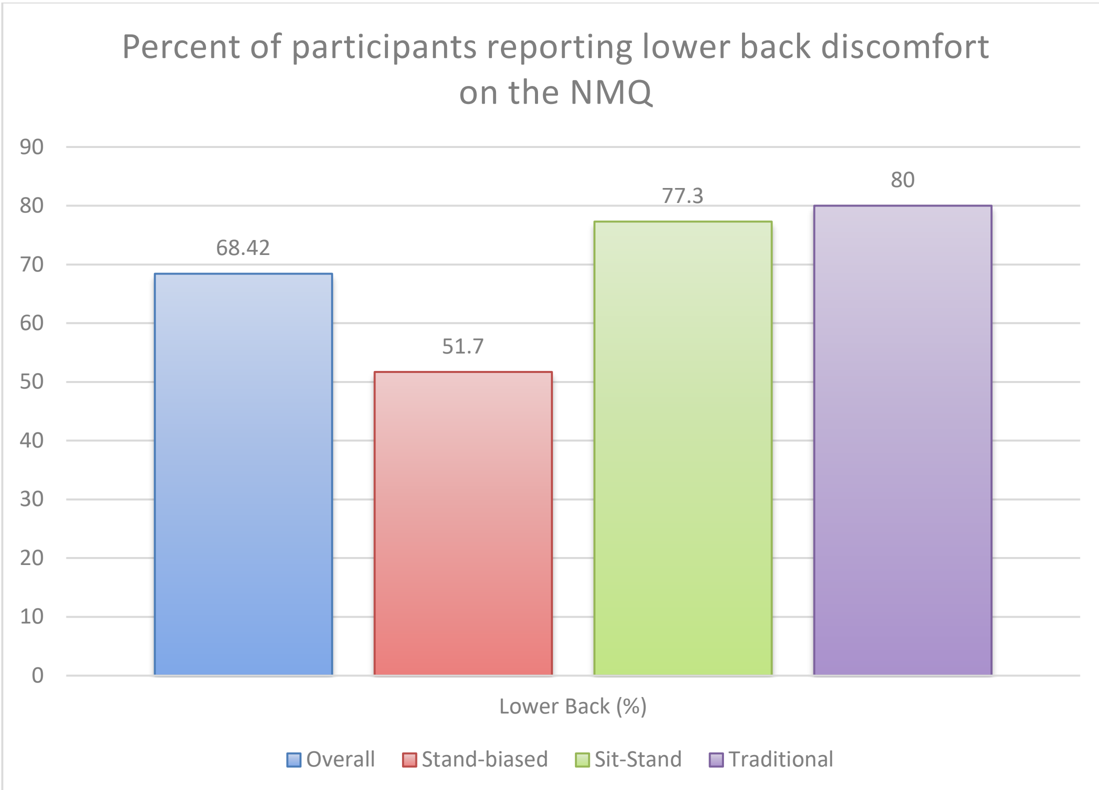


Figure F.11 Percent of participants reporting low back discomfort or pain in the last 12 months on the NMQ stratified by workstation type

