INTEGRATING SIT-STAND DESKS WITH SMART SOFTWARE

TO IMPROVE OFFICE WORKER HEALTH BEHAVIORS

A Dissertation

by

PANKAJ PARAG SHARMA

Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PUBLIC HEALTH

Chair of Committee,	Mark Benden
Committee Members,	Ranjana Mehta
	Adam Pickens
	Gang Han
Head of Department,	Mark Benden

August 2018

Major Subject: Epidemiology & Environmental Health

ABSTRACT

More than 80% of adults don't meet the weekly recommended physical activity guidelines and sedentary time accounts for more than 90% of the work day. Stand-capable desks have been successful in reducing sedentary behavior and improving BMI, productivity, and cognitive function. Wearables and computer technology have been used to objectively monitor activity levels. However, this technology presents limitations including short-term data collection, non-compliance, and cost. The challenge remains to find an effective method to increase the usage of sit-stand desks. Two longitudinal, field studies were conducted to record and increase sit-stand desk utilization using computer software and health behavior change components.

Study 1 (Australia) involved 194 government office workers who had electric sit-stand desks for at least one year prior to the study. The baseline phase consisted of computer software continuously recording sit-stand desk usage during computer use and the intervention phase consisted of software reminders with personalized feedback on their habits and goals. The findings showed that there was a significant increase in desk position changes and desk standing time while reducing desk sitting time.

Study 2 (Texas A&M University) involved 47 university workers who had height-adjustable sit-stand desks for at least one year prior to the study. The study used a novel approach to record sit-stand desk data using a USB accelerometer to detect desk position. The baseline phase consisted of computer software continuously recording sit-stand desk usage during computer use and the intervention phase consisted of software reminders with personalized feedback on their habits and a gamification component. The research findings revealed that team software reminders and group result dashboards increased desk usage.

Across the board, the software reminders (with personalized feedback and a gamification element) were an effective behavioral health intervention to increase sit-stand desk usage and improve workplace sedentary behavior. These findings contribute to sedentary behavior science by providing an effective behavioral change intervention using artificial intelligence computer software to reverse office worker physical inactivity.

DEDICATION

This dissertation is dedicated to my family and my wife. My parents (Drs. Pankaj & Archana Sharma) have been my biggest supporters throughout my life. They have succeeding in further their career fields while providing the love and support to make sure I succeed as well. I cannot thank them enough for everything they have done for me to this day. I will always continue to make them proud as I progress in my career. My brother, Anu Sharma aka Mr. Esquire, has been a big impact through the years. Although I have come to realization that I could never beat him in tennis, there is a valid reason behind that constant outcome. He is always one step ahead of me and has taught me some of the most valuable lessons in coping with life obstacles. His hard work and dedication have rubbed off on me and I am so grateful to have him always there for me.

My wife, Dr. Nikita Sharma, has been my ultimate savior during this degree program. She has been there from start to finish. I am very thankful for her willingness to listen to me, everything from my research frustrations to statistical anomalies that I come across. Her outlook on academics, career, and society have been instilled within me and because of her, I continue to become a better person, professionally and mentally. I love you.

ACKNOWLEDGEMENTS

I would like to acknowledge my chair, mentor, colleague, and friend, Dr. Mark Benden. Ever since he gave me a chance to be Thing #2 under his wing, I have attempted to make the most out of opportunity that he has given to me. His mentorship is an attribute that I will never forget as I move onto the next phases of life. I could come into his office at any time of the day or week (except when I was not there and on honeymoons), and we could speak about research problems, strategy, and next steps to succeed on a project. I really value the open communication he has kept with me and has always looked out for my best interests.

Dr. Benden has been a great colleague as well. At events and conversations with others, he would make me feel equal to him and had my back in every instance that came up. I feel very special to have had Dr. Benden as my chair and colleague, as I completed this degree program.

Finally, he has been an amazing friend. There isn't one conversation that we have where we don't end up laughing about something. It's truly amazing to see how much fun we had going through this process. I always respected him and would complete every task he would ask me to do with my full heart. It is a great feeling to know that after that kind of respect towards him, we could have some great times. Our road trip to New Mexico was one for the books and thanks for introducing me to Johnny Cash. Thank you for always believing in me.

P.S.- May the grass always continue to grow so it can be cut.

Yours truly,

Now Thing #1

CONTRIBUTORS AND FUNDING SOURCES

This work was supervised by a dissertation committee consisting of Dr. Mark Benden, CPE [chair], Dr. Ranjana Mehta, Dr. Adam Pickens of the Department of Environmental and Occupational Health, School of Public Health, Texas A&M University and Dr. Gang Han of the Department of Epidemiology and Biostatistics, School of Public Health, Texas A&M University.

All other work conducted for the dissertation was completed by the student independently.

This work was made possible in part by Office Ergonomics Research Committee, Grant Number M1501491 and Varidesk® Inc., Grant Number M1702075. Wellnomics® and Linak provided software and equipment for the research studies. Additionally, we would like to recognize Australia Comcare Government and the Texas A&M University Division of Student Affairs for allowing us to use their workers and office buildings as a research venue.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

CHAPTER I

INTRODUCTION

Physical Inactivity

In 2015, healthcare spending reached $3.2 trillion and is expected to increase by 5.5% through 2025 (Reinhardt et al., 2004). Chronic disease treatment has become the main driver of increased healthcare spending (Anderson and Horvath., 2004). Among the most expensive chronic diseases (cardiovascular disease, smoking/alcohol-related health issues, diabetes, cancer, Alzheimer's disease), obesity accounts for $147 billion of annual healthcare spending (Finkelstein et al., 2009). In 2010, 1 out every 3 adults in the United States were obese (Ogden et al., 2006). Obesity commonly occurs when energy intake (diet intake) exceeds energy expenditure (loss of energy via metabolic or physical activity) but can also be caused from environmental, social, economic, and genetic factors (Aronne et al., 2009). Obesity has been linked to causing type 2 diabetes, cardiovascular disease, kidney disease, sleep apnea, and depression (Aronne et al., 2009). As a result, obesity can impact individuals on a personal and occupational health level.

Obesity has been associated with job absenteeism and costs companies $4.3 billion annually. Lower work productivity costs $506 per obese worker every year (Cawley 2010). As the body mass index of a worker increases, so do the number of sick days, medical claims, and healthcare costs (Trogdon et al., 2008). Obesity effects employee health and employer healthcare costs, with healthcare costs being 36% higher for obese workers compared to normal weight workers (Finklestein et al., 2004). The guidelines for obesity treatment include reduced-caloric intake, behavior modification, and physical activity (Aronne et al., 2009).

The physical activity levels are based on the amount of energy expenditure from the activity and expressed in metabolic equivalents (METs). MET is the ratio of work metabolic rate to resting metabolic rate of 1 kcal/kg/hour and 1 MET is considered to be a resting metabolic rate during quiet sitting (Ainsworth et al., 2000). Physical activity intensity levels can be light (<3 METs), moderate (3-6 METs), and vigorous-intensity (>6 METs) (Ainsworth et al., 2000). Light-intensity activities include cooking, fishing, and standing and moderate to vigorous-intensity physical activities include walking, running, cycling, and swimming (Ainsworth et al., 2000).

Currently, recommendations only exist for moderate (150 minutes/week) and vigorous-intensity (75 minutes/week) physical activities but not for light-intensity physical activity (WHO et al., 2010). Within light-intensity activities, sedentary behaviors are defined as any activity with an energy expenditure of <1.5 METs while being in a seated or reclined posture (Tremblay et al., 2016). While adults could be meeting these recommended physical activity guidelines, sedentary time accounts for more than 90% of the day for most adults (Norton et al., 2010). Individuals can coexist with high physical activity and sedentary behavior, a phenomenon referred to as the Active Couch Potato (Owen et al., 2010). Among the adults who reported meeting the 150 minutes of physical activity recommendation, significantly associated dose-response relationships of sedentary time (TV time) were observed with increased metabolic risks that are associated with sedentary behavior (Healy et al., 2008). Research has shown that prolonged sitting periods (20-30 minutes or more) can increase the risk of developing cardiovascular disease, obesity, type 2 diabetes (Hamilton et al., 2007), increased waist circumference (Healy et al., 2008), and most recently discovered, lead to all-cause mortality (Diaz et al., 2017).

Due to sedentary jobs increasing by 83% since 1950, office workers are an ideal target population for behavioral interventions designed to decrease sedentary time (McCrady et al., 2009). Healy determined that increased breaks from sedentary time were beneficially associated with reduction of several health risks such as waist circumference, BMI, levels of triglycerides, and 2-hour plasma glucose levels (Healy et al., 2008). To date, most workplace sedentary behavior interventions have been short-term, pilot studies using wearable technology to measure desired outcomes. While this research and data has contributed to the knowledge of workplace sedentary behavior, there is a need for long-term interventions that are designed to increase and sustain more movement by continuously measuring quantitative sedentary behavior.

Workplace interventions intended to decrease sedentary behavior have been successful in the past. Some interventions have included tailored physical activity classes or counselling (Marshall et al., 2003, Opdenacker et al., 2008, Østerås et al., 2006), fitness-testing (Aittasalo et al., 2004), motivational emails, suggested walking routes, and walking with the aid of pedometers to track steps (Gilson et al., 2009). Interventions have also targeted occupational sitting time using software technology. A wrist-worn device that vibrates/beeps to increase movement and desktop computer applications that remind workers to go take a walk have been useful in decreasing sitting time by 6.6% (Swartz et al., 2014).

However, these interventions present two main limitations. First, most require additional time and money costs such as maintaining a health professional staff on-site for physical activity classes or fitness counseling, wearables/replacements for all workers, organizational meetings and consultation, and regular approval meetings from management to continue health promotion sessions and campaigns. Secondly, these interventions require workers to leave their workstation frequently in order to reduce their sitting time. Due to stepping away from the computer, this can lead to a lack of motivation and compliance to participate in breaks due to the perceived conflict of work demands while maintaining the company's productivity goals. This could lead to a disruption of work tasks and concentration (Henning et al., 1997). Therefore, sit-stand desks have been successful in reducing occupational sitting time while remaining at the workstation. Sit-stand desks have shown evidence of decreased sedentary time (Dutta et al., 2014), increased productivity (Garrett et al., 2016), improved BMI in children (Benden et al., 2011) and cognitive function (Mehta et al., 2015). For its benefits on health and productivity, their presence is becoming increasingly incorporated in office design environments.

Office workers are faced with a difficult situation in their work environments. Dr. Mark Benden's paradox states the following: "Adults naturally increase their BMI during their working career and thereby their need for sustained physical activity to minimize the trajectory of that increase. Ironically, they unnaturally are coerced to decrease their physical activity in the work environment via forced sedentarianism to gain productivity, which results in reduced productivity and weight gain."

Sit-stand desks

Sit-stand desks are available in two types: stand-biased and height-adjustable. Stand-biased desks remain in the standing position and a seat/stool is provided for the person. Height-adjustable desks require the desk position to be manually changed to a sitting or standing position (i.e. crank, pneumatic, electric, and now trending, table-top adjustable) and an adjustable chair is provided for the user. Height-adjustable desks are intended to accommodate the 5th percentile female to the 95th percentile male, which is over 90% of the population. This design can provide individual adjustability with proper ergonomic fit, use of safe work postures, and increase movement (Koskelo et al., 2007).

Previous sit-stand desk studies have been successful at reducing sedentary behavior. These studies have had similar study designs (control and intervention group) and objectively measured data using activity monitors (ActivPAL monitor, Gruve Accelerometer). ActivPALs™ and Gruve have been used in sit-stand desk studies as validated, wearable devices to measure sitting, standing, and stepping times in participants using sit-stand desks. (Lyden et al., 2012, Alkhajah et al., 2012). The studies recorded baseline and follow-up data for 7-day increments or 2 random days of the week. Results showed significant reductions in sitting time of 143 minutes/day, 89 minutes/8-hour work day, and sedentary time reduced by 5 minutes/hour. The studies have shown significant reductions in sitting and sedentary time (Alkhajah et al., 2012, Dutta et al., 2014, Neuhaus et al.,2014). However, the limitation with using wearables is that data can only be collected for a short duration (7 – 14 days) due to memory capacity (Edwardson et al., 2016). Additionally, these wearables require people to have a device attached to their skin, which cause skin itching and redness, inconvenience, non-compliance, and cost issues (Frost et al., 2016). As a result, these promising results only provide a snapshot of workplace sedentary time. Future methods should record data continuously and long-term to understand sedentary behavior and sit-stand desk usage.

Since the height-adjustable desks require the user to modify their behavior by changing the desk position, it is possible for users to forget about changing positions due to day-to-day work demands, no feedback or engagement on usage, and not bothering to use the function of the desk (Wilks et al., 2006). Through surveys of small companies in Sweden, Wilks reported that approximately only one in ten workers use the sit-stand function of their workstation on a daily basis. If the user does not change their behavior to use the height-adjustable desk, their actual usage may not be enough to experience the health and productivity benefits from the desks. The challenge remains to develop effective behavioral interventions that will increase and sustain the usage of the height-adjustable desk.

At present, there are no guidelines that state how many minutes a person should sit or stand or how often they should change postures. Recent research from Diaz has shown that accumulated sedentary time of 60 minutes or more was associated with a greater risk of all-cause mortality while the accumulation of 30 minutes or less of sedentary time was associated with less increased risk (Diaz et al., 2017). Experiments have shown that breaks from prolonged sitting every 30 minutes can elicit benefits to cardiometabolic health (Peddie et al., 2013). Standing for too long can also be detrimental to health. Prolonged standing periods have been associated with lower back discomfort (Gregory et al., 2008), carotid atherosclerosis (Krause et al., 2000), varicose veins (Tüchsen et al., 2005), and muscle fatigue (Garcia et al., 2015). According to the expert statement in the British Journal of Sports Medicine, desk-based workers should aim to "initially progress towards accumulating at least 2 h/day of standing and light activity during working hours, eventually progressing to a total accumulation of 4 h/day," assuming an 8 h work day (Buckley et al., 2015).

Given all preliminary evidence and expert recommendations, this illustrates the need for quantitative, behavioral interventions that are designed to measure and balance occupational sitting and standing time while being able to tailor individual goals and preferences using height-adjustable sit-stand workstations. This will help provide data and guidelines on potential dose-response relationships for occupational sedentary behavior.

Health Behavior Change Strategies

Health behavior theories have provided a better understanding of health behavior and serve as a foundation upon which interventions can be developed to improve public health. These theories have been proposed at five different levels: individual, interpersonal, group, organizational, and community (Noar et al., 2005). Health behavior theories primarily focus on the individual level and include theories such as Health Belief Model, Theory of Planned Behavior, Theory of Reasoned Action (Becker, 1974), Transtheoretical Model (TTM) (DiClemente and Prochaska, 1983), and the Social Cognitive Theory (Bandura, 1986). These theories can focus on specific behavioral areas such as alcohol use, substance abuse, smoking cessation, and physical activity.

The social cognitive theory (SCT) has been applied to promote physical activity behavior change through interventions (Wallace et al., 2000). The SCT framework consists of 5 core determinants: knowledge (aware of health risks and benefits), perceived self-efficacy (individuals have control over their health habits), outcome expectations (benefits for health habit change), goals (set goals and plans) and sociostructural factors (attempt to make health habit change but factors such as work pressure, weather, or more interesting things to do can effect change) (Bandura 2004). This framework focuses on the individual level and gives the opportunity to change health behavior using knowledge, goals, and outcome expectations.

In order to facilitate behavior change, specific behavior constructs in interventions have shown evidence of improving obesity and physical activity levels. Goal setting, self-monitoring, and self-reward are the most effective constructs used in a strategy to promote health behavior change (Payne et al., 2015). Other constructs include time management, self-talk, peer pressure, and follow-up. Both research studies applied the SCT framework and behavior change constructs (goal setting and self-monitoring) to improve and remain engaged with health behavior change using with sit-stand desks.

Gamification

In addition to behavior change constructs, game design elements have been implemented to promote and motivate physical activity, which is a process known as gamification (Zuckerman et al., 2014). Approximately 60% of workplace health initiatives include gamification elements (Lister et al., 2014). The most commonly used gamification components include storyline, competition, possibility of failure, leaderboards, score, ranking or standing, and levels.

Zuckerman observed that offering continuous measurement of walking time, daily goals, and real-time feedback on progress showed a significant increase in walking time compared to baseline. Several companies have incorporated technology to promote healthy behaviors such as Fitbit, Nike + Fuelband and Runkeeper and achievements can be shown on social media networks (King et al., 2013). Games have also been created to target specific health conditions. For example, the Bant mobile app targets young children with type 1 diabetes to improve their frequency of glucose monitoring with the use of incentives (Cafazzo et al., 2012). Virtual rewards (points, badges) and social comparisons (comparing results) are gamification elements that have shown evidence of increasing physical activity (Zuckerman et al., 2014). To date, there is no study that has incorporated a gamification element to increase sit-stand desk usage. This novel approach was used in study #2.

Gap in current research

Computer use is a risk factor for developing upper body symptoms and discomfort (Jensen et al., 1998). During the past two decades, the number of workers using a computer has increased dramatically and more than half of all employed adults in the United States use a computer for job requirements (US Bureau of Labor Statistics 2005). Consequently, software applications have been developed to measure computer use in order to stimulate breaks from using the computer during work.

A software package, WorkPace® (developed by Wellnomics®) has been developed as a validated tool to prompt users to take computer breaks by measuring all keystrokes, mouse clicks, and mouse movements (van den Heuvel et al., 2003, Blangsted et al., 2004). The software calculates the total duration of computer use based on the interval between the keystrokes and mouse clicks/movements. If the interval is shorter than 30 seconds, the time recorded is active computer use. When the intervals have a duration greater than 30 seconds, the time recorded is considered inactive computer use and no computer use data is recorded. Thus, based on personal active computer use, the software provides pop-up reminders on the computer screen to users to take a break from their computer work.

To date, there have been a few studies that have investigated the impact of computer prompt reminders on occupational sitting and standing. Results showed objectively measured changes relative to control groups in total sitting time (n=29; non-significant decrease of 7%); standing time (n=19; mean increase of 9%); and duration of sitting periods >30 minutes (n=14; significant decrease of 12%), with all interventions ranging from 3 days to 4 months and used computer prompts as a reminder to take a break from sitting for a set time (i.e. every 30 min) regardless of time spent in a seated position (Donath et al., 2015, Swartz et al., 2014, Evans et al., 2012). Though successful in decreasing sitting time, these computer prompts could be considered ‘non-intelligent’ because the prompt frequency assumed there are no individual differences in sitting and standing times and that all workers remain at their workstation throughout the work day. The prompts fail to take into consideration time spent away from the desk for breaks (meetings, bathroom, walk breaks or lunch). Thus, future interventions would be most effective with field studies using larger sample sizes that examine the long-term use of ‘intelligent’ computer prompts that remind workers to change positions based on time present at the workstation and tailored to their individual preferences or goals.

Due to limitations of previous wearable and computer prompt interventions, the current gap in research is that there is no effective method to objectively record daily sitting and standing time outcomes using sit-stand desks for months/years, without the use of wearable devices. Recently, sit-stand desks have become integrated with software by connecting the desks to the computer (via a cable) to allow the software to measure accurate times the desk is in a sitting/standing position. However, this integration has not yet been studied and tested in a field setting over months of work time.

The software tool used for our two research studies (Wellnomics Sit Stand 1.0®) was built upon the previous WorkPace package and has the ability to measure the time the sit-stand desk is in a certain position (seated or standing) based on the presence of a worker using the computer. The main advantage of this novel approach and artificial intelligence software application was continuous data collection while taking into account the time employees are away from their workstation for restroom breaks, lunch, meetings, and other activities. Each worker can receive personalized sitting or standing reminders based on their own active computer usage to increase their sit-stand desk utilization by remaining engaged with their health behavior status.