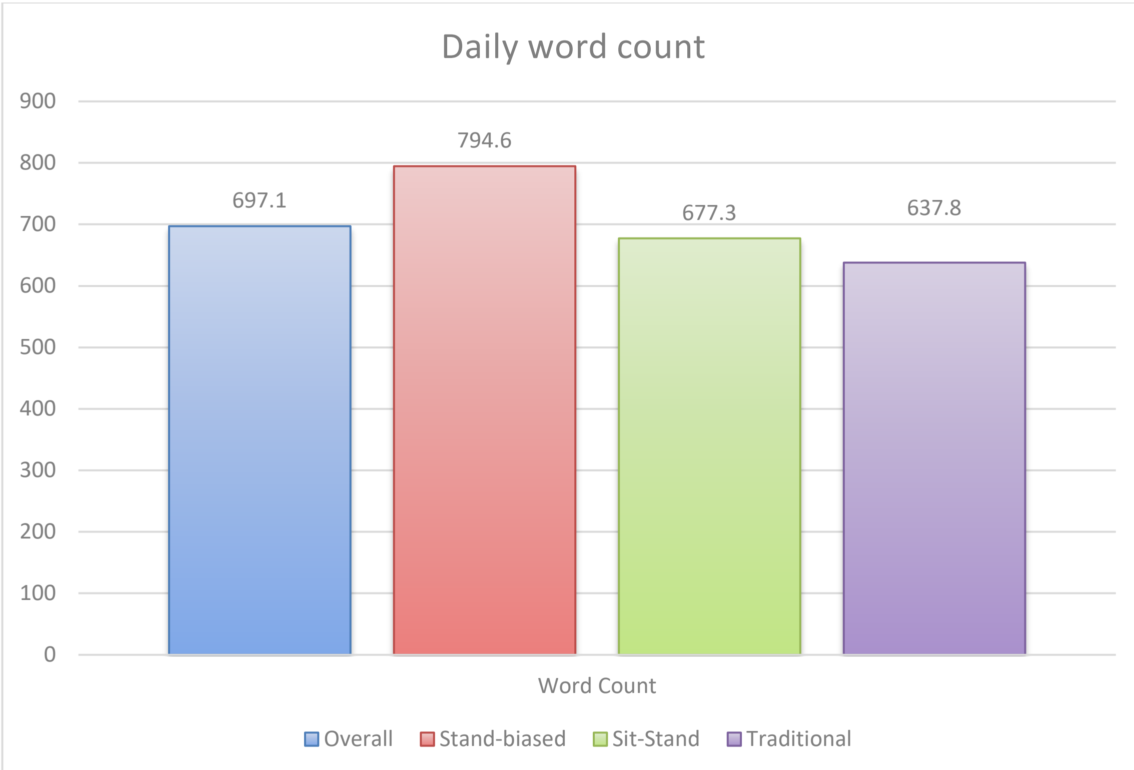


Figure F.12 Average daily word count for participants stratified by workstation type

APPENDIX G: STAND-BIASED HSC STAND-BIASED WORKSTATION FOLLOW-UP STUDY GRAPHICS

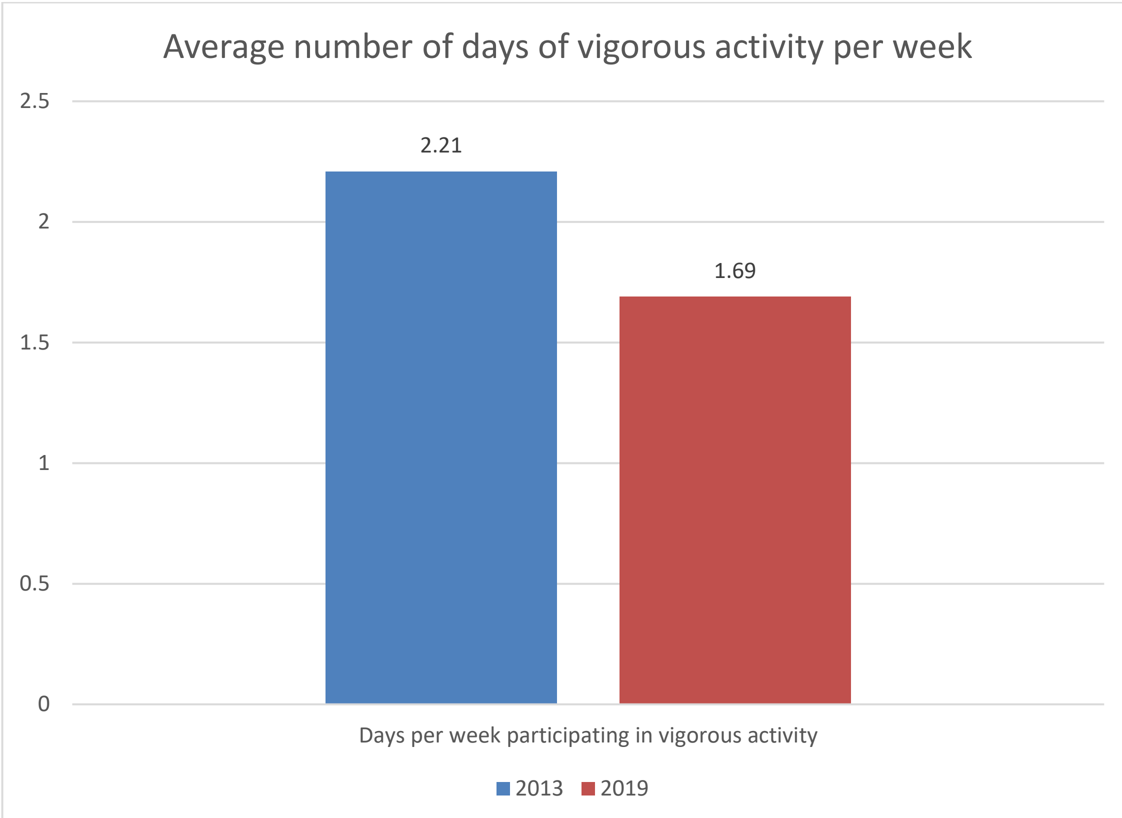


Figure G.1 Average number of days per week that participants reported engaging in moderate activities in 2013 compared to 2019

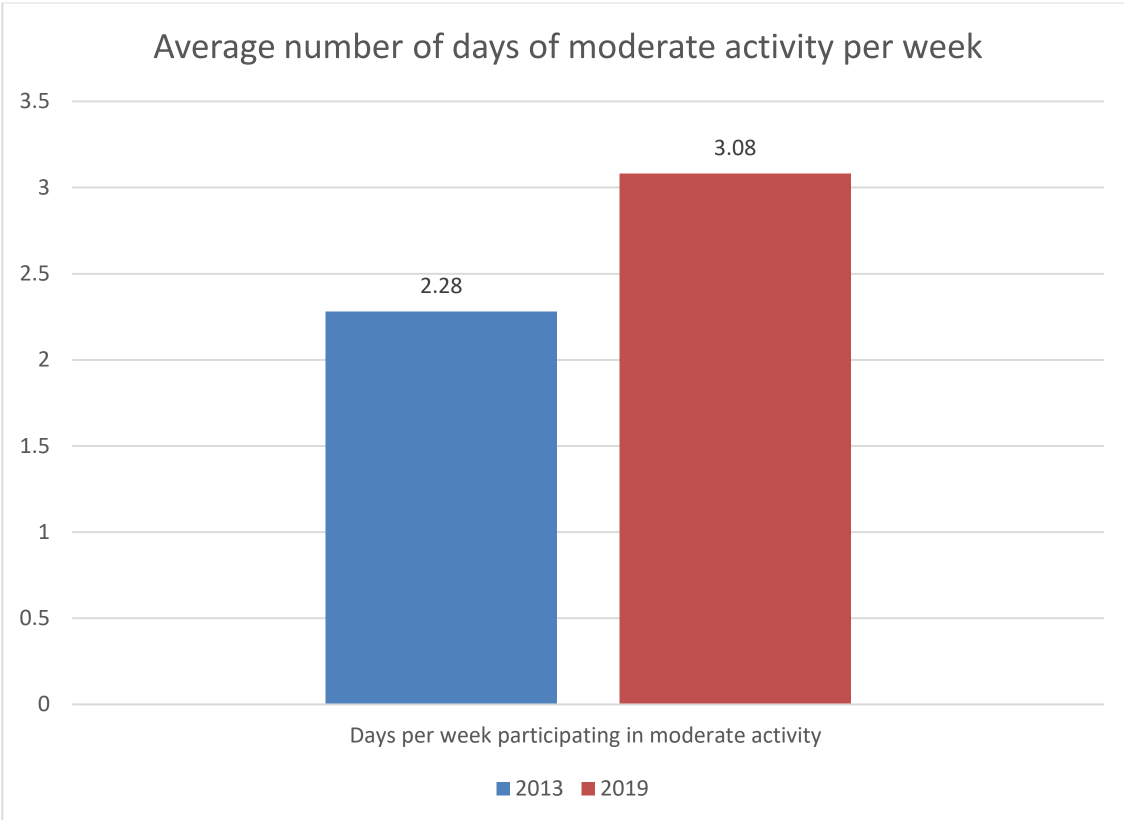


Figure G.2 Average number of days per week that participants reported engaging in moderate activities in 2013 compared to 2019