As companies and universities invest in sit-stand desks for their employees, there is a need for an effective behavioral method that will ensure the desks are being utilized to experience health and productivity benefits. The methods used in the two research studies can be used as a way for organizations to measure sit-stand desk usage with a number, rather requiring workers to fill out self-reported surveys. From a manufacturing/designer perspective, sit-stand desks are built to last for a certain time period. However, the findings from this research can contribute towards the design of future sit-stand desks in terms of increasing product sustainability and warranty, based on current desk usage. For example, if we can understand how many times a day/year the sit-stand function is being used by the worker, product developers can ensure they are built to last. The Business and Institutional Furniture Manufacturer's Association (BIFMA) sponsors the development and maintenance of the safety, performance, and sustainability standards for furniture. Organizations like BIFMA can use the research findings in developing additionally desk guidelines for product performance and safety. In order to understand product warranty and sustainability, it is important to understand how long products are actually being used once it is in the hands of the user. This research evaluates a method that can quantify and increase the usage of such desk products.

The objective of the two research studies conducted were to determine if computer software reminders (independent variable) using health behavior constructs and gamification elements can increase sit-stand desk utilization (dependent variable). Ultimately, the methods and research findings will serve as a reference for future interventions to quantitatively measure and increase sit-stand desk usage. The primary occupational health implications of this research are 1) a quantitative metric that employers can use to keep their workers accountable for sit-stand desk usage and 2) to promote a physically active work environment using personalized feedback and competition.

CHAPTER II

3-MONTH IN SITU WORKPLACE STUDY: A QUANTITATIVE EVALUATION OF ELECTRIC SIT-STAND DESK USAGE

Occupational Applications

Sit-stand desk interventions are targeted to reduce sedentary time in modern workplaces with an ultimate goal of improving health and productivity. Because sit-stand desks require workers to take an active role in changing the desk position, usage compliance of the sit-stand function is a challenge. This research study used computer software to objectively record continuous data on electric sit-stand desk usage during computer use in order to understand the current desk usage behavior in a large office environment on ~300 workers for 3 months. We found that workers completed ~1 desk position change per work day and one-fourth of the workers always had the desk in a seated position (during computer use). The methods used demonstrate a novel approach to continuously record sit-stand desk usage during active computer use to ensure that workers are using the sit-stand function.

Office workers are an ideal target population to reduce sedentary time for desk-based jobs. Height-adjustable sit-stand desks can decrease occupational sitting time, but few studies have examined the continuous usage patterns of the desks in naturalistic work environments or with a large sample size.

The purpose of this study was to use a novel approach to determine current electric sit-stand desk usage for office workers who had an electric sit-stand desk for at least one year. The study integrated electric sit-stand desks with computer software to measure continuous data on the time desks were in a sitting or standing position during active computer use in 364 workers in a government office. The primary outcome measure was the frequency of desk position changes.

Another outcome measure was the time desks were in a sitting or standing position during active computer use.

Workers completed an average (SD) of 1.29 (1.91) desk position change per work day. Overall, 43% of the workers either changed their desk position once/twice a week, once a month, or never. In a given workday, workers had their desks in a seated position for majority of the time (~89%) and in a standing position for the remaining time (~11%).

This study reveals that one-third of the workers used the sit-stand function of the desk only once or twice per week and the desk was in the seated position for majority of the time during computer use. The methods and outcomes used will serve as a reference for future studies to measure sit-stand desk usage and determine if interventions to increase usage are successful.

Introduction

Stand-capable desks have been used to reduce occupational sitting time while remaining at the workstation. This intervention has shown evidence of decreased sedentary time (Dutta et al., 2014) and improved BMI (Wendel et al., 2016), productivity (Garrett et al., 2016), and cognitive function (Mehta et al., 2015). A meta-analysis of activity-permissive workstations, across 19 field-based trials and 19 laboratory investigations (n = 2 to 66 per study), reported that while activity-permissive workstations reduced sedentary times by 77 minutes/8-hr workday, health- and work-related outcomes were not affected (Neuhaus et al., 2014).

Height-adjustable sit-stand desks provide adjustability for proper ergonomic fit, safe work posture and variation, and increased movement (Koskelo et al., 2007). However, this type of desk requires the worker to consciously change the desk height to a sitting or standing position. In a survey of 4 companies in Sweden, Wilks et al. (2006) reported that approximately only one in ten workers use the sit-stand function of their workstation. The study attributed this usage pattern to lack of feedback to or engagement of the worker with the functions of the desks. As a result, it is likely that the actual desk usage may not be sufficient for individuals to experience health and productivity benefits.

In their meta-analysis, Neuhaus et al. (2014) notes that duration of the activity-permission workstation exposures was relatively short; lab-based exposure protocols ranged from 1 hour to 2 weeks, and the field-based investigations employed a mean intervention duration of 15 weeks (1 day to 12 months). The longest protocol (12 months) study employed 36 office workers (Parry et al., 2013) and the largest study monitored 62 office workers for 12 weeks (Koepp et al., 2013). Both these field studies were testing the effectiveness of treadmill desks in workers who were introduced to the intervention for the purpose of the study. However, large in-situ studies, conducted over a period of time, are needed to document continuous sit-stand desk usage patterns in office workers to understand challenges associated with non-compliance, particularly after the intervention novelty has worn off.

One of the barriers to effectively determine the use of sit-stand functions in desks is the lack of proper evaluation techniques of actual sitting and standing times during active desk usage (i.e., when individuals are at their desks). In a recent study, Barbieri et al. (2017) used computer software to record every change in desk height and the corresponding timestamp of the change for 9 office workers. Although the software recorded desk position time and changes, the method did not take into account the time spent away from the workstation due to normal day-to-day work activities and introduced the desks for the purpose of the study. Since employees leave their workstations for various reasons (e.g., meetings, conference calls, bathroom breaks) and because routine office work involves computer-based tasks, optimal data collection methods could potentially measure desk usage that reflects the time workers are present or away from the workstation based on individual computer usage. The present study aims to address this gap with a novel method that uses software to continuously record sit-stand desk usage during computer use, which takes into account the time spent away from the desk.

Software packages, such as WorkPace®, have been used as a validated tool to measure active computer use (ACU) by recording all keystrokes, mouse clicks, and mouse movements (van den Heuvel et al., 2003, Blangsted et al., 2004). By analyzing the intervals between keystrokes and mouse clicks/movements, these programs can accurately determine the durations and times workers are actively using their computers, when compared to self-reports of computer use by workers. While these objective measures differ in their magnitude to self-report measures, these two measurement types have exhibited a strong correlation (i.e., directionality) with each other (Blangsted et al., 2004). As such, these active computer use evaluation methods may serve as an objective indicator of when workers are actively working at their desks, over the more commonly used self-report measures.

The primary objective of the present study was to use a novel method to determine the continuous sit-stand desk usage in a naturalistic work environment with a large sample size. Sit-stand desk usage was quantitatively measured using a commercially available software that recorded every desk position change completed by the workers throughout the work day. The software also collected continuous data on the times electric sit-stand desks were in sitting and standing positions during active computer use. Understanding worker interactions related to usage of sit-stand functions, or lack thereof, can facilitate designers and ergonomists understand current desk utilization and be used as a quantitative metric for employee desk usage.

Methods

Participants

During the 3-month data collection period, there were 454 workers with recorded data. The eligibility criteria for this secondary analysis was a total of ≥20 hours ACU and ≥5 days per worker during the 3 months. 364 out of 454 workers were eligible for this analysis (N = 364). All participants were employees of Comcare, an Australian governmental organization responsible for workplace safety and compensation for Australian government workplaces. Their office routine consisted of a majority of computer-based work (filing claims, reports, etc.) and other non-computer tasks (phone calls, meetings, reading). All office buildings were open-space plans on multiple floors. All employees in this organization were provided electric sit-stand desks in 2012. After desk deployment, an ergonomist was onsite for several weeks to assist all staff to setup their desk properly and the workstation setup guidelines were provided to all employees. Out of 7 Comcare sites nationally, three sites, located in Sydney, Canberra, and Melbourne, were randomly selected to have employees included in the study. Study awareness occurred at an organizational level where all employees who had an electric sit-stand desk for at least one year were invited to participate in the study. Awareness of data collection activities for this study were completed by the Health & Safety division of Comcare through email and fliers in all office sites. All data were collected through computer software (described later), de-identified by Comcare, and provided to Texas A&M University researchers for secondary analyses. Texas A&M Institutional Review Board approved the secondary analyses protocol. Due to secondary analyses, the research team was not able to obtain demographic information on the workers (age, gender).

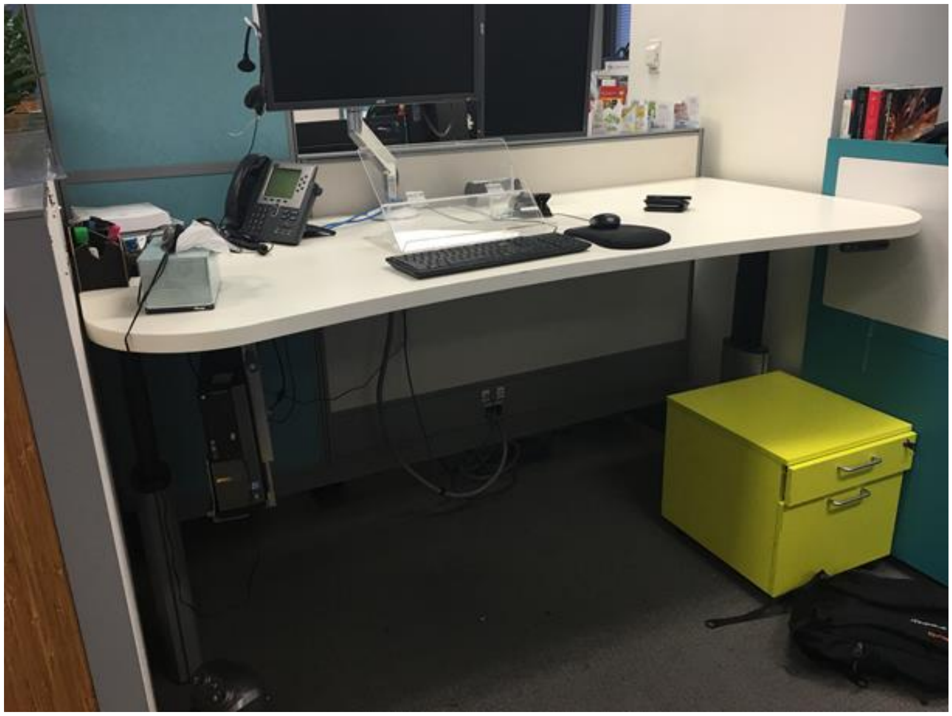
Electric Sit-stand Desk and Computer Integration

For this study, the sit-stand desks (Paradigm Sit Stand, UCI, Australia) had an electric motor to adjust the height (60.5 cm – 128 cm) using an electronic control box that was attached to the inner desk surface. The control box had an up and down button, to allow workers to adjust the desk to sitting (Fig. 1A) and standing heights (Fig. 1B), and three memory preset buttons to allow workers to set heights for positions that would be stored in the memory of the electronic control (Fig. 1C). All workstations had a task chair (Vegas Chair, Schiavello, Australia) with an adjustable seat height (41.6 cm – 51.6 cm).

A

FIGURE 1. Electric sit-stand desk and memory presets. Seated (A) and standing (B) position; and electronic control box to change desk positions with memory preset buttons (C).

B



C

Figure 1 Continued

Each worker's electric sit-stand desk was connected to their desktop PC via a cable (Linak® USB2LIN06 USB connector cable, Linak®, Denmark) from the electronic control box to the computer through a USB port. A software package (Wellnomics® Sit Stand version 1.0, Wellnomics LTD., New Zealand) was installed on all workers' desktop PCs. The sit-stand software package was built off of WorkPace® and programmed to work in conjunction with the electronic control box and cable to record continuous data on each desk position that was completed by the worker. Additionally, the software collected data on the times the desk was in each position (sitting or standing) during active computer use. Inactive computer use was defined as the duration, greater than 30 seconds, during which there was no keyboard or mouse use. The software had a 'hook' that was installed in the event chain where any mouse or keyboard activity was automatically notified to the software. Thus, active computer use was calculated based upon discrete events from the mouse/keyboard. Once the worker resumed any keyboard/mouse activity, active computer use time began and the software recorded the desk position along with the duration the desk was in that position.

It is possible that workers could be at their desks completing non-computer work tasks in a seated or standing position (e.g., reading, phone calls, etc.) but only ACU was used to determine the desk position time. If a worker was in a period of inactive computer use and changed the desk position, the desk position change was still recorded but computer use remained inactive until any keyboard/mouse activity was resumed. Therefore, the software recorded every time the sit-stand desk function was used, regardless of computer use. While a strict criteria, this approach offers greater quality control and confidence in the times noted in this study included a worker present at their desk and completed worker action to change desk positions.

Software Interface

The sit-stand software required workers to record their desk position heights by placing the desk in sitting and standing positions based on Safe Work Australia Ergonomic guidelines. Once the desk heights were recorded in the memory of the software, it determined the amount of time the desk was in each position. The margin of error for the software to determine each position was ±10 cm. The workers were informed that the software was placed into *monitor only* mode. In this mode, the software recorded continuous data on the number of times the desk position was changed and the time desks were in a sitting (Sit-ACU) or standing position (Stand-ACU) during active computer use.

Study Design

The data were collected for a 3-month time period. The company installed the necessary cables and software for all workers in October 2016. After the installation, the software required participants to complete an ergonomic setup for their workstation that consisted of adjusting the desk height to sitting and standing positions according to Safe Work Australia ergonomic recommendations. Once the setup was completed by each worker, prompts from the software package informed the workers that the software was placed into *monitor only* mode. From November 1, 2016 through January 31, 2017, the software continuously recorded the aforementioned outcome measures.

Study Outcomes

The software package was the primary source of data collection and continuously measured workers for 3 months (November 2016 through January 2017). The primary outcome was the frequency of desk position changes per work day. Other outcomes included the time desks were in a sitting (Sit-ACU) or standing position (Stand-ACU) during computer use and the maximum time desks were in a position before changing to another position (Max-Sit/Stand ACU) during computer use.

Statistical Analysis

Analysis on the secondary data, provided by Comcare to Texas A&M researchers, was conducted using SPSS 22 (IBM SPSS Statistics). To determine usage patterns, the overall means, standard deviations (SD), and box plots were pooled for all 3 months and calculated for active computer use, sit/stand-ACU, desk position changes per work day, and max sit/stand ACU. Weekly trends were analyzed by calculating the means of study variables of each worker and the variance was used to determine the consistency of the trends across all weeks. The relationship between active computer use and the outcome measures (Sit-ACU, Stand-ACU, and desk position changes per work day) were assessed using Spearman's correlation.

Results

During the 3 months of data collection, an average of 42 work days per worker was recorded. Due to the company's holiday period, one week of data (from December 22, 2016 – January 2, 2017) was excluded from the analysis. The workers had an overall mean (SD) of 4 (0.95) ACU hours per work day. The summary results of the outcome measures are presented in Table 1.

TABLE 1. Study #1 overall group means baseline only.

	Mean (*SD*)
ACU	4.02 (0.95) hrs
Sit-ACU	3.57 (1.19) hrs
Stand-ACU	0.45 (0.78) hr
Desk Position Changes Per Work Day	1.29 (1.91) changes per work day
Max Sit-ACU	3.07 (1.38) hrs
Max Stand-ACU	1.00 (0.85) hr

For the primary outcome measure, the mean frequency of desk position changes per work day results are shown in Fig. 2. While 21% (76 out of 364 workers) changed their desk positions to sitting or standing more than two times a day, approximately 11% (40 out of 364 workers) changed their desk positions once a month or never.

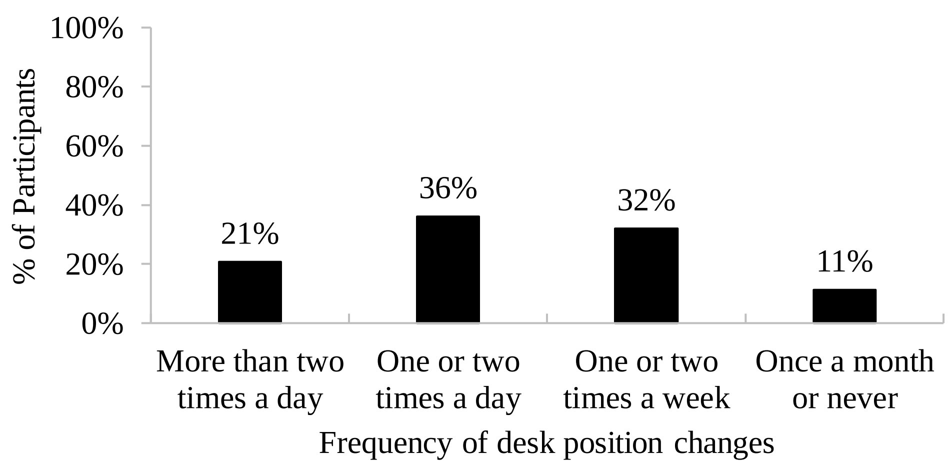


FIGURE 2. Frequency of desk position changes.

Figure 3 illustrates the weekly trends of sit/stand-ACU. This figure indicates that, based on the percent of computer use, the range of desk in a seated position was 88% - 91% and standing position was 9% - 12%. On average, the workers had the desk in a seated position ~89% of the time and in a standing position ~11% (during computer use). For the frequency of workers using the sit-stand function of the desk over 3 months, the range was 1.11 – 1.50 (*SD* = 0.13) desk position changes per work day. The weekly trends for Sit-ACU, Stand-ACU, and desk position changes per work day were consistent during the 3-month collection period with low variances (0.03, 0.002, 0.02, respectively) and *SD* (0.18, 0.04, 0.13, respectively). This indicates that the desk usage patterns did not vary over time.

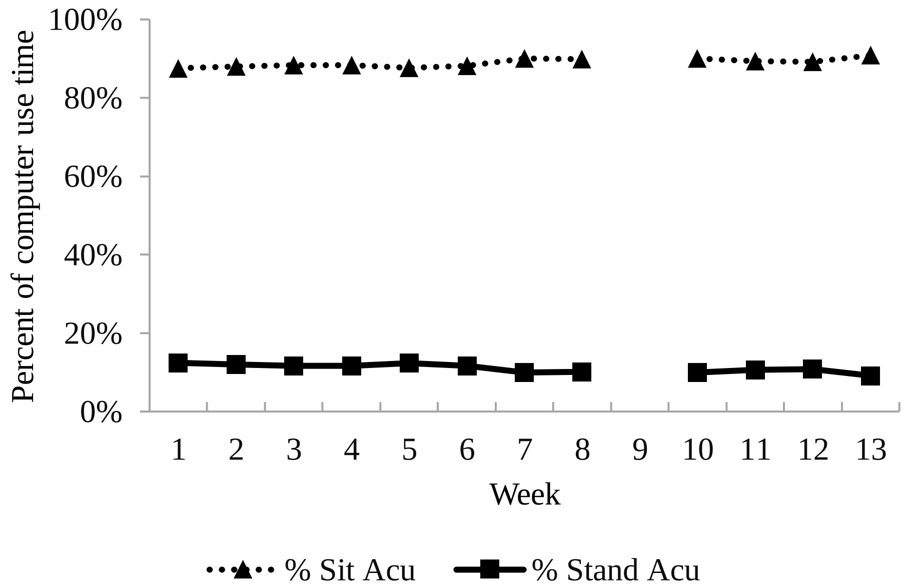


FIGURE 3. **Sit- and Stand-ACU as percent of computer use time.** Week 9 was excluded due to company holiday period.

Since sit/stand-ACU are dependent on the amount of computer use, it is important to understand the differences in the proportion of computer use time spent in each desk position. Figure 4 illustrates that 26% of the workers (96 out of 364) never had the desk in the standing position during computer use time (desk was in standing position 0% of time during computer use).