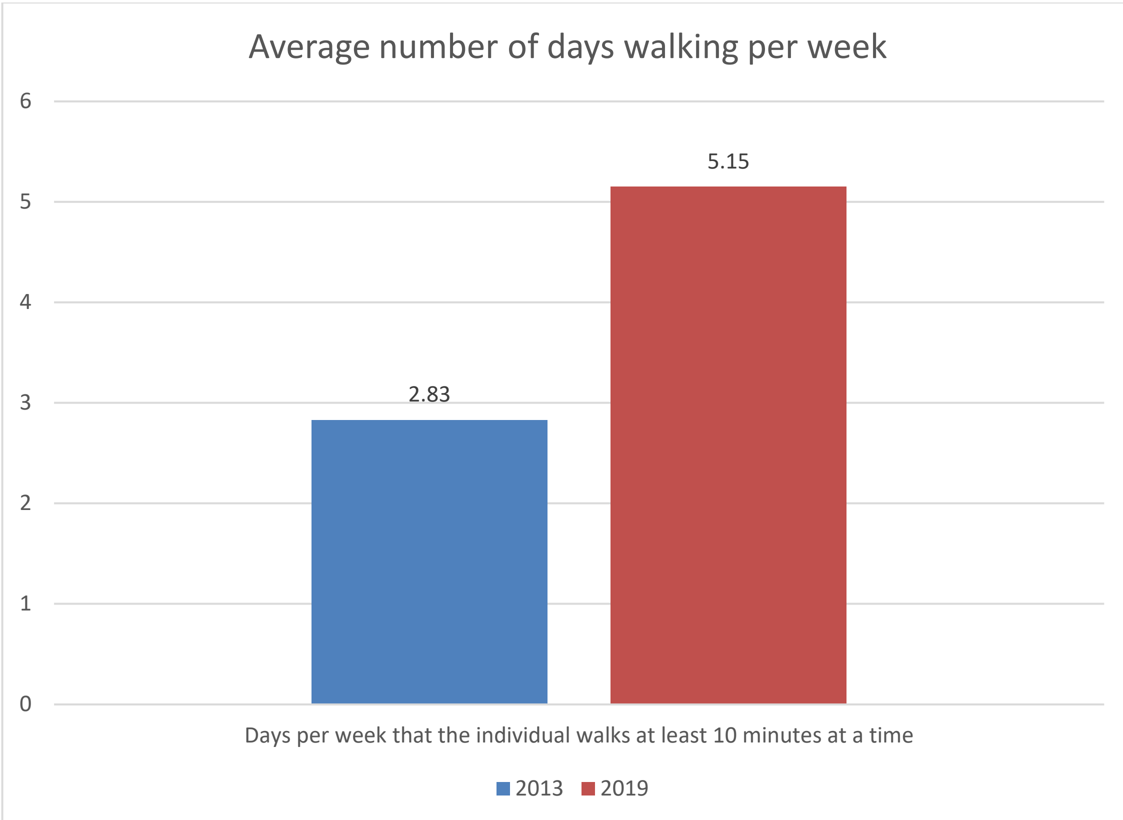


Figure G.3 Average number of times that participants reported walking 10 or more minutes at a time per week in 2013 compared to 2019