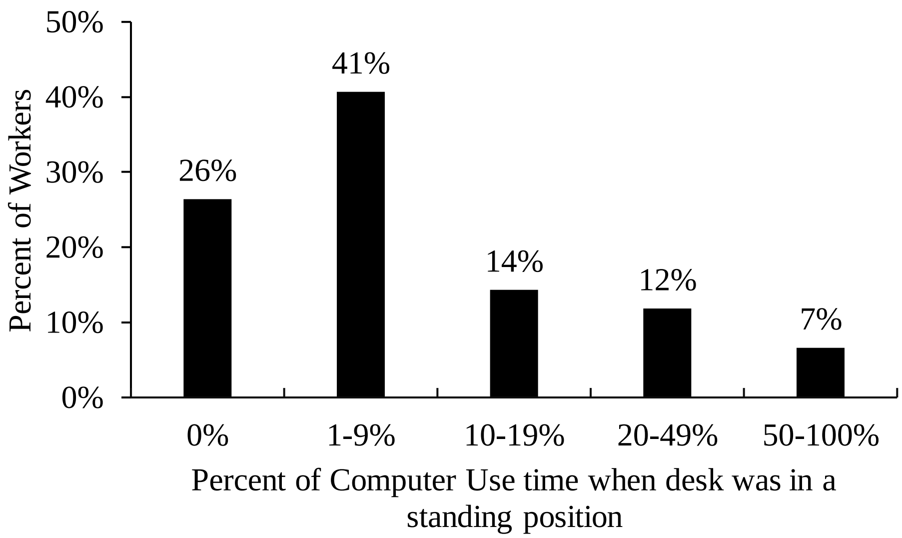


FIGURE 4. Percent of workers with desk in standing position.

The relationship between active computer use and the outcome measures (Sit-ACU, Stand-ACU, and desk position changes per work day) were assessed using Spearman's correlation based on ranks. Higher computer use was highly correlated with Sit-ACU (r_s =0.85), suggesting that the more time workers spent on the computer, the more time the desk was in a sitting position. Computer use was not associated with the desk in a standing position (r_s =0.25) or the number of desk position changes per work day (r_s =0.27).

Figure 5 shows the box plots of Sit/Stand-ACU and desk position changes per work day during the 3-month period.

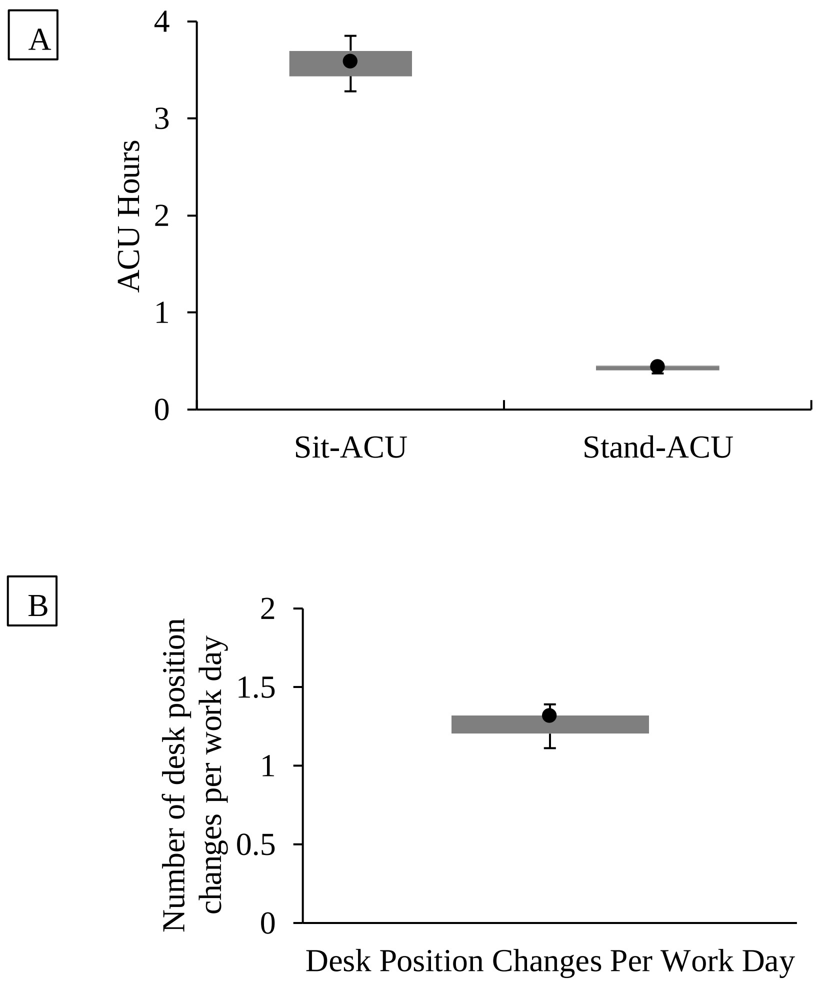


FIGURE 5. Box plots of Sit/Stand-ACU and desk position changes. Black dot indicates overall pooled average for the 3 months. The boxes represent quartiles 1-3 and the whiskers indicate 95% confidence intervals.

Discussion

The present study was aimed at documenting sit-stand desk usage patterns in a large sample (N = 364) of office workers for a 3-month period. One unique aspect of the present study was the quantitative approach of obtaining sit-stand desk usage *during active computer use* by integrating the electric sit-stand desk and computer through commercially available software programs. The study was also novel in that the sit-stand desk usage patterns were obtained from workers who have had at least one year of sit-stand desk exposure, thereby monitoring sustained desk usage behaviors. In order to capture the entire work day's physical activity levels, the novel method should be used complementary with wearables.

During the three months, workers had a mean of ~4 hours of active computer use. This is higher than comparable cohorts, where the workers averaged 1.8 (Anderson et al., 2008) and 2.4 (Ijmker et al., 2010) computer use hours per work day. For this study population, in a given work day, workers had their desks in a seated position for majority of computer use time (~89%) and in a standing position for the remaining time (~11%). One-fourth of the workers never placed the desk in a standing position during computer use. Overall, ~70% of the workers had the desk in a standing position for 10% or less during computer use. Note that these usage patterns are during active computer use only. Further, computer use was not associated with the desk being in a standing position or completing desk position changes. Instead, computer use was associated with the desk in a sitting position. Considering that the workers have the option to place the desk in a standing position, this finding shows that the desk is mainly placed in the seated position as workers use their computer. These results a sub-population of office workers (high duration computer users) that should be targeted for interventions designed to increase their time the desk is in the standing position during computer use.

On average, the workers completed ~1 desk position change/work day. Furthermore, 43% of workers either changed their desk position once/twice a week, once a month, or never. To date, this is the first data to represent the continuous, quantitative usage of the sit-to-stand function with a large sample size for three months. This was further compounded by the fact that the overall median maximum time desks were in a seated position was ~3 hours (during computer use). Nevertheless, these findings can inform future interventions by providing a reference baseline of current steady-state, sit-stand desk utilization. Since we can now quantify actual desk usage, future studies should incorporate interventions that will increase desk usage and determine if there are any associated effects on biomarkers, ergonomics, and health costs.

One of the major strengths of the present study was that the company had provided electric sit-stand desks to all workers 4 years prior the study. Since the entire workforce had sit-stand workstations and were included in the study, this approach eliminated the possibility of volunteerism bias. Another strength was the observed steady state behavior of sit-stand desk users. Additionally, secondary data analyses were only conducted from those workers who had at least one year of sit-stand desk exposure. Research has shown that sit-stand desk habits do not significantly change after a 6-month period (Pickens et al., 2016). The workers likely passed the adoption phase for the sit-stand desks, i.e., the trends did not seem affected by any new sit-stand desk use behavior, which indicated that usage patterns were consistent throughout the data collection period. This is an important observation, as understanding such usage patterns can aid in the design of future studies, as these results provide a consistent baseline of desk usage.

The study had two limitations. First, because of the secondary data analyses approach, the research team were not able to obtain demographic information (e.g., age, gender, stature, weight, etc.) to conduct a detailed analyses of sit-stand desk usage. Large in-situ studies that can be experimentally designed to obtain these valuable demographic information are difficult to design and are associated with challenges, such as attrition, volunteerism bias, and other confounds. It is not surprising that the largest study to determine actual desk usage through software, published to date, included 9 office workers for 2 months (Barbieri et al., 2017). Second, future work is warranted to integrate non-computing times into the desk usage statistics when workers are at their desks. To better understand desk usage patterns that can better inform population behavior on such interventions, it is important to include factors such as long-term desk usage, larger sample size, multiple in-situ sites, and continuous and objective measures of sit-stand behaviors. As such, the present study prioritized these factors while acknowledging the limitations of traditional experimental design controls.

The present study adopted a quantitative approach to determine the continuous usage of electric sit-stand desks that can be argued to ensure workers are using the sit-stand desk functions. When organizations decide to invest in these workstations, the approach used in this study can help upper-management to monitor the usage of the desks and to design workplace interventions and awareness campaigns to increase their usage, when needed. Methods and findings from this study can be used as a metric for employees and manufacturers to quantify desk/product usage. These quantitative measures, achieved through simple electronic instrumentation (as demonstrated in the present study), can potentially be combined with wearables and other indoor tracking methods, which could lead to a more accurate determination of desk usage times and activities during the workday. These automated and precise assessments can enhance long-term monitoring of activity-permissive interventions, which in turn will allow for their longitudinal evaluation on activity and health outcomes in sedentary workers.

CHAPTER III

AI SOFTWARE CAN NOW MONITOR AND PROMPT OFFICE WORKERS TO IMPROVE HEALTH BEHAVIORS

Significance

Breaking up long periods of occupational sitting time and increasing postural transitions can lead to increased energy expenditure and decreased metabolic risks. Sit-stand desks have been successful in reducing workplace sedentary behavior but the challenge remains for an effective method to increase and sustain the usage in order to experience the health and productivity benefits. The aim of this study was to determine if software reminders can change and increase electric sit-stand desk usage.

A 1-year field study of 194 office workers was conducted at three random Australian government office locations that have had sit-stand desks since 2012. Data collection used a novel method of computer software that continuously recorded objective electric sit-stand desk usage during computer use, while taking into account the time a worker spends away from their desk (breaks, meetings). During the baseline period, all workers' desk usage was recorded by the software and the intervention period consisted of software reminders to all workers to change desk positions. Workers received real-time feedback on their habits and goals through the software. Pairwise comparisons were conducted to determine differences between the baseline and intervention. Overall pooled means for each month were calculated to determine desk usage patterns and effect sizes (Cohen's d) were analyzed to test for significance of the intervention

The intervention increased desk usage by increasing ~1 change to ~2 changes per work day. There was a 76% reduction in workers who never changed desk positions. Medium to large effect sizes from the intervention were observed in all three primary outcome measure (desk in sitting/standing position and desk position changes per work day). Higher duration computer users showed the largest improvements in desk usage behavior.

The behavioral intervention successfully increased sit-stand desk usage. These findings demonstrate an effective health behavior intervention that will increase postural transitioning and interrupt prolonged inactivity while remaining at the workstation. Now that we can quantify an increase in desk usage, future research should explore associated effects with biomarkers, diet intake, and health costs.

Background

Obesity occurs when energy intake is exceeded by energy expenditure (EE) (Levine et al., 2005). Physical inactivity can lead to an increased risk of obesity and levels are classified by the following MET (metabolic equivalent) activity intensity: light (<3 METs), moderate (3-6 METs), and vigorous (>6 METs) (Blair et al., 1999; Pate et al., 1995). Although recommendations only exist for moderate to vigorous activity (150 mins per week) (McCrady & Levine, 2009), adults are not meeting these recommendations while also spending increased time in a seated or reclined position at work, known as being sedentary behavior (≤1.5 METs) (WHO 2010).

Prolonged bouts of sitting time (>20-30 mins) are associated with higher levels of fasting insulin and increased risk of type 2 diabetes and are positively correlated with waist circumference and the prevalence of obesity (Healy et al., 2011; Healy et al., 2008; Gupta et al., 2016). Frequently interrupting prolonged sitting can reduce metabolic risk independent of moderate/vigorous physical activity levels and can improve postprandial glucose metabolism, triglyceride levels, BMI, and waist circumference (Honda et al., 2016; Bergouignan et al., 2016; Hamilton et al., 2008). The EE for a postural transition (sit-to-stand or stand-to-sit) is 35% and

28% higher than that of sitting and standing, respectively (Júdice et al., 2016). Additionally, the EE increases for a postural transition as the weight increases (Hatamoto et al., 2016). Thus, increasing postural transitioning may be an important interventional target for overweight or obese individuals who should be increasing their EE.

It has been theorized, in rodent models, that bones sense changes in body mass and as a result, can alter appetite and diet intake to return the body to its previous weight (Jansson et al., 2018). The body's "gravitostat" is the bones' sensor that can be triggered by body weight bearing down on bones. During prolonged sitting time, most body weight is supported by seat cushions, which leaves bones unaware of how much weight is being taken on by the bones (Jansson et al., 2018). Therefore, if sitting time can be reduced, bones could have a better sense of body weight and can signal reduced appetite and diet intakes that would result in weight loss. Sit-stand desks have been used to reduce occupational sedentary behavior and improve BMI and productivity (Dutta et al., 2014; Wendel et al., 2016; Garret et al., 2016). The intention of the desks is to disrupt prolonged periods of sitting and standing time. Most require worker action to change desk positions. Due to the responsibility placed on the worker to change desk positions, there have been compliance and usage issues, which have led to minimal health and productivity benefits (Wilks et al., 2006). Health behavior change constructs (self-monitoring and goal setting) have shown to be effective components of promoting physical activity but have yet to be adopted to test effectiveness of sit-stand desks to change behavior (Pearson et al., 2012).

An expert statement (Public Health England and the Active Working Community Interest Company) says that desk-based workers should aim to "initially progress towards accumulating at least 2 hr/day of standing and light activity during working hours, eventually progressing to a total accumulation of 4 hr/day" (Buckley at al., 2015). To date, there is currently no quantitative study, conducted over time, to determine if workers are meeting this recommendation. Therefore, the purpose of this study was to determine the effectiveness of a health behavior change intervention designed to increase sit-stand desk usage and help reverse workplace physical inactivity. Continuous, objective data was collected on the time desks were in a sitting and standing position during computer use for 194 workers during a 1-year time period in 3 naturalistic work settings and used computer reminders to increase movement at the workstation.

Methods

Participants

Participants were adult workers at a government group in Australia (Comcare) where office work included computer-based tasks and other work (meetings, reading, conference calls). During the 1-year data collection period, 624 workers had recorded data. The eligibility criteria for this secondary analysis was ≥20 ACU hours and ≥5 work days per worker (equivalent to at least one work week) for each of the following time periods: 3 months baseline, first 3 months of the intervention, and the last 3 months of the intervention. These criteria ensured the entire cohort of workers completed the study from the beginning to the end. Out of 624 workers, 194 workers were eligible for this analysis (N =194). From an organizational level, all workers were provided electric sit-stand desks in 2012. Three out of 7 office sites nationally (Canberra, Melbourne, and Sydney) were randomly selected to have workers included in this study. Recruitment for this study occurred from a management level. All workers who had a sit-stand desk for at least 1 year were invited to be a part of the study through management meetings. All data were collected through computer software (described later), de-identified by Comcare, and provided to Texas A&M University researchers for secondary analyses. Texas A&M

Institutional Review Board approved the secondary analyses protocol and due to this, the researchers were not able to obtain demographic information on the workers (age, gender).

Data Collection

Each worker's electric sit-stand desk had a cable (Linak® USB2LIN06 USB connector cable, Linak®, Denmark) that connected the desk to the USB port of the desktop PC connected to their desktop PC. A software (Wellnomics® Sit Stand version 1.0, Wellnomics LTD., New Zealand) was installed on all workers' desktop PCs. The validated sit-stand software worked in conjunction with the cable to record data continuously on the times the desks were in each position (sitting or standing) during active computer use (Blangsted et al., 2004). For each worker, the desk heights were recorded in the memory of the software, based on recommended ergonomic heights. Inactive computer use was defined as the duration, greater than 30 seconds, during which there was no keyboard or mouse use. Once the worker resumed any keyboard/mouse activity, active computer use time began and the software recorded the desk position along with the duration the desk was in that position.

The software used two modes in this study: *monitor only* (3 months) and *software reminders* (9 months). In *monitor only* mode, the software recorded continuous data, during active computer use (ACU), for the time desks were in a sitting (Sit-ACU) or standing position (Stand-ACU). In *software reminders* mode, every worker received computer software reminders to change desk positions.

Once the software reminders mode was activated, a reminder arrow (pointed up or down based on their current desk position) to change desk positions appeared on the worker's computer monitor display. The workers had the option to change their desk position, postpone the reminders, or ignore them. Workers could change the frequency of the reminders or choose to not receive any computer reminders. Further, they could interact with the prompt, as it provided real-time statistics in order to monitor individual progress for that day, week, or month. The prompt displayed the following metrics: stand-ACU, the percent time the desk was in a standing position, and average number of desk position changes per work day. The primary outcome measures for this study were Sit/Stand-ACU and desk position changes per work day.

Study Design

The data were collected for a 1-year time period. The study consisted of two phases: baseline (3 months) and intervention (9 months). The cables and software were installed for all workers in all three office locations in October 2016. After the installation, each worker placed the desk in a sitting and standing position and the software recorded the heights. After the setup, the software informed the workers that the software was placed into *monitor only* mode. During the baseline phase (November 1, 2016 through January 31, 2017), the software was placed into *monitor only* mode for all workers and continuously recorded the outcome measures.

During the intervention phase (February 1, 2017 through November 24, 2017), the software was placed into *computer reminders* mode. In the intervention, all workers received computer software reminders to change their desk position and the outcome measures were continuously recorded. For this study, the default setting for the frequency of the reminders was set to 30 minutes sitting and 20 minutes standing (ex: after 30 minutes of Sit-ACU, the worker would receive a reminder to change the desk to a standing position; after 20 minutes of Stand-ACU, the worker would receive a reminder to change the desk to a sitting position). This default setting was based on musculoskeletal medicine research, which suggests postural transitions every 20-30 minutes, as well as evidence showing that interrupting long bouts of sitting time

(>30 minutes) provides metabolic benefits (Ryan et al., 2011; Atlas et al., 2001; Dunstan et al., 2012).

Statistical Analysis

The analysis was conducted using SPSS 22 (IBM SPSS Statistics). Pairwise comparisons analysis was conducted to determine the mean differences between baseline and the intervention using means, SD, and histograms. We tested for significance of the intervention using effect size (using Cohen's d), paired two sample for means t-test (ACU and Sit/Stand ACU) and non-parametric tests using the Wilcoxon Signed-Rank test (desk position changes per hour and work day). The overall pooled means were calculated for every month of data collection period to determine usage patterns before and after the intervention (1 week of company holiday period was excluded from this monthly usage analysis). The linear relationship and slope were calculated using the pairwise mean differences of each outcome measure with relevance to computer usage to determine the improvements made from the intervention.

Results

For the baseline phase, the 194 workers had an average of 163 ACU hours and 40 work days recorded per worker. For the intervention phase, the average data recorded was 637 ACU hours and 159 work days per worker. Pairwise comparisons of difference in outcome measure means are shown in Table 1. All three primary outcome measures had a significant change ($p < 0.05$) from baseline to intervention, with medium to large effect sizes (Cohen's d) observed in each outcome (Sit-ACU: 0.48, Stand-ACU: 0.41, Desk position changes per work day: 0.68).

Table 2. Study #1 overall group means baseline and intervention.

	Baseline Mean (*SD*)	Intervention Mean (*SD*)	Pairwise Mean Difference (*SD*)
ACU	4.03 (0.93) hrs	3.87 (0.86) hrs	-0.16 (0.61) hr
Sit-ACU	3.61 (1.14) hrs	3.27 (0.97) hrs	-0.34* (0.71) hr
Stand-ACU	0.42 (0.72) hr	0.60 (0.68) hr	0.18* (0.44) hr
Desk Position changes per work day**	1.04 (1.54) changes	2.31 (2.37) changes	1.27* (1.88) changes

*Significant change (p <0.05)

**Wilcoxon signed rank test

Figure 6 illustrates the effect from baseline to intervention for every month of the study. For all outcome measures, the last month recorded was an improvement compared to baseline, indicating the intervention was successful.