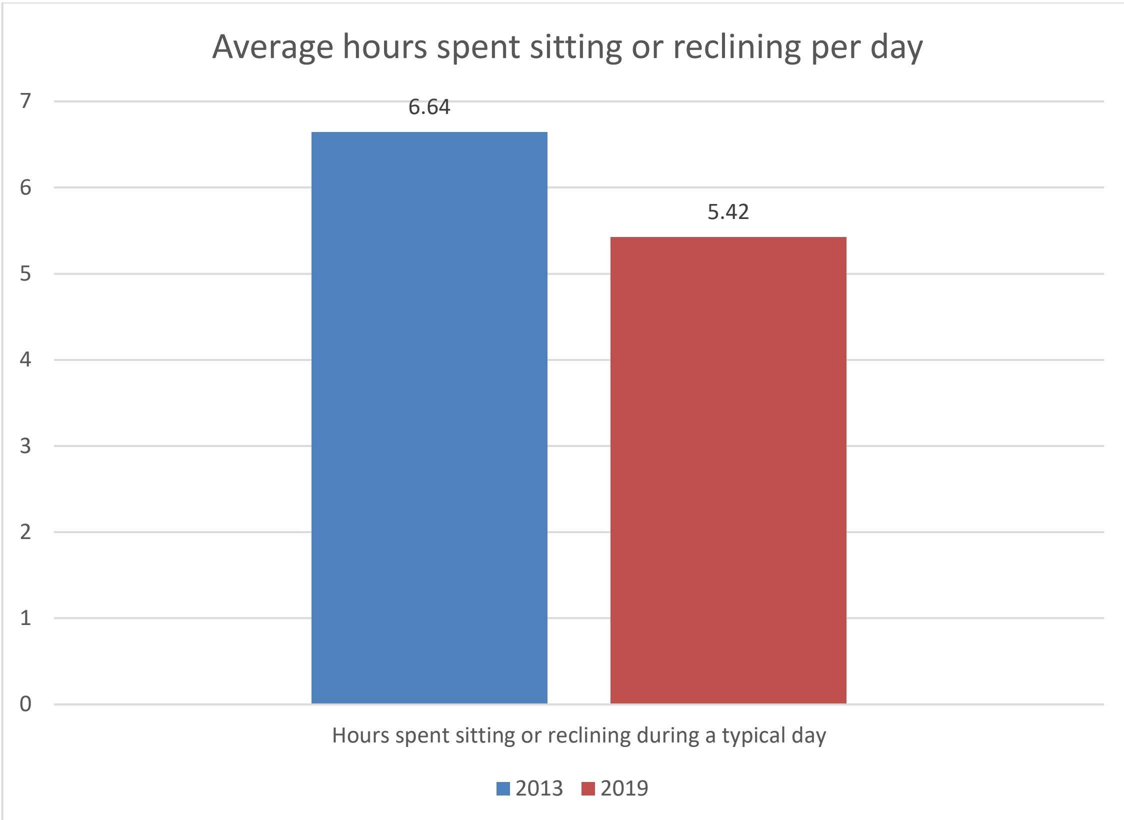


Figure G.4 Average number of self-reported hours spent in a seated or reclining position during a typical workday in 2013 compared to 2019