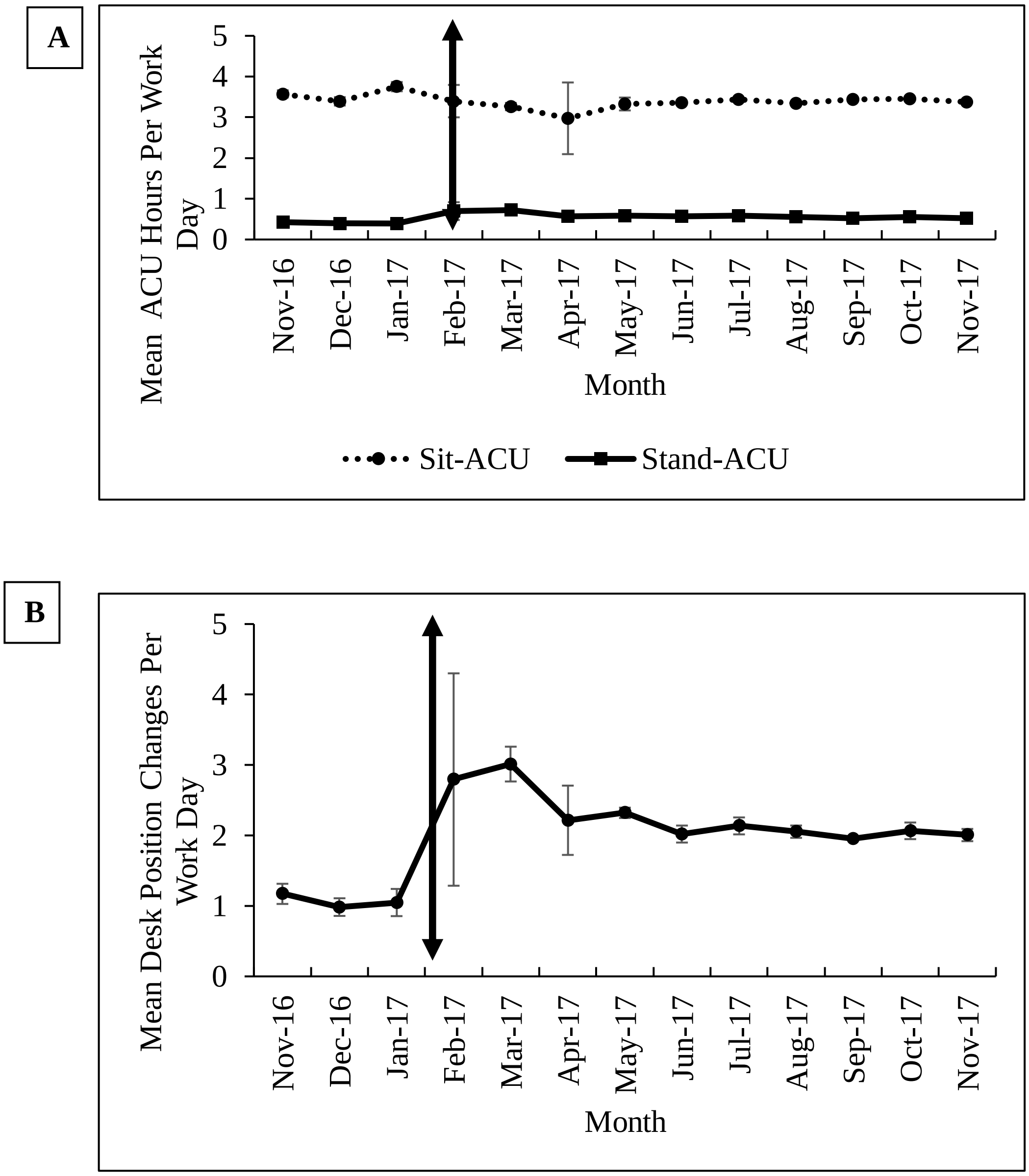


FIGURE 6. Overall pooled outcome measure means by each month. The double-arrowed vertical line represents the start of the intervention. Means of Sit/Stand-ACU (A), Desk position changes per work day (B), and Time between desk position changes (C) show health behavior improvement for each outcome measure. Error bars indicate 95% CI.

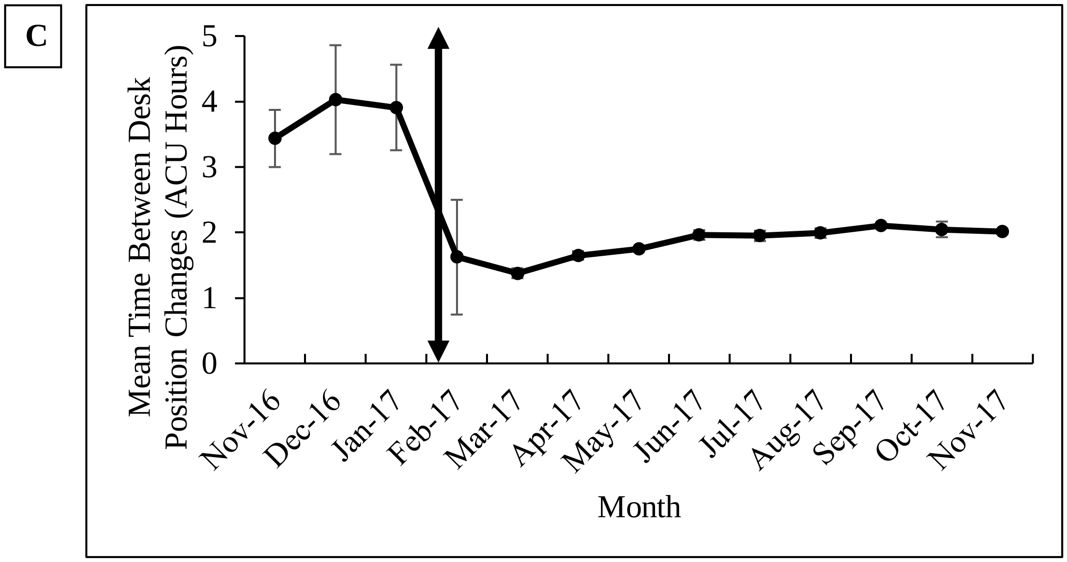


Figure 6 Continued

A significant linear relationship was observed with the pairwise mean differences for each computer usage sub-group (2, 3, 4, 5 mean ACU hours per work day) for all 3 outcome measures (Sit-ACU: slope = -0.37, p <0.0001, Stand-ACU: slope = 0.09, p <0.05, Desk position changes per work day: slope 0.33, p <0.05). The largest improvements in Sit- and Stand-ACU were seen in the workers who used the computer, on average, for 5 hours/work day (39 minutes reduced and 25 minutes increased, respectively). The largest improvements for desk position changes per work day were seen by the workers who used the computer, on average, for 5 hours/work day (increased by 2.56 desk position changes).

The frequency of desk position changes per work day improved for workers from the baseline to the intervention (Fig. 7). The largest sub-population of workers with improvement were made by those who had a mean of ≥ 3 desk position changes per work day. Out of 194 workers, these group of 20 workers (baseline) increased to 83 workers (intervention), or a 330%

increase in workers who completed ≥ 3 desk position changes per work day. Another improvement were the workers who never made any desk position changes. From the baseline to the intervention phase, these group of 33 workers reduced to only 7 workers, which is equivalent to a 76% decrease in workers who never made any desk position changes. Further, the overall average desk position compliance (rate at which workers would change their desk position when provided a software reminder) was 61%.

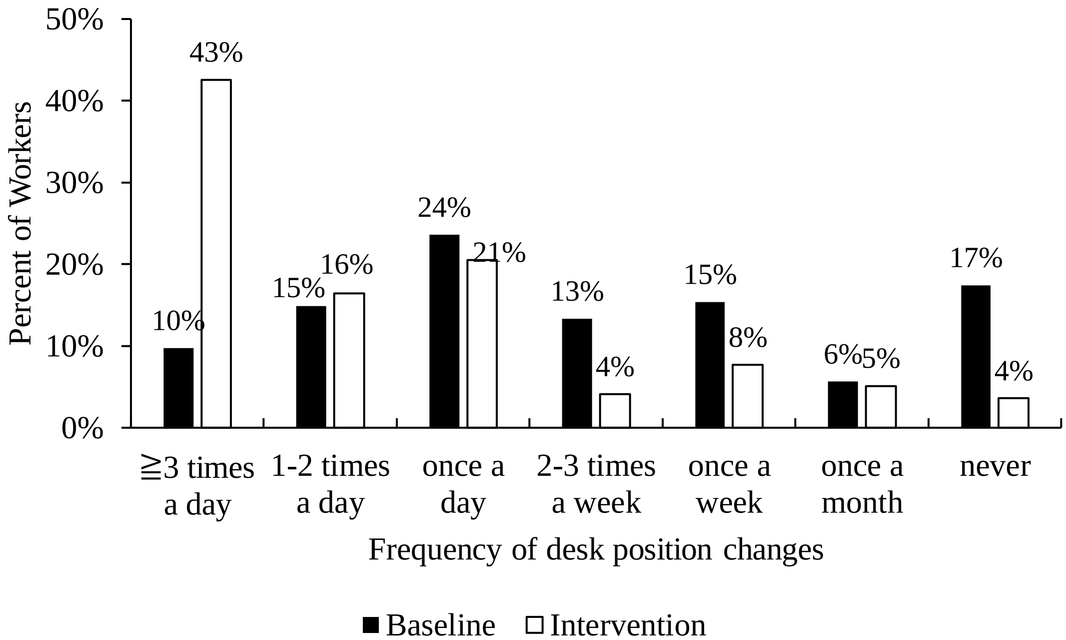


FIGURE 7. Frequency of desk position changes baseline to intervention.

The time desks were in a sitting or standing position are related to the ACU time. As a result, it is important to look at the Sit/Stand-ACU as a percent of computer use (Fig. 8). For the baseline phase, 26% of the workers never had their desk in a standing position. After the intervention, this was reduced to only 9% of the workers, indicating that the software reminders made workers use their desk in the standing position more often. The summary of results for the entire study is presented in Table 3.

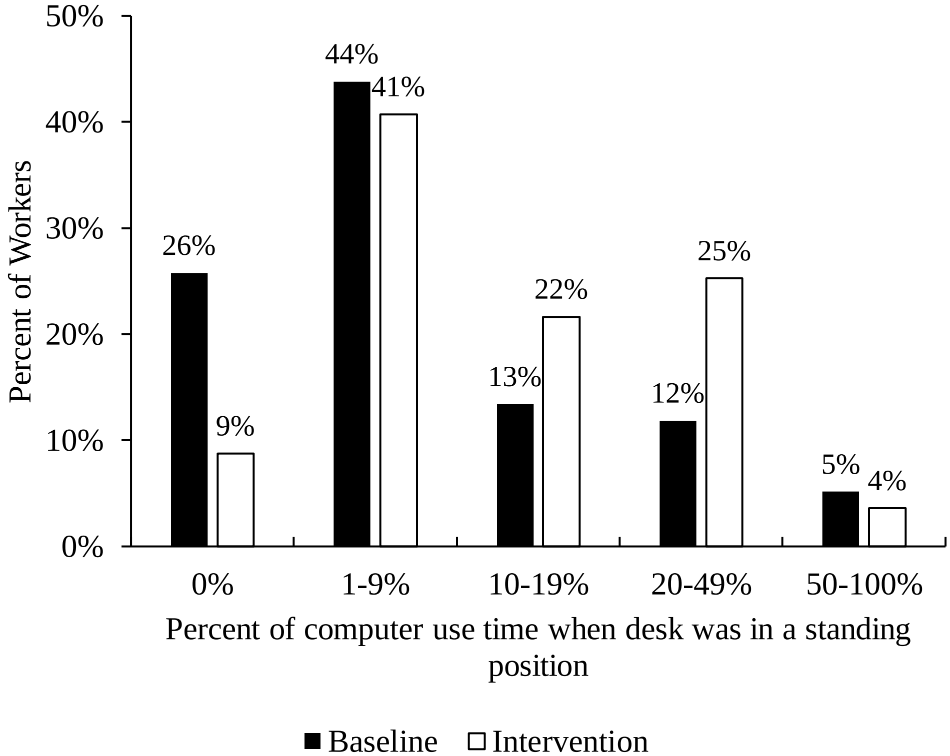


FIGURE 8. Percent of workers with desk in standing position (intervention).

Table 3. Summary of results

Message	**Variables Analyzed**	**Result**
The intervention was successful: workers increased their desk position change frequency and desk standing time while also reducing desk sitting time.	Sit/Stand-ACU (Fig. 6A), Desk position changes work day (Fig. 6B)	Reduced Sit-ACU ($p < 0.05$; effect size=0.48) Increased Stand-ACU ($p < 0.05$; effect size=0.41) and desk position changes work day ($p < 0.05$; effect size=0.68)
The intervention disrupted the maximum time periods desks were in a position before the worker changed the desk position.	Time desk in a position before change of position (Fig. 6C)	Reduced the mean maximum time desk was in the same position by ~2 hrs ($p < 0.05$)
For each outcome measure, as computer usage increased, the improvement increased as well.	Sit/Stand-ACU (Fig. 6A), Desk position changes per work day (Fig. 6B)	Linear relationship between pairwise mean differences and computer use for 3 out of 4 outcome measures Sit-ACU: slope = -0.37, $p < 0.0001$, Stand-ACU: slope = 0.09, $p < 0.05$, Desk position changes per work day: slope 0.33, $p < 0.05$

Message	Variables Analyzed	Result
Workers increased their frequency of changing desk positions.	Desk position changes per work day (Fig. 7)	76% decrease in workers who never changed desk position; 330% increase in workers who changed their desk position ≥ 3 times a day

Discussion

The computer-based behavioral intervention was effective at increasing sit-stand desk utilization. To date, studies using sit-stand desks with computer reminders have met the primary intention of reducing sitting time while increasing standing time and position changes with office workers (Barbieri et al., 2017; Donath et al., 2015; Swartz et al., 2014; Evans et al., 2012). However, they have been short-term studies that have not taken into account the time individuals are absent from the workstation (meetings, breaks, lunch). This study was able to account for time only spent at the workstation, which is an important factor when determining the effect of a physical activity intervention designed for sit-stand desks. Additionally, this is the first study to collect continuous and objective sit-stand desk usage data while engaging workers with their habits for a 1-year time period. The intervention accomplished this goal without requiring workers to leave their desk or wear sensors. This is important to note when designing a long-term, sustainable method that can be used in a naturalistic work environment. Therefore, the results from this study provide a novel, effective behavioral intervention towards monitoring and reversing worker physical inactivity.

Overall, the workers reduced their proportion of desk sitting time (90% to 82%) and increased their desk standing time (10% to 18%). Approximately one-fourth of the workers never had their desk in a standing position during computer use. After the intervention, only 9% of the workers were left in this category. The findings from each outcome measure were statistically ($p < 0.05$) and clinically significant (medium to large effect sizes), revealing that this intervention had a positive impact on improving the workers' sedentary behavior lifestyle. Further, the workers increased their sit-to-stand desk transition frequency with the help of the software reminders. During the baseline phase, the workers averaged ~1 desk position change per work day. After the intervention, the workers averaged ~2 changes per work day. Likewise, the average time a desk was in a position before a change significantly reduced from ~3.79 to 1.85 hrs (51% reduction).

There was a significant relationship with the improvements made on all 3 outcome measures in relation to computer use. The workers who spent a longer time using the computer (5 hours/day) made the largest improvements in desk sitting/standing time and desk changes per work day. This finding shows that higher duration computer users have the ability to show the greatest improvement in changing their desk usage habits and responded well to the behavioral intervention. Given that breaking up prolonged bouts of being in the same position and postural transitioning have a greater energy expenditure than sitting/standing, the improvement from the intervention should be used to target sub-populations (overweight/obese individuals, high duration computer users) who need to increase their movement throughout the work day.

In order to engage workers with their health behavior change, the software interface provided each worker real-time feedback on their desk usage (self-monitoring) and the option to change the frequency of the reminders (goal setting). For this study, we used a reminder default setting of 20 minutes standing for every 30 minutes sitting, based on previous research recommendations (Gallagher et al., 2014). The ratio of sit-to-stand time can vary based on occupational settings and work tasks. For example, workers who spend less time at their workstation may have a different compliance level with the reminders. The compliance to default settings should be evaluated on different types of office workers. Aggressive strategies to increase the frequency of changing position reminders could be used as an approach by upper management to motivate teams of employees by setting organizational desk usage goals.

Based on monthly observations for the 1-year time period, the intervention was most effective for the first ~3 months. A longitudinal, randomized study should be conducted to add more health behavior change constructs after a 3-month period to see if effects can be sustained beyond 3 months. Gamification elements (weekly reports/leaderboards, reward points, badges) can motivate workers to remain engaged with their physical activity health behavior change (Parades et al., 2013).

Strengths and Limitations

A strength to note was the inclusion requirement of steady-state sit-stand desk users (had desk for ≥1 year). Therefore, the study design was not affected by an adoption phase for the desks. Second, the organization provided desks to the office sites 4 years prior to the study, which eliminates the possibility of volunteerism bias. A limitation was all workers in this study were previously using a stretch-break software (Wellnomics® Workpace®) that would remind them to take a break from their workstation (i.e. walk around the floor, stretch break, take a flight of stairs). Since workers had a previous exposure to a computer software that prompted them to take a break, their acceptance to comply with this computer-based intervention could vary. It is important to address that due to security concerns, the software had to be approved by government group's Information Technology. This process took several steps until final approval was given. Even though the process was extensive and problematic, this software, as a data collection method, is better for the long-term and requires low maintenance/costs.

Conclusion

These findings reveal an effective intervention using computer technology that will increase movement during the workday. Since we can now quantify and increase postural transitioning and desk usage (continuously), future research should use this health behavior intervention to study the effect of increased workday movement on biomarkers, diet intake, and employee health costs/injury data. With the methods and results from this research, we can identify and target high-risk individuals to improve their health behaviors.

CHAPTER IV

5-MONTH UNIVERSITY WORKER STUDY USING PERSONALIZED SOFTWARE AND GAMIFICATION TO INCREASE SIT-STAND DESK USAGE

Significance

The quantitative use of table-top adjustable sit-stand desks have yet to be determined, due to the lack of an evaluation method. This 5-month field study on 47 university staff members used a novel approach of combining USB accelerometer sensor and computer software reminders to continuously record and increase desk usage. Additionally, this is the first study to incorporate a gamification element (overall group results) to increase sit-stand desk usage. During the baseline phase (3 months), desk usage data were continuously recorded for all workers. After the intervention of personalized computer reminders (2 months), staff members increased desk position changes from 1 change every 2 work days to 1 change per work day. Further, during the baseline phase, 4% of the staff changed desk positions once or twice a day, which increased to 36% of the staff in this sub-group from the intervention. The gamification element (1 month with software reminders) did not have a significant improvement on desk usage habits. Overall, the intervention was successful but longer, personalized gamification intervention studies are warranted to determine if the desk usage behavior change can be improved and sustained.

Introduction

The increase in technological developments in buildings have allowed humans to expand less energy and this has contributed to towards the workplace obesity epidemic (Wells et al., 2007). Traditional office buildings have been designed in the direction of "human energy conservation," including conveniently located elevators along with many sitting options (Wells et al., 2007). This is concerning given the evidence of the effects of prolonged sitting on health (cardiovascular disease, type 2 diabetes, venous thrombosis) (Dunstan et al., 2012). Experiments have shown that breaks from prolonged sitting every 30 minutes can elicit benefits to cardiometabolic health (Peddie et al., 2013). Standing for too long can also be detrimental to health. Prolonged standing periods have been associated with lower back discomfort (Gregory et al., 2008), carotid atherosclerosis (Krause et al., 2000), varicose veins (Tüchsen et al., 2005), and muscle fatigue (Garcia et al., 2015). As a result, activity-permissive workstations are being incorporated into the workplace to reduce workers' sedentary behavior and improve associated health outcomes (Gorman et al., 2013).

On the market, the two primary types of sit-stand workstations are stand-biased and height-adjustable (electric, crank, pneumatic, and now trending, table-top adjustable). Due to its ready-to-use design out of the box, some table-top adjustable desks save assembly time, have cheap setup costs, and provide ergonomic adjustability. The desks require worker action to change it to sitting and standing heights and therefore, a physical activity behavior change is needed. In order to ensure workers are using the desk to experience the associated health benefits, an intervention is needed to help remind them to use the sit-stand function of the desk.

Research has shown that digital health behavior interventions that use gamification elements can provide a framework for change (Cugelman 2013). Gamification elements include providing clear goals, offering challenges, allocating points, using leaderboards and personalized feedback (Cugelman et al., 2011). Devices and applications such as Fitbit, RunKeeper, and Nike+ Fuelband have been used as digital technology to improve physical activity habits using gamification components (Middelweerd et al., 2014). However, to date, there has been no study that has investigated similar gamification elements using sit-stand desks and its impact on increasing sit-stand desk usage.

The objective of this research study was to determine the impact of personalized software reminders and gamification on table-top adjustable sit-stand desk usage. One unique aspect of this study was that a validated USB accelerometer was mounted on the desks in conjunction with software as a novel method to collect continuous data for the entire work day.

Methods

Participants

During the 5-month data collection period, 74 staff members had recorded data. The eligibility criteria for this secondary analysis was ≥20 ACU (active computer use) hours and ≥5 work days per worker during each study phase (baseline & intervention). Out the 74 staff, 47 workers were eligible for this analysis (N = 47). Participants were staff members from the Texas A&M University Division of Student Affairs in College Station, Texas. Office work consisted of computer-based tasks and meetings with students. As part of a university initiative to promote an active workplace, adjustable table-top sit-stand desks were provided to a group of employees who provided a reason/justification. After evaluation from the upper management of the Division of Student Affairs, 162 staff were given the desks. The staff were distributed among 12 buildings throughout the campus. Office design were traditional, individual offices for each staff member. The Texas A&M University School of Public Health researchers and Division of Student Affairs leaders recruited workers for the study via e-mails. Workers were provided with information regards to the study design and length of study. The interested staff members responded through an online survey indicating their interest. Out of 162 staff, 65 chose not to participate in the study or didn’t respond to the survey and 97 expressed interest to participate. The 97 workers were provided the Texas A&M University Institutional Review Board approved consent form to participate in the study. Out of the 97, 74 workers submitted a signed consent form.

Data Collection

Data was collected through a computer software (Wellnomics® Sit-stand Texas A&M) which recorded the number of desk position changes and the time desks were in a sitting or standing position during active computer use. In order to determine the desk position, a novel approach was used by integrating a lab-validated USB accelerometer sensor with the computer software. The sensor (Phidget Spatial 3-axis ±8g accelerometer) was validated in the lab by comparing video timestamps with raw data output from the computer software (within 2.6% agreement) for 5-hour time periods on 3 separate days. The primary outcome measure for this study was the frequency of desk position changes. Other measures included the time desks were in a sitting and standing position and the maximum time the desks were in a position before a change was made. A survey about sit-stand desk usage was sent to all participants at the beginning of the study.

As per IRB approved protocol, all data were de-identified by Texas A&M University Division of Student Affairs Information Technology and then provided to Texas A&M University School of Public Health researchers for secondary analyses. Since data was de-identified, we were not provided with any demographic information on the workers.

Study Design

The data were collected for a 5-month period. The adjustable sit-stand desks were given to the workers during Summer 2016. The sensor was validated in the lab during Summer 2017 and workers were recruited for the study during August 2017. The validated USB accelerometer sensor was mounted on all participants' desks by a Texas A&M researcher in September 2017 and the software was installed for all participants in October 2017 by the Division of Information Technology. After installation, the software required workers to complete an ergonomic setup for their table-top adjustable sit-stand desk.

Once the setup was completed by each worker, the software informed each worker through a reminder that the software application was going into *monitor only* mode (recorded continuous data on desk sitting and standing time and worker continued work as normal). From November 1, 2017 through January 31, 2018, the software measured the primary outcome of the number of desk position changes completed by the staff members. Additionally, the software recorded the time desks were in a sitting or standing position and the maximum time the desks were in a position before a change was made by the worker (both during active computer use).

On February 1, 2018, all workers were sent an email describing the second phase of the study (intervention) which consisted of software reminders to change desk positions. From February 1, 2018 through March 30, 2018, the software was in *reminder* mode and recorded the mentioned outcomes. The default setting for the reminders were 30 minutes sitting then a reminder to stand for 20 minutes (Ryan et al., 2011; Atlas & Deyo 2001; Dunstan et al., 2012; Gallagher et al., 2014). Each worker could change the reminder settings to their preferences or ignore the reminders. Additionally, real-time statistics on personalized desk usage (number of desk position changes per work day & percent ACU time desk in a standing position) were provided when the workers opened the software application.

The third phase of the study (intervention with gamification) began on March 1, 2018. During this phase, the workers continued to receive software reminders but were also shown their group's sit-stand desk habits as a means to compete and motivate to increase sit-stand desk usage. A "dashboard" was sent via email to all workers on March 1, 2018. The dashboard consisted of baseline and current overall pooled group means along with goals for the next two weeks. An updated dashboard email was sent to all workers on March 15, 2018. A total of two dashboard emails were sent to incorporate the gamification component (overall social comparison).

Statistical Analysis

The analysis was conducted using SPSS 22 (IBM SPSS Statistics). Pairwise comparisons analysis was conducted to determine the mean differences between baseline and the intervention using means, SD, and histograms. We tested for significance of the intervention using paired two sample for means t-test. The overall pooled means were calculated for every month of data collection period to determine usage patterns before and after the intervention. Two weeks of company holiday period and one week of accidental exposure to intervention were excluded from this analysis.

Results

For the baseline phase, the average data recorded were 112 ACU hours and 34 work days per worker. For the intervention phase, the average data recorded were 82 ACU hours and 31 work days per worker. Pairwise comparisons of difference in means for the outcome measure are shown in Table 4. Two outcome measures (desk position changes per work day and maximum ACU time desk in a position before a change) significantly improved from the intervention ($p < 0.05$).

Table 4. Study #2 overall group means and pairwise comparisons.

	Baseline Mean (*SD*)	Intervention Mean (*SD*)	Pairwise Mean Difference (*SD*)
ACU	3.03 (1.11) hrs	3.08 (1.15) hrs	0.05 (0.42) hrs
Sit-ACU	2.32 (1.31) hrs	2.21 (1.23) hrs	-0.11 (0.72) hrs
Stand-ACU	0.71 (1.07) hr	0.86 (0.99) hr	0.15 (0.70) hrs
Desk Position Changes Per Work Day	0.46 (0.72) desk changes per work day	1.41 (1.36) desk changes per work day	0.95 (1.20) desk changes per work day*
Max ACU time desk in a position before change	6.17 (1.79) hrs	2.32 (0.61) hr	3.85 (0.65) hrs*

*Significant change (p <0.05)

Figure 9 shows the differences among all workers in the frequency of desk position changes per work day. The largest sub-population of workers with the greatest improvement were those who completed 1-2 desk position changes per work day. Out of 47 staff members, these group of 2 staff members (4%) increased to 17 staff members (36%) after the intervention. Another important finding was 8 staff members were changing desk positions once a month. After the intervention, no staff members were left in this sub-group, indicating an improvement of increasing desk usage in other sub-group.

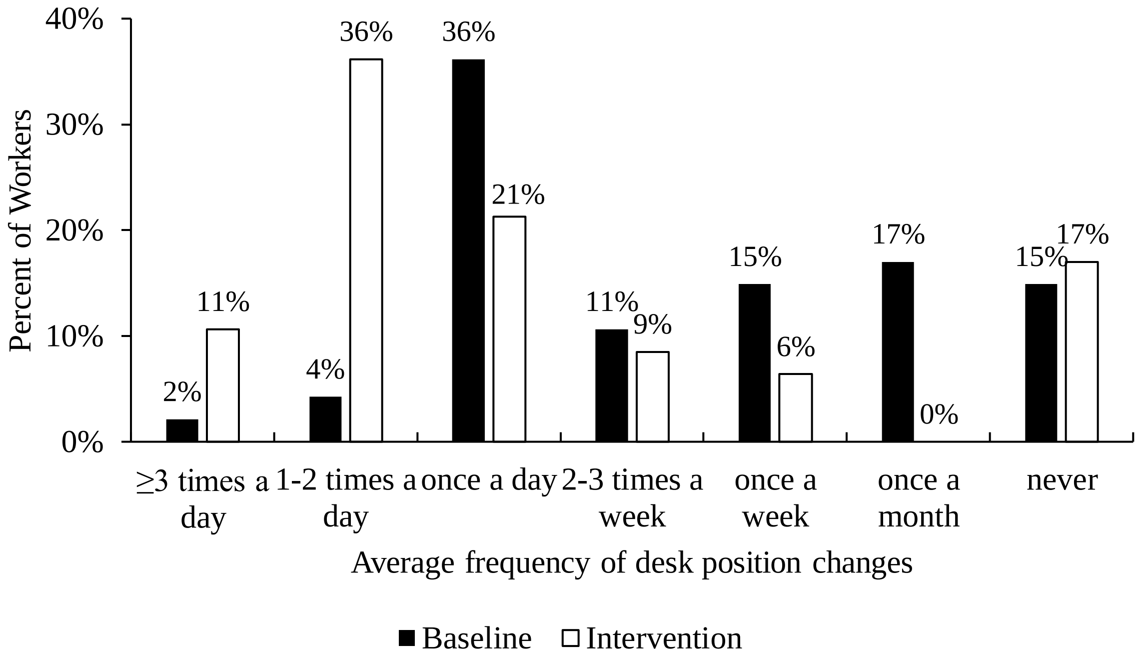


FIGURE 9. Frequency of desk position changes among workers. The average frequency of desk position changes as a percent of staff members from baseline to intervention are represented here. The two weeks of holiday period (December 25, 2017 – January 5, 2018) and one week of accidental intervention exposure (November 13 – 17, 2017) were excluded from this analysis.

Figure 10 illustrates the monthly trends for two outcomes measures (average number of desk position changes and maximum ACU time the desk was in a position) at each phase of the study: baseline (Nov, Dec, Jan), intervention (February), and gamification (March). For the average number of desk position changes (Fig. 10A) and the maximum ACU time the desks were in a position before a change (Fig. 10B), there was an overall improvement from the computer reminders from beginning to the end of the study. During the baseline phase, staff members completed ~1 desk position change every 2 work days. After the intervention, they completed ~1 desk position change per work day. The added gamification component for the month of March (in addition to the reminders) did not show significant further improvement.

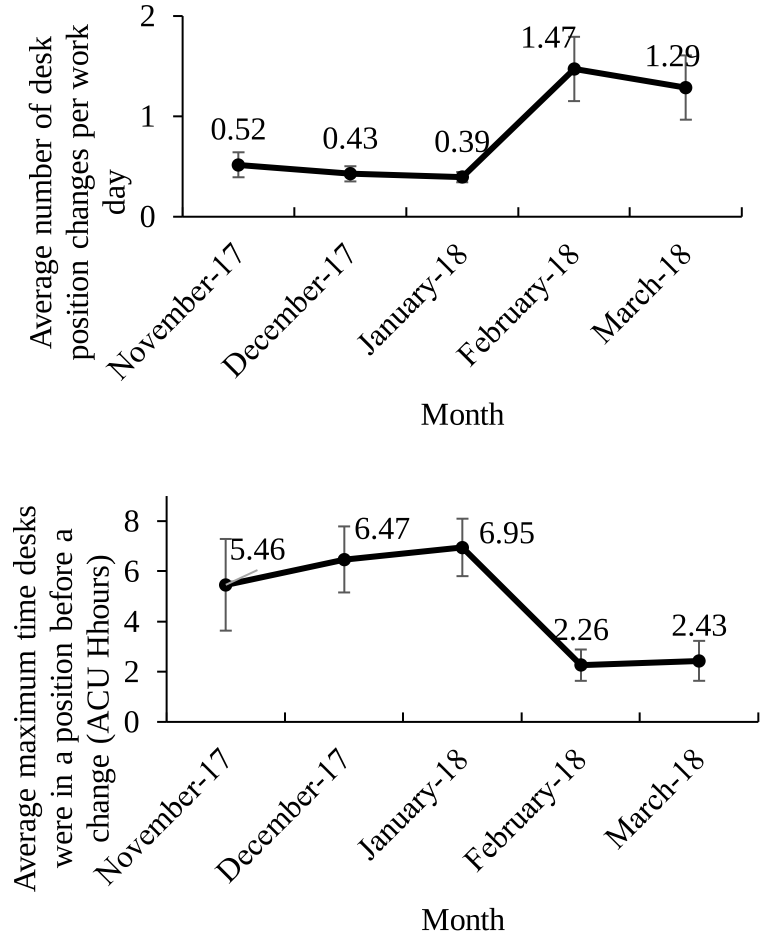


FIGURE 10. Monthly trends of desk changes and max time desk in a position. Desk position changes per work day (A) and average maximum time desks were in a position before a change in ACU hours (B) are shown. Dashed line with two arrows indicates the beginning of the intervention. The two weeks of holiday period (December 25, 2017 – January 5, 2018) and one week of accidental intervention exposure (November 13 – 17, 2017) were excluded from this analysis. Error bars represent 95% confidence intervals.

It is important to look at sit/stand-ACU as a percent of computer use time. Figure 11 displays the monthly trends of Sit/Stand-ACU as a percent of computer use. During the baseline phase, the staff members had their desk in the standing position 77% of computer use time and the desk was in standing position for the remaining 23% of computer use time. After the intervention was complete, the staff members improved and had their desk in the standing position 72% of computer use time and the desk was in standing position for the remaining 28% of computer use time. In particular, with percent time desks were in a standing position, staff members shifted from 0-19% into the 20-49% and 50-100% sub-groups (Fig. 12). These findings show that because of the intervention, improvements were made on increasing the time desks were in a standing position as a percent of computer time.

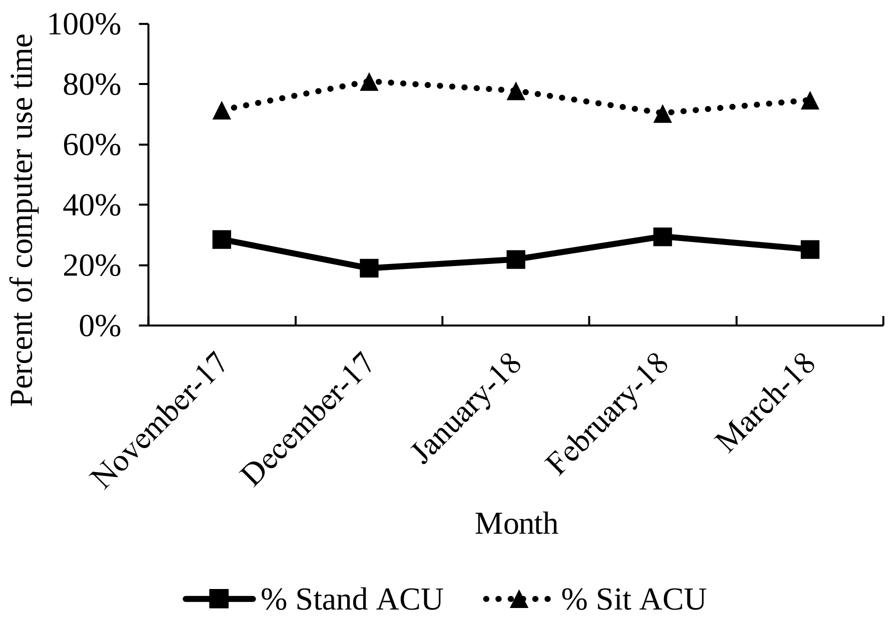


FIGURE 11. Monthly trends of time desks in sitting and standing position.

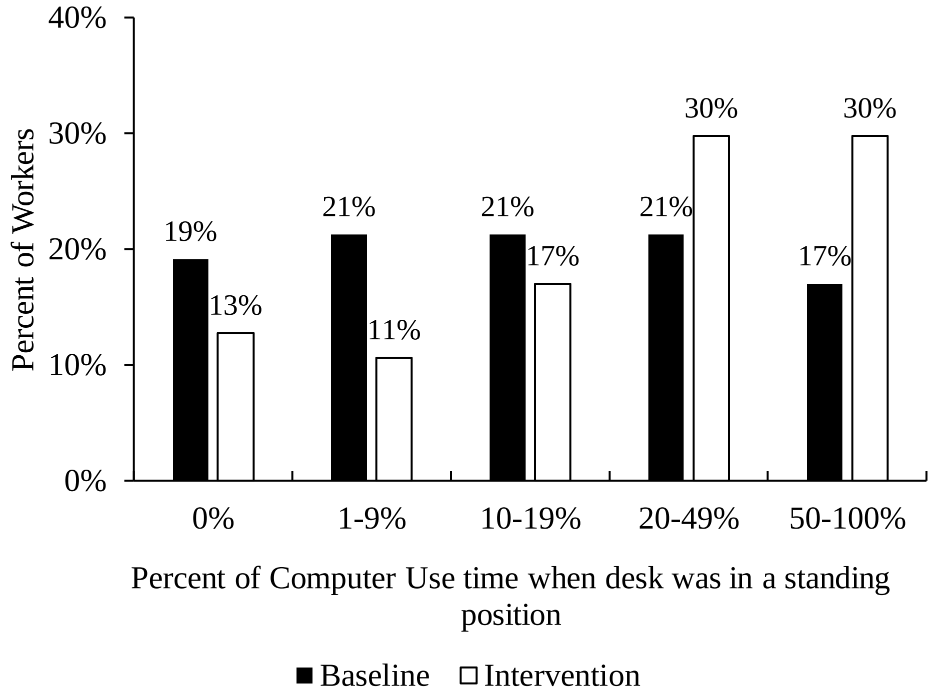


FIGURE 12. Workers in sub-groups of time when desk in standing position. The two weeks of holiday period (December 25, 2017 – January 5, 2018) and one week of accidental intervention exposure (November 13 – 17, 2017) were excluded from this analysis.

The survey results revealed that 51% of the participants (24 out of 47 staff members were influenced by their co-workers' habits with their sit-stand desk and 49% were not influenced. Specifically, the staff members were influenced when either they discussed their sit-stand habits with their co-workers or when they saw them using their sit-stand desk. Out of the 51% who were influenced, all of them agreed that they were motivated to stand more and change desk positions more frequently because of their co-workers.

Discussion

Overall, the intervention increased sit-stand desk usage for the staff members. Before the intervention, 4% of the staff changed desk positions once or twice a day. After the software reminders and gamification, 36% of the staff were in this sub-group. Additionally, participants had their desk in a standing position as a percent of computer for a longer time after the intervention. The software reminders successfully changed and improved the sit-stand desk behavior for the staff members.

We didn’t find a significant effect from the gamification component (bi-weekly emailed social comparison results). It is possible that some participants did not read the email and therefore it did not reflect in additional behavior improvement. For future studies, there should be a case-crossover design and the gamification should be tested for 3-6 months to determine any significant effects. Ideally, the social comparison feature should be built within the software so workers can see live updates on their results towards their goals. Subsequently, the software could then provide tailored health messages to workers, which have the potential to larger, effective impacts on creating behavior change (Abrams et al., 1999).

The main strength was that all staff members had their sit-stand desk for at least 1 year prior to the start of the study. The desks were not given to participants as a purpose of the intervention and therefore eliminated the effect of a novelty period by ensuring that all workers were steady-state desk users. The first limitation of the study was the recruitment pool of participants for the study. All potential participants requested a sit-stand desk through the university and therefore were the only ones eligible to participate in the study. Furthermore, only the individuals who signed a consent form were allowed to be participants of the study. The individuals who signed a consent form could have primarily joined the study because they wanted to make a physical activity change, which could have created volunteerism bias. The second limitation was that all staff members were accidentally exposed to one week of the intervention (software reminders) during the baseline phase. This was due to a technical issue but was solved immediately. The mentioned results excluded this data but could have influenced the workers' behaviors onward since they experienced the intervention ahead of time. The technical issue shows the potential problems that researchers can face when conducting digital health intervention studies in a field setting. For this reason, it is important that information technology, software personnel, and researchers should be prepared to troubleshoot and solve technical problems.