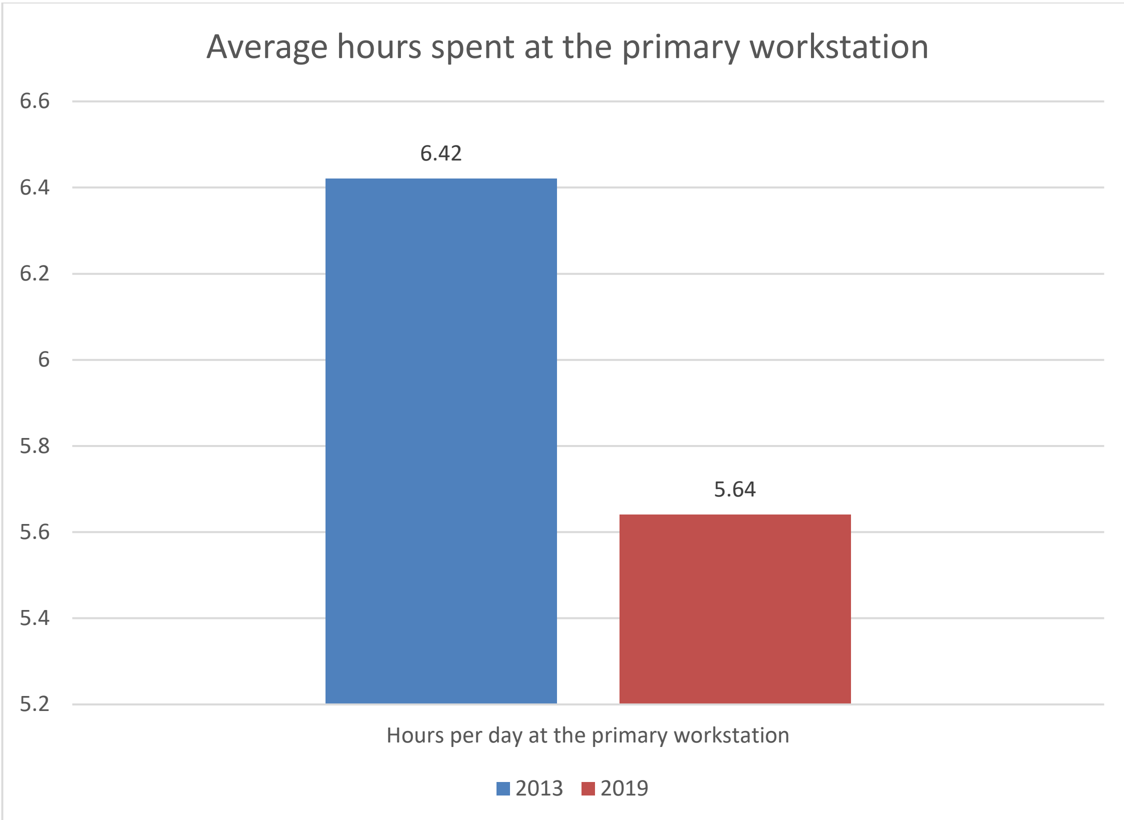


Figure G.5 Average number of self-reported hours spent at the primary workstation in 2013 compared to 2019