The Transtheoretical Model theory demonstrates that physical activity behavior change is maintained when it is changed and sustained for 6 months or more (Prochaska 2013). In this case, the intervention was provided for two months. Future interventions should be at least 6 months to 1 year to determine if the behavior change is maintained. Another gamification element that should be explored in future studies is providing points to achieve badges for increasing sit-stand desk usage (Zuckerman et al., 2014). Since all data were de-identified, we were unable to place staff members in specific teams. Team gamification has been shown to improve behavior change and future work should study the desk usage outcome from this added element (Zuckerman et al., 2014). Nonetheless, this is the first study to introduce gamification with sit-stand asks as a concept to help improve health behaviors and can be used as an interactive approach to increase sit-stand desk usage in future studies.

CHAPTER V

CONCLUSION

Study comparisons

Both research studies were long-term, field settings (1-year and 6-months) using adult workers. The studies used novel methods (artificial intelligence software and USB accelerometer sensors) to measure the time desks were in each position, based on the presence of a worker. Each study used the same software application with similar versions (Wellnomics Sit-stand) as the primary source of continuous data collection. As similarities exist with both studies, they can be compared to understand objective human sit-stand desk behavior with two different desk types (electric and table-top adjustable) and determine the effectiveness of the computer-based intervention on two different populations (entire organization vs volunteered participants).

From a study design perspective, there were similarities and differences between the two studies (Table 5). The following were similarities in both studies: same software interface and reminders, all workers had their height-adjustable desk for at least one year prior to the study (no novelty period with the desks), all workers were located in different buildings/cities, the baseline time period was 3 months, and the intervention phase was at least 2 months. Due to these similarities, the studies are comparable and the findings confirm that the computer-based intervention was effective at increasing sit-stand desk usage.

The four primary differences between the studies were the type of study population, previous exposure to similar software technology, type of height-adjustable desk, and a gamification component. In study #1 (Australia government workers), all workers were given electric sit-stand desks across the organization so there was no volunteerism bias. In study #2

(Texas A&M University workers), a specific group of workers (who provided justification/reasoning) were given table-top adjustable sit-stand desks. This study population could have been more motivated to use their sit-stand desk and thus, their usage habits may differ from a group of workers who didn't volunteer to get sit-stand desks.

The second difference was that the first study's worker population had previous exposure to a software application that prompted them to take breaks from work based on computer usage. Since this worker population had been exposed to a previous technology that promoted work breaks, based on their individualized computer use, their acceptance level to comply with this sit-stand desk intervention could vary. The third difference was the type of height-adjustable desk for each study. Study #1 had electric sit-stand desks that changed desk positions using memory preset buttons. For the study #2, the workers had table-top adjustable desks that required the worker to manually change the desk position using handles on the side of the desk. The final difference was that study #2 had an additional gamification component (overall group means on desk usage statistics were sent to all participants) to increase engagement with health behavior change.

Table 5. Similarities and differences of both studies.

Study	**Type of sit-stand desks**	**Time workers had desks**	**Type of study population**	**Location of workers**	**Previous exposure to an intervention**	**Intervention Health behavior change constructs**
#1 (Australia)	Electric	At least 1 year	All workers in organization	3 cities	Exposed to stretch-break software with reminders	Self-monitoring, personalized feedback
#2 (Texas A&M University)	Table-top adjustable	At least 1 year	Workers volunteered for the study	12 buildings	No previous exposure	Gamification (group dashboard), Self-monitoring, personalized feedback

The baseline phase for each study was 3 months and both study populations received at least 3 months of the behavioral intervention (software reminders). It is important to note that the pooled group mean computer use for study #1 and study #2 differed (~4 hours and ~3 hours, respectively). When observing the monthly desk usage habits from baseline to intervention, similar improvement patterns were observed in both studies for all the mean outcome measures: stand-ACU, sit-ACU, desk changes per work day, and time between desk position changes (Fig. 13).

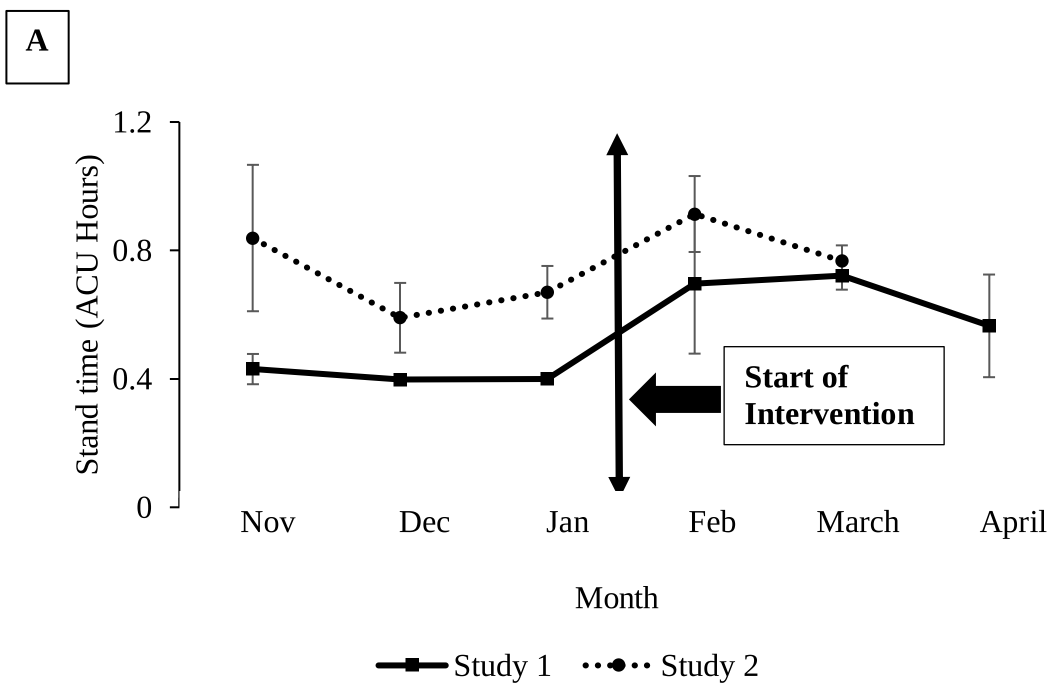
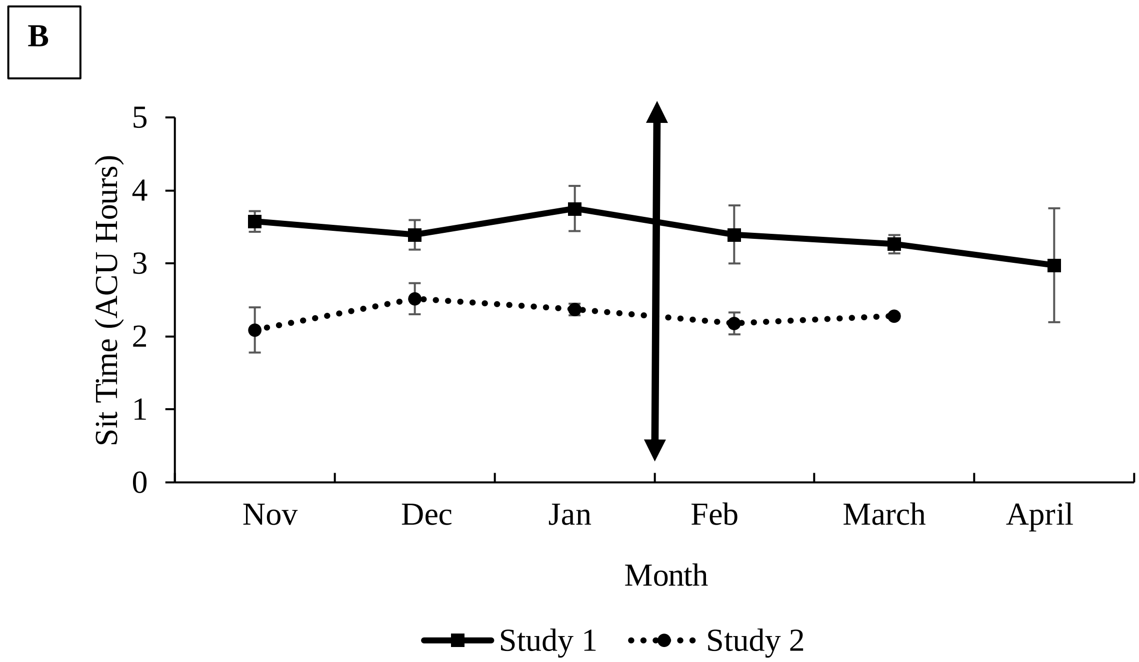


FIGURE 13. **Study #1 vs Study #2 comparisons for each outcome measure.** Stand-ACU (A), sit-ACU (B), mean time between desk position changes (C), and desk position changes per work day (D) are shown. Double-arrowed vertical line indicates the start of the intervention period. Error bars represent 95% confidence intervals.



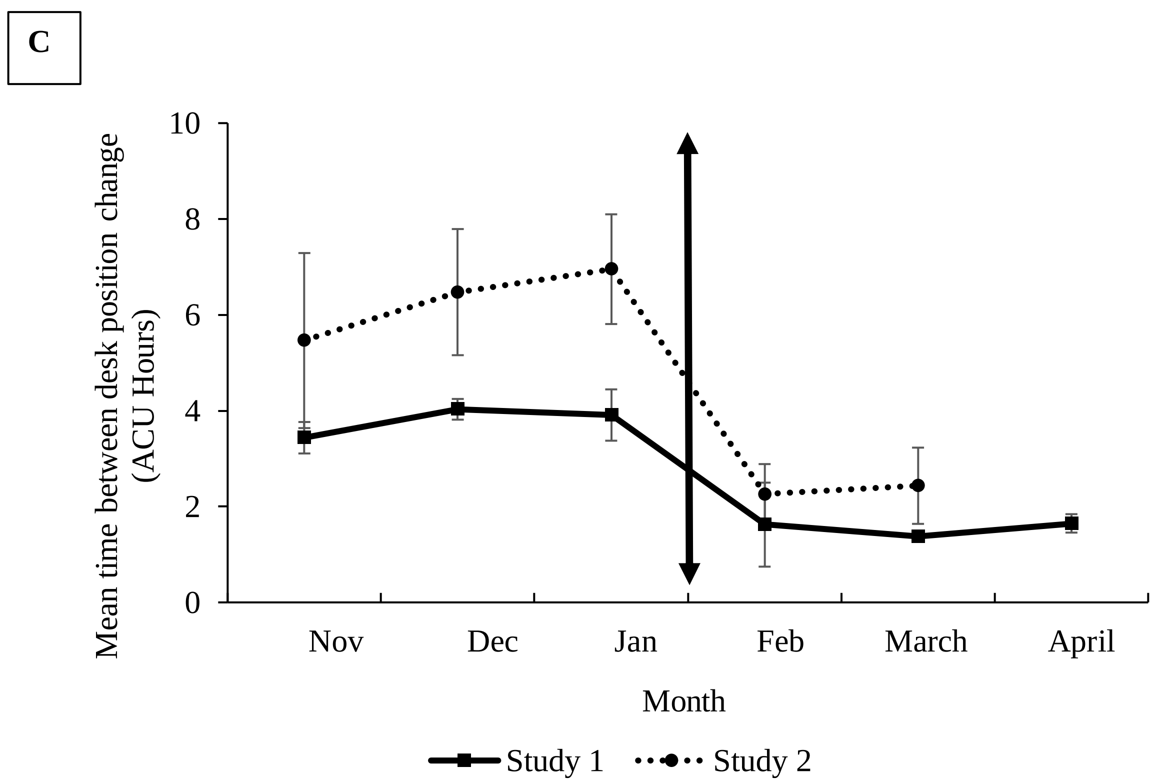


Figure 13 Continued

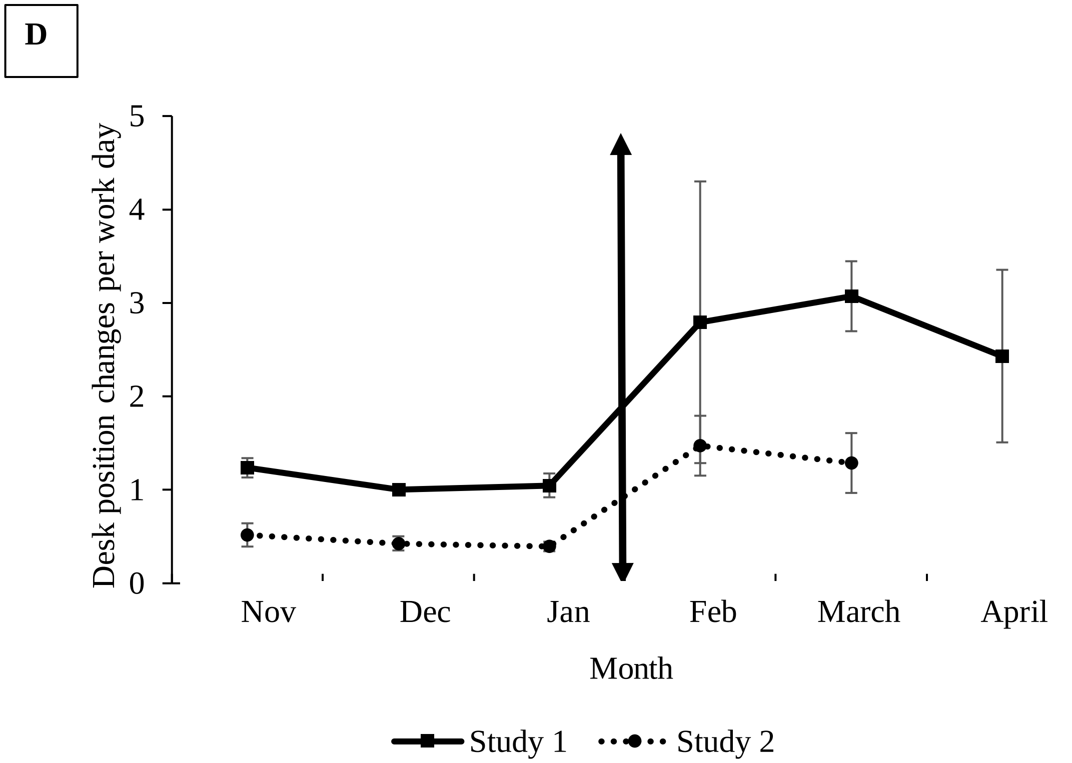


Figure 13 Continued

Collectively, the intervention improved sit-stand desk usage behavior for both study populations by reducing sitting time and increasing standing time and desk position change frequency. This indicates a change in behavior and acceptance of the behavioral intervention from the workers to increase sit-stand desk usage. After the intervention began, an initial improvement spike lasted only 1 to 3 months from the software reminders. Even though there was all-around improvement at the end, the challenge remains for future studies to explore a sustainable method (additional gamification components and health behavior constructs) to keep habits from going back to normal after 3 months of the intervention.

There are two findings from both studies that quantitatively reveal sit-stand desk utilization increased. First, the intervention was able to successfully break up prolonged periods of workers remaining in one desk position. This is observed by the improvement in the following three group mean outcome measures: number of desk position changes per hour, number of desk position changes per work day, and time between desk position changes (Table 6). The workers changed their desk usage habits after the computer reminders.

Table 6. Summary of desk usage results from both studies.

Mean Outcome Measure	Study	Baseline	Intervention
Desk changes per work day (Fig. 13D)	Study #1	1 change/day	2 changes/day
	Study #2	2 changes/2 days	3 changes/2 days
Time between desk position changes (Fig. 13C)	Study #1	4 hours	1.5 hours
	Study #2	6 hours	2.5 hours

The second significant finding was the improvement of daily/monthly frequency of desk position changes before and after the intervention. For both studies, there was a greater number of workers in the groups “>3 times a day” and “1-2 times a day” after the intervention. Similarly, after the intervention, there were less workers in the groups of “never” changed their desk position or “once a month.” In study #1, workers who changed their desk position 1 or more times a day improved from 25% to ~60% (Fig. 14). In study #2, workers who changed their desk position 1 or more times a day improved from ~5% to ~50% (Fig. 15). This shows that workers shifted from the low desk usage spectrum to the more frequently changing desk positions spectrum. Additionally, it is important to observe the shift of desk usage frequency categories for the workers that never used the desk. Figure 16 indicates that almost half of the workers who never used the sit-stand function shifted to the once a day or many times a day category. This shows the improvement potential from this intervention for the baseline low frequency desk users. With these results, we can now use smart software reminders to reverse and improve the health behavior of those workers who are not actively using their sit-stand desk, regardless of desk type.

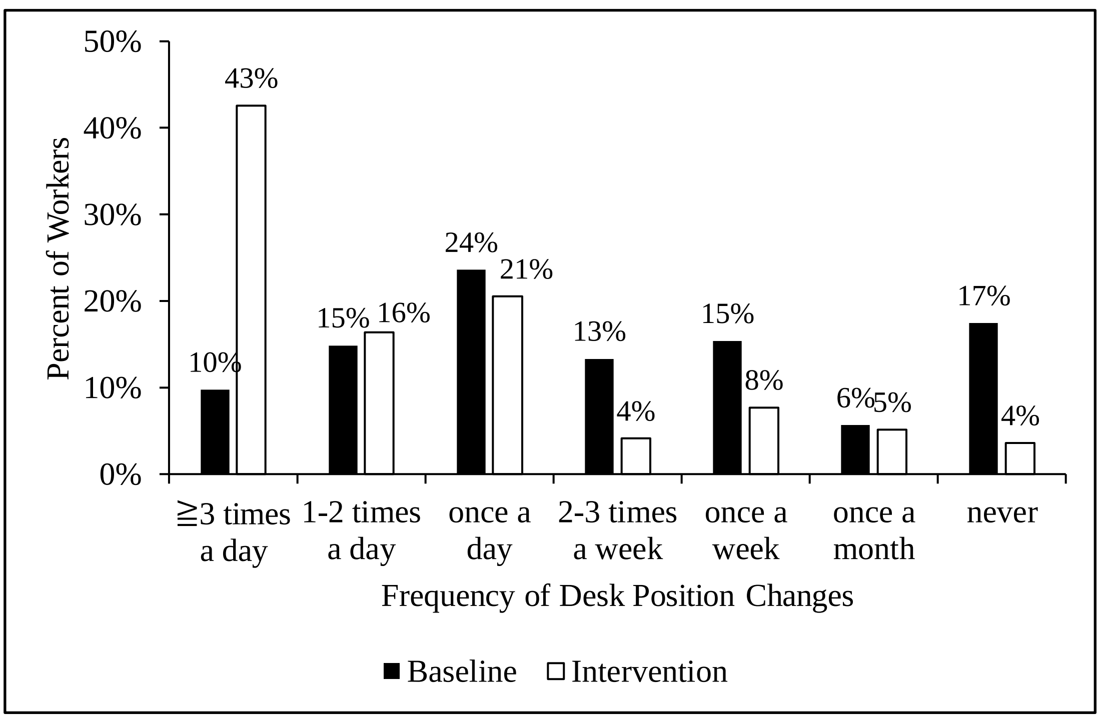


FIGURE 14. Study #1 frequency of desk position changes.

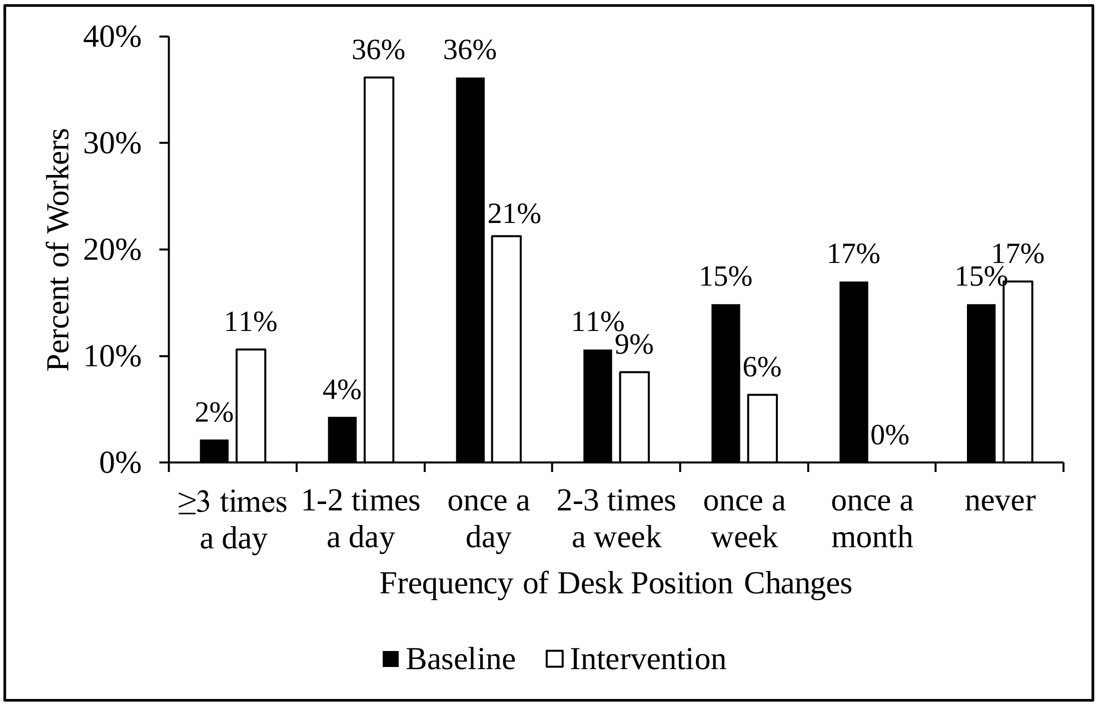


FIGURE 15. Study #2 frequency of desk position changes.

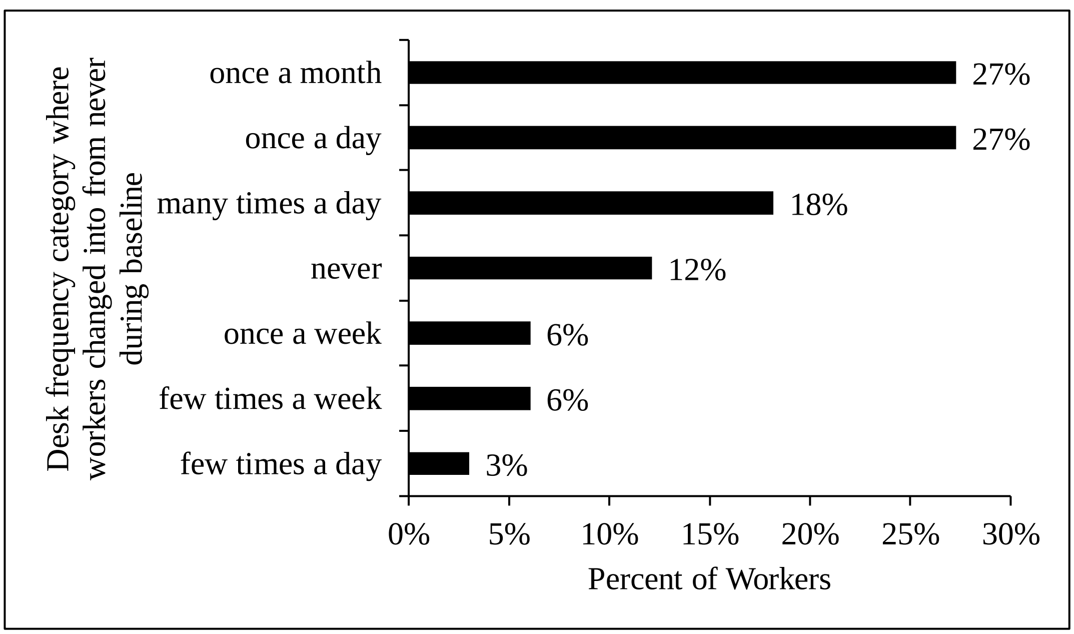


FIGURE 16. Category shift desk position change frequency. This is shown for workers who were in the 'never' category during baseline

The results from both interventions showed diminished effects. The Transtheoretical Model (TTM) framework states that health behavior change is considered maintained if the change is greater than 6 months (DiClemente and Prochaska, 1983). Since study #1 had the longer intervention (9 months), we can apply the TTM framework to the study. The results indicated that the treatment (software reminders) wore off after 3 to 6 months and therefore the behavior change was not maintained from this intervention. Although overall outcome measures were better compared to baseline, the effect began to fade away. Immediate positive outcomes are observed in physical activity behavior change interventions but in most cases, the effects from the intervention are the strongest within one or two years (Young 2014). If no supplementary components are added to the intervention (tailored counseling, feedback, personal goals), the treatment effect tends to fade back to normal behavior, which has been the case with intervention studies that involved regaining prior weight loss, dietary choices, smoking (Middleton et al., 2013; Kumanyika et al., 2000; DiClemente et al., 1991). As medications for chronic illnesses are prescribed for long-term, health behavior change interventions (with sit-stand desks) should use long-term treatments in order for a practical application of behavior change in the workplace (Young 2014). However, there will always be barriers to change such as physical activity levels outside of work, stress, and pre-existing health conditions (Middleton et al., 2013).

Overall, both study populations showed improvements in behavior change but had differences in the results. The Texas A&M University workers had their desk in the standing position for a longer time than compared to the Australian government workers. However, the Texas A&M workers changed desk positions less frequently than the Australian workers. It is possible that since the table-top adjustable desk has to be manually lifted from one position to the other, workers like to leave it in the standing position for a longer time. On the other hand, the electric desk can be changed with preset buttons therefore making it easier for the worker to change desk positions more frequently. These results may suggest that table-top adjustable desks are good for having the desk in a standing position for a longer period of time and the electric desks can be good for changing positions more frequently. Conversely, the Texas A&M university workers volunteered to have sit-stand desks so they may be motivated to stand longer. This should be studied more in depth with larger in-situ workplace studies. In general, the findings show broad similar patterns of improvement from the computer reminders for both study populations.

The design of the environment plays a large role in worker behavior. We were able to see overall and incremental improvements. However, it is worth considering a default type of sit-stand desks that are provided to the workers. It was evident that workers struggled with the interaction of the sit-stand function. They could eventually lose engagement with their behavior change after several years and could decline to back to normal behavior. Therefore, if desks were permanently in the standing position (stand-biased desks), it could be a natural transition for workers to stand and move more since the default desk height is in a standing position. This should be explored with future studies to determine if workers prefer and interact better with a stand-biased desk type with no action required versus height-adjustable.

Research process

The development and execution of two field studies with adult office workers was a challenging experience. Both research studies involved funding from several organizations and collaboration was very important. This research would not have been possible without the support of the funders (Linak, Wellnomics, Varidesk, OERC) and the study venues (Comcare Australia and Texas A&M University) that allowed us to use their workers as participants. In order for research studies like these to be conducted, the upper management of the host site/organization must see the importance of sedentary behavior research and place an emphasis on making changes in the workplace. Once this consensus has been reached, then the conceptualization can begin. In addition, field studies require researchers and host venues to have patience, communication, and respect for participants in order for it to be a successful study. Each study had its challenges prior to the commencement of data collection.

Study #1 was a global research study and required a visit to be made to Australia to ensure the study resources and contacts within the government organization were on the same page. I had to meet with several upper management staff members at each location (Sydney, Canberra, and Melbourne) to explain the research study design protocols and objectives of the study. Although all data were de-identified, it is still health data at the end of the day so the organizations have to be careful about the use of the data and findings.

During the visit, I was able to interview 10 workers at each location to get their thoughts on the upcoming study. This was very valuable because I was able to interact with the participants, listen to their opinions on the future study, and get to know their work lifestyle. Several participants made it clear that when the intervention would begin, they would be ignoring the computer reminders and would continue to do their work. The reasoning for this varied from worker to worker (walk to work, stand on the train every day for work commute, and simply because the reminders would be annoying). This is important to disclose because if these studies were conducted in a controlled lab setting, the data would not be able to represent these natural human reactions to a behavioral health intervention. Therefore, we must capture entire workforces in the field for years in order to truly understand human behavior with desks and the long-term effectiveness of this technological health intervention on the population.

Study #2 took place at the same university as the researchers, which was convenient for communication and data access. There was an initial challenge with the data collection apparatus and study recruitment. At the time, the Wellnomics software worked well for electric sit-stand desks and collected continuous data because there was an electrical component to the desk (connect the desk to the computer via Linak cable). However, this study population had table-top adjustable desks so there was no electrical component. There were two attempts made in order to develop a feasible data collection method. First, we attempted to create a study design that would require wearables (ActivPALs) to be worn by the study participants on their thighs. After receiving IRB approval, we recruited participants and explained to them the need for wearable compliance. After attempting to recruit 152 workers to participate in the study, only 6 staff members signed the IRB-approved consent form and negative feedback was received to the researchers. It was clear that the workers did not want to have wearables attached to them.

The second attempt was to use a customized limit switch and photo sensor to determine the desk position and detect the presence of a worker at the desk. However, the main issue with this sensor was that the photo sensor to detect presence only worked if the person was within 12" of the desk and directly aligned in front of the sensor. Additionally, there were several wires that made the setup look bulky and connectivity issues that made the method not feasible. Since participants were spread across 12 buildings, the customized sensor was unreasonable to program and implement for each location. Finally, we discovered a simple USB inclinometer (Phidgets Spacial 3-axis accelerometer) that could be easily mounted on the sit-stand desk. In order to determine desk position time and incorporate reminders, Wellnomics created a software version to read data from the inclinometer to give the same data output as the software from study #1. After lab validation, the software and sensor were ready to be used for the study.

There were several technical issues that occurred from the software in study #2. During the baseline phase, the software's internal expiration date for the baseline phase was entered incorrectly during the installation process. Therefore, for two weeks during the baseline phase, workers accidentally received software reminders to change positions and were exposed to the intervention. This issue was resolved after working with the IT department. The second issue occurred during the second month of intervention period. The software license key expired for all participants so the software stopped recording data. Again, this issue was resolved by the IT department but caused no data to be collected ~2 weeks. Based on these issues experienced in this research study, it is possible that some problems can occur with implementing software as a data collection method. Hence, on-site IT staff should be knowledgeable and familiar with the software to troubleshoot or prevent problems.

Public health relevance and policy implications

As our society evolves, we are increasingly spending more time in higher technology environments (work, home, school) that limit the need for human movement. "Technology induced inactivity," introduced by Dr. Mark Benden, states that technology has made our work more sedentary. To our convenience, technology has been developed to help make daily tasks easier for us so we can move less. For example, the Nest Thermostat allows us to control the temperature of our home using a smartphone without the need to walk to the wall thermostat to change the temperature or settings. Technological advances like these and building designs have caused an accumulation of habitual sedentary behavior on a daily basis, which can result in metabolic health effects.

In an attempt to reduce health costs and improve worker health, industries are becoming innovative by re-engineering work space designs in order to create active environments. Specifically, with workstation design, they are steering away from the traditional seated, closed-office environment. Instead, the workstations are being designed as an open-floor plan, ergonomic space to encourage workplace physical activity while completing work tasks (activity-permissive workstations). As a positive effect of open-floor plan design changes, there have been improvements in employee satisfaction, team-building, and productivity (Frontczak et al., 2012). Given the trending change of workstation redesign, there should be effective methods to measure workplace sedentary behavior that can contribute to developing recommendations to accommodate for this new transformation.

Sedentary behavior has been associated with health risks independent of moderate-to-vigorous physical activity levels. Currently, there are recommendations for 150 minutes of weekly moderate-to-vigorous physical activity but none for sedentary behavior. An expert statement says workers should aim for 2 hours of standing or light activity during work hours (Buckley et al., 2015). To date, the leading technology used to assess workplace sedentary behavior have been wearables that have accelerometers which record the time spent sitting and standing. However, these data capture only 7-14 days at a time and require high reliability and compliance levels from the workers to keep the device affixed to their skin/body. The computer-based methods and intervention used from the two studies don’t require wearable compliance from the workers since all data is collected via the computer. More importantly, personalized feedback was given to workers based on their presence at the workstation. This smart software provided accurate data on time spent at the desk and adjusted the reminders accordingly. Thus, we can use this methodology as a long-term, quantitative technique to record and increase the usage of a sit-stand desk to help promote active work environments.

It is important to note that the desk times and data in these studies were recorded during times of computer use. The data does not capture non-computer tasks such as reading papers, phone calls made while remaining at the workstation, having a meeting with a co-worker while sitting or standing at the workstation, etc. Therefore, the approach (quantitative sit-stand desk usage) from these studies can be used as a complimentary method to wearables to understand the physical activity levels of the entire day. This would provide a combination of objective desk usage patterns (via computer software) and sedentary behavior (via wearables) to show a holistic view of sedentary workplace habits.

Now that sit-stand desk usage can be objectively recorded and increased using artificial intelligence software, the research findings have public health and policy implications. The primary public health relevance is that there is a method to record and improve worker behaviors at their workstation using personalized feedback. In previous research, these results have been collected as self-report data. As a result, organizations can use these objective methods as a metric for employee health. Additionally, it can be used as an accountability metric to ensure the desks are being used.

The height-adjustable sit-stand desks provide ergonomic and cost of benefits to employees and employers. The adjustability of the workstation allows for workers to use the desks according to their proper ergonomic setup and comfort. Traditionally, with seated desks, the adjustability is limited and facilities management had to build the desks and then move desks to difference office spaces, depending on the needs/stature of the incoming employee for that office workspace. Alternatively, sit-stand desks eliminate the need for facilities management to setup workstations after every employee and therefore it is a quick, cost-effective option for workspace management. Additionally, the software from this research ensures that workers are constantly using proper ergonomic postures throughout the workday. Workers would receive a notification on the reminder if the desk position was being placed in the incorrect height. Hence, the software/sensors used from the research studies should be commercialized as a required component that comes with the purchase of sit-stand desks. This would ensure the desk products are being used correctly and constantly.

The low implementation costs/time associated with the methods and intervention is using technology to our advantage to help create a positive physical activity behavior change in the workplace. Since workers increased their postural transitioning with the software reminders by completing more desk changes, their energy expenditure was greater. This is important, as we can now target sub-populations (overweight or obese individuals) who should be increasing their energy expenditure to help improve their metabolic health. Additionally, for higher computer users (who can be more prone to sedentary behavior effects due to longer sitting time), this intervention provides a way for them to increase their physical activity while remaining at the workstation and break up long periods of inactivity.

For policy implications, organizations can use the methods to create company policies and goals for their workers to increase movement. Since data can be analyzed and interpreted on an aggregate level and workers are constantly receiving feedback on their habits, this method can help establish policies based on specific worker populations. For example, industries that heavily rely on computer-based tasks (banking/finance, academia, software and computer technology, government claims, insurance) can use these methods to develop recommended sedentary behavior policies based on its worker population.

Future direction of research

In regards to improving occupational physical activity, we now have an effective intervention that can increase office worker movement using height-adjustable desks. Employers can use the methods to identify teams within the company that are using their sit-stand workstation poorly and conduct health behavior campaigns to increase usage based on each floor or department. This could help the company decide how many desks should be made available based on the type of work style (how often workers come into the office if they work at home for some days of the week) and use the results as a way to determine the size of floor space to reduce real-estate costs. This research can also be applied to the work at home population who have sit-stand desks to ensure they are using safe ergonomic work postures and increase their desk usage. Since the research revealed that there can be a co-worker social influence on desk usage habits, interventions with larger groups of office workers should be explored further to help understand the influence of office floor plan design on desk usage.

The next step for this research area is to determine the long-term impact of increased desk usage on lifestyle factors and biomarkers. Diet intake and sleep schedule play an important role in nutrition, stress levels, and alertness and biomarkers (leptin, glucose, and cholesterol) should be explored to observe health outcomes from increased sit-stand desk usage. By incorporating lifestyle factors and biomarkers in this research, we can help identify a possible dose-response relationship with sit-stand desk usage and health implications.

Workplace design can have an impact on worker health and productivity. The recent trends include activity-permissive workstations/meeting areas, open-space floor plans, and improving air quality and lighting. These should be evaluated in combination with increased desk usage to determine the impact on worker health. For example, cognitive function scores have been better under Green+ building conditions (higher outdoor ventilation rate and artificially elevated carbon dioxide levels) than compared to conventional building conditions (Allen et al., 2016). Therefore, studies should observe the long-term effects of such workplace design components using quantitative data to understand the effect on total worker health.

REFERENCES

Ainsworth, B. E., Haskell, W. L., Whitt, M. C., Irwin, M. L., Swartz, A. M., Strath, S. J., ... & Jacobs, D. R. (2000). Compendium of physical activities: an update of activity codes and MET intensities. *Medicine and science in sports and exercise*, *32*(9; SUPP/1), S498-S504.

Aittasalo, M., Miilunpalo, S., & Suni, J. (2004). The effectiveness of physical activity counseling in a work-site setting: a randomized, controlled trial. *Patient Education and Counseling*, *55*(2), 193-202.

Alkhajah, T. A., Reeves, M. M., Eakin, E. G., Winkler, E. A., Owen, N., & Healy, G. N. (2012). Sit–stand workstations: a pilot intervention to reduce office sitting time. *American journal of preventive medicine*, *43*(3), 298-303.

Allen, J. G., MacNaughton, P., Satish, U., Santanam, S., Vallarino, J., & Spengler, J. D. (2016). Associations of cognitive function scores with carbon dioxide, ventilation, and volatile organic compound exposures in office workers: a controlled exposure study of green and conventional office environments. *Environmental health perspectives*, *124*(6), 805.

Anderson, G., & Horvath, J. (2004). The growing burden of chronic disease in America. *Public health reports*, *119*(3), 263-270.

Aronne, L. J., Nelinson, D. S., & Lillo, J. L. (2009). Obesity as a disease state: a new paradigm for diagnosis and treatment. *Clinical cornerstone*, *9*(4), 9-29.Bandura, A. (1986). Social foundation of thought and action: A social-cognitive view. *Englewood Cliffs*.

Atlas, S. J., & Deyo, R. A. (2001). Evaluating and managing acute low back pain in the primary care setting. Journal of general internal medicine, 16(2), 120-131.

Bandura, A. (2004). Health promotion by social cognitive means. *Health education & behavior*, *31*(2), 143-164.

Barbieri, D. F., Mathiassen, S. E., Srinivasan, D., Dos Santos, W. M., Inoue, R. S., Siqueira, A. A. G., ... & Oliveira, A. B. (2017). Sit–Stand Tables With Semi-Automated Position Changes: A New Interactive Approach for Reducing Sitting in Office Work. IISE Transactions on Occupational Ergonomics and Human Factors, 5(1), 39-46.

Becker, M. H. (1974). The health belief model and personal health behavior. *Health education monographs*, *2*, 324-473.

Benden, M. E., Blake, J. J., Wendel, M. L., & Huber Jr, J. C. (2011). The impact of stand-biased desks in classrooms on calorie expenditure in children. *American Journal of Public Health*, *101*(8), 1433-1436.

Bergouignan, A., Latouche, C., Heywood, S., Grace, M. S., Reddy-Luthmoodoo, M., Natoli, A. K., ... & Kingwell, B. A. (2016). Frequent interruptions of sedentary time modulates contraction-and insulin-stimulated glucose uptake pathways in muscle: ancillary analysis from randomized clinical trials. Scientific reports, 6, 32044.

Blair, S. N., & Brodney, S. (1999). Effects of physical inactivity and obesity on morbidity and mortality: current evidence and research issues. Medicine and science in sports and exercise, 31, S646-S662.

Blangsted, A. K., Hansen, K., & Jensen, C. (2004). Validation of a commercial software package for quantification of computer use. *International Journal of Industrial Ergonomics*, *34*(3), 237-241.