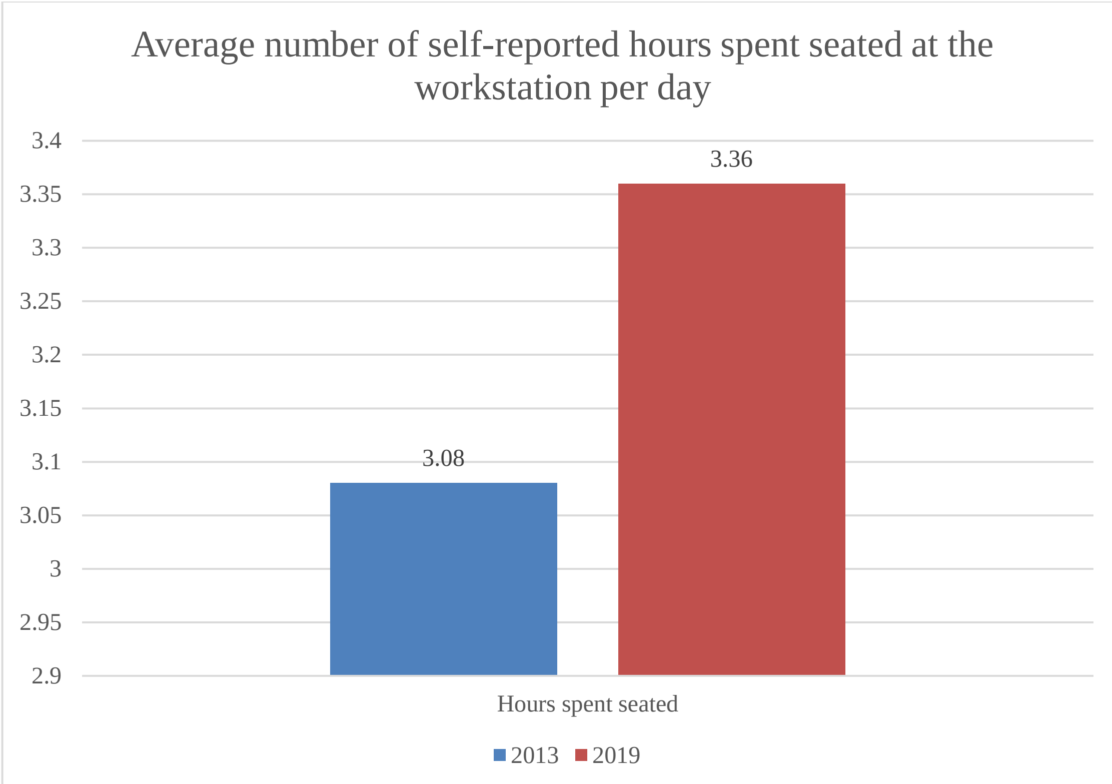


Figure G.6 Average number of self-reported hours spent seated at the primary workstation in 2013 compared to 2019

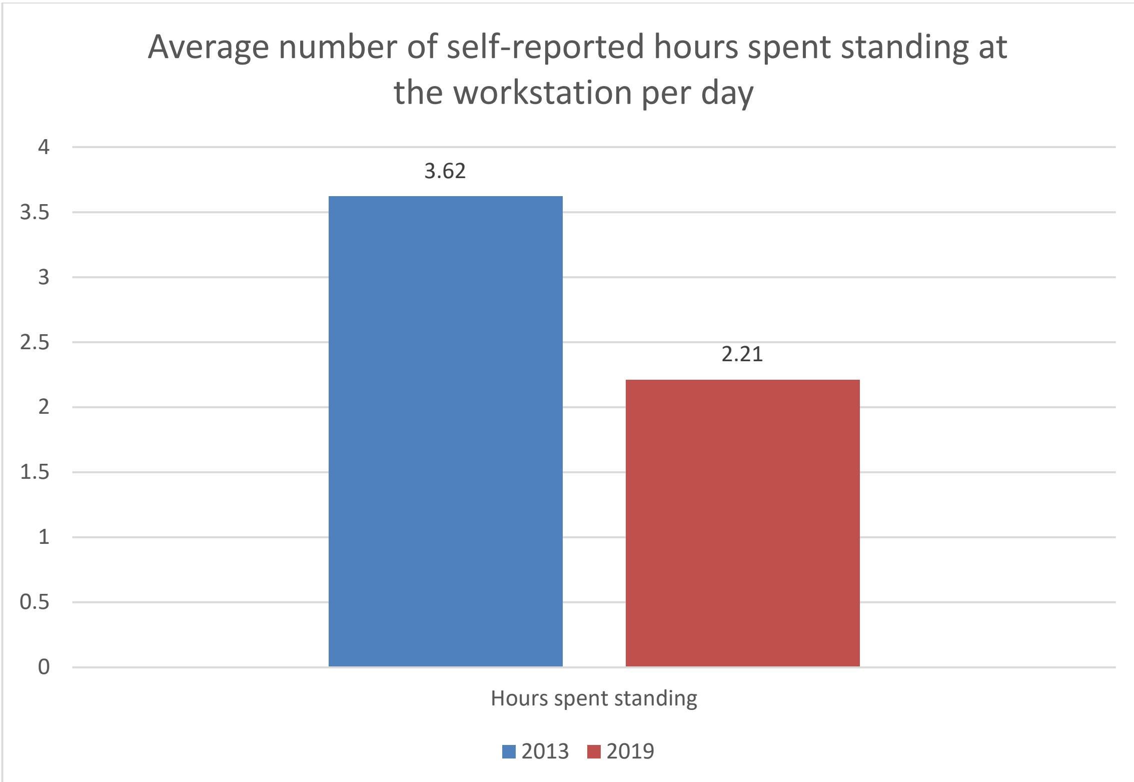


Figure G.7 Average number of self-reported hours spent standing at the primary workstation in 2013 compared to 2019