Buckley, J. P., Hedge, A., Yates, T., Copeland, R. J., Loosemore, M., Hamer, M., ... & Dunstan, D. W. (2015). The sedentary office: a growing case for change towards better health and productivity. Expert statement commissioned by Public Health England and the Active Working Community Interest Company. *Br J Sports Med*, bjsports-2015.

Cafazzo, J. A., Casselman, M., Hamming, N., Katzman, D. K., & Palmert, M. R. (2012). Design of an mHealth app for the self-management of adolescent type 1 diabetes: a pilot study. *Journal of medical Internet research*, *14*(3).

Cawley, J. (2010). The economics of childhood obesity. *Health affairs*, *29*(3), 364-371.

Chau, J. Y., Van der Ploeg, H. P., Dunn, S., Kurko, J., & Bauman, A. E. (2012). Validity of the occupational sitting and physical activity questionnaire. *Medicine and science in sports and exercise*, *44*(1), 118-125.

Church, T. S., Thomas, D. M., Tudor-Locke, C., Katzmarzyk, P. T., Earnest, C. P., Rodarte, R. Q., ... & Bouchard, C. (2011). Trends over 5 decades in US occupation-related physical activity and their associations with obesity. *PloS one*, *6*(5), e19657.

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., ... & Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine & science in sports & exercise*, *35*(8), 1381-1395.

Diaz, K. M., Howard, V. J., Hutto, B., Colabianchi, N., Vena, J. E., Safford, M. M., ... & Hooker, S. P. (2017). Patterns of Sedentary Behavior and Mortality in Us Middle-aged and Older Adults: A National Cohort Study. *Annals of Internal Medicine*.

DiClemente, C. C., & Prochaska, J. O. (1983). Stages and processes of self-change of smoking: toward an integrative model of change. *Journal of consulting and clinical Psychology*, *51*(3), 390-395.

DiClemente, C. C., Prochaska, J. O., Fairhurst, S. K., Velicer, W. F., Velasquez, M. M., & Rossi, J. S. (1991). The process of smoking cessation: an analysis of precontemplation, contemplation, and preparation stages of change. *Journal of consulting and clinical psychology*, *59*(2), 295.

Donath, L., Faude, O., Schefer, Y., Roth, R., & Zahner, L. (2015). Repetitive daily point of choice prompts and occupational sit-stand transfers, concentration and neuromuscular performance in office workers: an RCT. *International journal of environmental research and public health*, *12*(4), 4340-4353.

Dunstan, D. W., Wiesner, G., Eakin, E. G., Neuhaus, M., Owen, N., LaMontagne, A. D., ... & Healy, G. N. (2013). Reducing office workers' sitting time: rationale and study design for the Stand Up Victoria cluster randomized trial. *BMC Public Health*, *13*(1), 1057.

Dutta, N., Koepp, G. A., Stovitz, S. D., Levine, J. A., & Pereira, M. A. (2014). Using sit-stand workstations to decrease sedentary time in office workers: a randomized crossover trial. *International journal of environmental research and public health*, *11*(7), 6653-6665.

Edwardson, C. L., Winkler, E. A., Bodicoat, D. H., Yates, T., Davies, M. J., Dunstan, D. W., & Healy, G. N. (2016). Considerations when using the activPAL monitor in field-based research with adult populations. *Journal of Sport and Health Science*.

Evans, R. E., Fawole, H. O., Sheriff, S. A., Dall, P. M., Grant, P. M., & Ryan, C. G. (2012). Point-of-choice prompts to reduce sitting time at work: a randomized trial. *American journal of preventive medicine*, *43*(3), 293-297.

Finkelstein, E. A., Fiebelkorn, I. C., & Wang, G. (2004). State-level estimates of annual medical expenditures attributable to obesity. *Obesity*, *12*(1), 18-24.

Finkelstein, E. A., Trogdon, J. G., Cohen, J. W., & Dietz, W. (2009). Annual medical spending attributable to obesity: payer-and service-specific estimates. *Health affairs*, *28*(5), w822-w831.

Frontczak, M., Schiavon, S., Goins, J., Arens, E., Zhang, H., & Wargocki, P. (2012). Quantitative relationships between occupant satisfaction and satisfaction aspects of indoor environmental quality and building design. *Indoor air*, *22*(2), 119-131.

Frost, R., McClurg, D., Brady, M., & Williams, B. (2016). Optimising the validity and completion of adherence diaries: a multiple case study and randomised crossover trial. *Trials*, *17*(1), 489.

Garcia, M. G., Läubli, T., & Martin, B. J. (2015). Long-term muscle fatigue after standing work. *Human factors*, *57*(7), 1162-1173.

Garrett, G., Benden, M., Mehta, R., Pickens, A., Peres, S. C., & Zhao, H. (2016). Call center productivity over 6 months following a standing desk intervention. *IIE Transactions on Occupational Ergonomics and Human Factors*, *4*(2-3), 188-195.

Gilson, N. D., Puig-Ribera, A., McKenna, J., Brown, W. J., Burton, N. W., & Cooke, C. B. (2009). Do walking strategies to increase physical activity reduce reported sitting in workplaces: a randomized control trial. *International Journal of Behavioral Nutrition and Physical Activity*, *6*(1), 43.

Gregory, D. E., & Callaghan, J. P. (2008). Prolonged standing as a precursor for the development of low back discomfort: an investigation of possible mechanisms. *Gait & posture*, *28*(1), 86-92.

Gupta, N., Hallman, D. M., Mathiassen, S. E., Aadahl, M., Jørgensen, M. B., & Holtermann, A. (2016). Are temporal patterns of sitting associated with obesity among blue-collar workers? A cross sectional study using accelerometers. BMC public health, 16(1), 148.

Hamilton, M. T., Hamilton, D. G., & Zderic, T. W. (2007). Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes*, *56*(11), 2655-2667.

Hamilton, M. T., Healy, G. N., Dunstan, D. W., Zderic, T. W., & Owen, N. (2008). Too little exercise and too much sitting: inactivity physiology and the need for new recommendations on sedentary behavior. Current cardiovascular risk reports, 2(4), 292.

Hatamoto, Y., Yamada, Y., Higaki, Y., & Tanaka, H. (2016). A novel approach for measuring energy expenditure of a single sit-to-stand movement. European journal of applied physiology, 116(5), 997-1004.

Healy, G. N., Wijndaele, K., Dunstan, D. W., Shaw, J. E., Salmon, J., Zimmet, P. Z., & Owen, N. (2008). Objectively measured sedentary time, physical activity, and metabolic risk. *Diabetes care*, *31*(2), 369-371.

Healy, G. N., Dunstan, D. W., Salmon, J., Cerin, E., Shaw, J. E., Zimmet, P. Z., & Owen, N. (2008). Breaks in sedentary time. *Diabetes care, 31*(4), 661-666.

Healy, G. N., Dunstan, D. W., Salmon, J. O., Shaw, J. E., Zimmet, P. Z., & Owen, N. (2008). Television time and continuous metabolic risk in physically active adults. *Medicine & Science in Sports & Exercise*, *40*(4), 639-645.

Henning, R. A., Jacques, P., Kissel, G. V., Sullivan, A. B., & Alteras-Webb, S. M. (1997). Frequent short rest breaks from computer work: effects on productivity and well-being at two field sites. *Ergonomics*, *40*(1), 78-91.

Honda, T., Chen, S., Yonemoto, K., Kishimoto, H., Chen, T., Narazaki, K., ... & Kumagai, S. (2016). Sedentary bout durations and metabolic syndrome among working adults: a prospective cohort study. BMC Public Health, 16(1), 888.

Jansson, J. O., Palsdottir, V., Hägg, D. A., Schéle, E., Dickson, S. L., Anesten, F., ... & Cone, R. D. (2018). Body weight homeostat that regulates fat mass independently of leptin in rats and mice. Proceedings of the National Academy of Sciences, 115(2), 427-432.

Júdice, P. B., Hamilton, M. T., Sardinha, L. B., Zderic, T. W., & Silva, A. M. (2016). What is the metabolic and energy cost of sitting, standing and sit/stand transitions?. European journal of applied physiology, 116(2), 263-273.

King, D., Greaves, F., Exeter, C., & Darzi, A. (2013). 'Gamification': Influencing health behaviours with games. *Journal of the Royal Society of Medicine Vol 106, Issue 3, pp. 76-78.*

Koskelo, R., Vuorikari, K., & Hänninen, O. (2007). Sitting and standing postures are corrected by adjustable furniture with lowered muscle tension in high-school students. *Ergonomics*, *50*(10), 1643-1656.

Krause, N., Lynch, J. W., Kaplan, G. A., Cohen, R. D., Salonen, R., & Salonen, J. T. (2000). Standing at work and progression of carotid atherosclerosis. *Scandinavian journal of work, environment & health*, 227-236.

Kristensen, T. S., Hannerz, H., Høgh, A., & Borg, V. (2005). The Copenhagen Psychosocial Questionnaire-a tool for the assessment and improvement of the psychosocial work environment. *Scandinavian journal of work, environment & health*, 438-449.

Kumanyika, S. K., Bowen, D., Rolls, B. J., Van Horn, L., Perri, M. G., Czajkowski, S. M., & Schron, E. (2000). Maintenance of dietary behavior change. *Health Psychology*, *19*(1S), 42.

Levine, J. A., Lanningham-Foster, L. M., McCrady, S. K., Krizan, A. C., Olson, L. R., Kane, P. H., ... & Clark, M. M. (2005). Interindividual variation in posture allocation: possible role in human obesity. Science, 307(5709), 584-586.

Lister, C., West, J. H., Cannon, B., Sax, T., & Brodegard, D. (2014). Just a fad? Gamification in health and fitness apps. *JMIR serious games*, *2*(2).

Marshall, A. L., Leslie, E. R., Bauman, A. E., Marcus, B. H., & Owen, N. (2003). Print versus website physical activity programs: a randomized trial. *American journal of preventive medicine*, *25*(2), 88-94.

McCrady, S. K., & Levine, J. A. (2009). Sedentariness at work: how much do we really sit?. *Obesity*, *17*(11), 2103-2105.

Mehta, R. K., Shortz, A. E., & Benden, M. E. (2015). Standing up for learning: A pilot investigation on the neurocognitive benefits of stand-biased school desks. *International journal of environmental research and public health*, *13*(1), 59.

Middleton, K. R., Anton, S. D., & Perri, M. G. (2013). Long-term adherence to health behavior change. *American journal of lifestyle medicine*, *7*(6), 395-404.

Neuhaus, M., Healy, G. N., Dunstan, D. W., Owen, N., & Eakin, E. G. (2014). Workplace sitting and height-adjustable workstations: a randomized controlled trial. *American journal of preventive medicine*, *46*(1), 30-40.

Noar, S. M., & Zimmerman, R. S. (2005). Health Behavior Theory and cumulative knowledge regarding health behaviors: are we moving in the right direction?. *Health education research*, *20*(3), 275-290.

Norton, K., Norton, L., & Sadgrove, D. (2010). Position statement on physical activity and exercise intensity terminology. *Journal of Science and Medicine in Sport*, *13*(5), 496-502.

Ogden, C. L., Carroll, M. D., Curtin, L. R., McDowell, M. A., Tabak, C. J., & Flegal, K. M. (2006). Prevalence of overweight and obesity in the United States, 1999-2004. *Jama*, *295*(13), 1549-1555.

Opdenacker, J., & Boen, F. (2008). Effectiveness of face-to-face versus telephone support in increasing physical activity and mental health among university employees. *Journal of Physical Activity and Health*, *5*(6), 830-843.

Østerås, H., & Hammer, S. (2006). The effectiveness of a pragmatic worksite physical activity program on maximal oxygen consumption and the physical activity level in healthy people. *Journal of Bodywork and Movement Therapies*, *10*(1), 51-57.

Owen, N., Healy, G. N., Matthews, C. E., & Dunstan, D. W. (2010). Too much sitting: the population-health science of sedentary behavior. *Exercise and sport sciences reviews*, *38*(3), 105.

Paredes, P., Tewari, A., & Canny, J. (2013). Design principles for the conceptualization of games for health behavior change. CHI 2013.

Pate, R. R., Pratt, M., Blair, S. N., Haskell, W. L., Macera, C. A., Bouchard, C., ... & Kriska, A. (1995). Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. Jama, 273(5), 402-407.

Payne, H. E., Moxley, V. B., & MacDonald, E. (2015). Health behavior theory in physical activity game apps: a content analysis. *JMIR Serious Games*, *3*(2).

Pearson, E. S. (2012). Goal setting as a health behavior change strategy in overweight and obese adults: a systematic literature review examining intervention components. Patient education and counseling, 87(1), 32-42.

Peddie, M. C., Bone, J. L., Rehrer, N. J., Skeaff, C. M., Gray, A. R., & Perry, T. L. (2013). Breaking prolonged sitting reduces postprandial glycemia in healthy, normal-weight adults: a randomized crossover trial. *The American journal of clinical nutrition*, *98*(2), 358-366.

Reinhardt, U. E., Hussey, P. S., & Anderson, G. F. (2004). US health care spending in an international context. *Health Affairs*, *23*(3), 10-25.

Ryan, C. G., Dall, P. M., Granat, M. H., & Grant, P. M. (2011). Sitting patterns at work: objective measurement of adherence to current recommendations. Ergonomics, 54(6), 531-538.

Sarkin, J. A., Johnson, S. S., Prochaska, J. O., & Prochaska, J. M. (2001). Applying the transtheoretical model to regular moderate exercise in an overweight population: validation of a stages of change measure. *Preventive medicine*, *33*(5), 462-469.

Swartz, A. M., Rote, A. E., Welch, W. A., Maeda, H., Hart, T. L., Cho, Y. I., & Strath, S. J. (2014). Prompts to Disrupt Sitting Time and Increase Physical Activity at Work, 2011–2012. *Preventing Chronic Disease*, *11*, E73.

Tremblay, M. S., Carson, V., Chaput, J. P., Connor Gorber, S., Dinh, T., Duggan, M., ... & Janssen, I. (2016). Canadian 24-hour movement guidelines for children and youth: an integration of physical activity, sedentary behaviour, and sleep. *Applied Physiology, Nutrition, and Metabolism*, *41*(6), S311-S327.

Trogdon, J. G., Finkelstein, E. A., Hylands, T., Dellea, P. S., & Kamal-Bahl, S. J. (2008). Indirect costs of obesity: a review of the current literature. *Obesity Reviews*, *9*(5), 489-500.

Tüchsen, F., Hannerz, H., Burr, H., & Krause, N. (2005). Prolonged standing at work and hospitalisation due to varicose veins: a 12 year prospective study of the Danish population. *Occupational and environmental medicine*, *62*(12), 847-850.

Turk, D. C., & Melzack, R. (Eds.). (2011). *Handbook of pain assessment*. Guilford Press.

U.S. Department of Labor, Bureau of Labor Statistics. Computer and Internet Use at Work in 2003. *Current Population Survey 2003.* Web. 20 December 2017. https://www.bls.gov/news.release/ciuaw.nr0.htm van den Heuvel, S. G., de Looze, M. P., Hildebrandt, V. H., & Thé, K. H. (2003). Effects of software programs stimulating regular breaks and exercises on work-related neck and upper-limb disorders. *Scandinavian journal of work, environment & health*, 106-116.

Wallace, L. S., Buckworth, J., Kirby, T. E., & Sherman, W. M. (2000). Characteristics of exercise behavior among college students: application of social cognitive theory to predicting stage of change. *Preventive medicine*, *31*(5), 494-505.

Wellnomics. (2010). *Scientific validation of Wellnomics Recorder (WorkPace) as a tool for measuring computer use exposure* [White Paper]. Retrieved October 30, 2017, from Wellnomics Software: http://wellnomics.com/support/research/white-papers/.

Wendel, M. L., Benden, M. E., Zhao, H., & Jeffrey, C. (2016). Stand-biased versus seated classrooms and childhood obesity: A randomized experiment in Texas. American journal of public health, 106(10), 1849-1854.

Wilks, S., Mortimer, M., & Nylén, P. (2006). The introduction of sit–stand worktables; aspects of attitudes, compliance and satisfaction. *Applied ergonomics*, *37*(3), 359-365.

World Health Organization. (2010). Global Recommended levels of physical activity adults.

Zuckerman, O., & Gal-Oz, A. (2014). Deconstructing gamification: evaluating the effectiveness of continuous measurement, virtual rewards, and social comparison for promoting physical activity. *Personal and Ubiquitous Computing*, *18*(7), 1705-1719.

Young, S. (2014). Healthy behavior change in practical settings. *The Permanente Journal*, *18*(4), 89.

APPENDIX A

TEXAS A&M UNIVERSITY HUMAN RESEARCH PROTECTION PROGRAM
INFORMED CONSENT DOCUMENT

A Texas A&M University study: Can we compete for physical activity using sit-stand desks?

Introduction
The purpose of this form is to provide you information that may affect your decision as to whether or not to participate in this research study. Also, if you decide to be involved in this study, this form will be used to record your consent.

If you agree, you will be asked to participate in a research study examining sedentary work with sit-stand workstations by using an inclinometer attached to your desk and software to determine sitting/standing times. The purpose of this study is to examine the effect of sit-stand desks on your overall well-being, activity level, and determine if competing in teams can motivate people to move more at the workplace. You have been selected to be a possible participant because you work in the Division of Student Affairs at Texas A&M University and you have received a sit-stand workstation. This study is being sponsored/funded by Texas A&M University.

Definitions:
Sit-stand workstation: regular height chair with desk that can be adjusted manually between seated or standing height (this is your Varidesk)

Inclinometer sensor: sensor that detects if your Varidesk is in a sitting or standing position. This will be installed and mounted on your Varidesk by the Division's Department of Information Technology (DoIT).

Sit-stand software: software will collect data on the time spent sitting or standing while you are using your computer. This will be installed on your sit-stand workstation by the Division's Department of Information Technology (DoIT).

What will I be asked to do?
If you decide to participate in this study, you will allow the placement of the desk position sensor on your sit-stand workstation. This will be installed and maintained by the Division's Department of Information Technology. The sensor will remain mounted on your desk for the time of the study (6 months). In addition, the DoIT will install the sit-stand software on your computer. This software will remain installed on your computer for the time of the study.

After 3 months of the software and desk position sensor collecting data on sit/stand times, participants will be divided into teams. Each team will receive sit/stand statistics on a weekly basis as a way for teams to compete against each other. The winning team will be determined at the end of the study. Each member of the winning team will receive $100 compensation at the end of the study. No personal or identifiable information will be collected.

IRB NUMBER: IRB2016-0577D
IRB APPROVAL DATE: 07/19/2017
IRB EXPIRATION DATE: 07/18/2018

An online survey will be administered at the beginning, during and end of the study, (3 times total,10 minutes each) which will be related to your current workstation setup, training you received about the sit-stand desk once you received it, and previous sitting and standing habits at your workstation. The survey will also ask age, gender, height, and weight.

Additionally, you will be asked to about your body discomfort level, perceived productivity, and employee motivation. Finally, you will have the choice to abstain from answering any questions in the questionnaire without penalty.

No identifiable information about you related to this study will be shared with Texas A&M University and nothing from this study will be used in making any decisions related to your employment with Texas A&M University. You will be assigned a random participant number to track your data from start to finish.

What are the risks involved in this study?
The risks associated with this study are minimal, and are not greater than risks you ordinarily encounter in daily life. However, keep in mind that participation in this research study is not a substitute for consultation with a physician for any medical or health-related condition you may have.

What are the possible benefits of this study?
Information from this study will help with standing office changes to help reduce sedentary time, improve health, and understand employee motivation.

There will be an opportunity for monetary compensation later in the study when participants are organized into teams and can compete against each other to see which teams are more active in the workplace. You must participate in all data collection periods to be eligible to receive the compensation at the end of the study.

Do I have to participate?
No, you do not have to be in this research study. Participation is voluntary and is not a condition of your employment with Texas A&M University nor a condition of receiving a sit-stand desk with the Division of Student Affairs. There is no penalty for choosing not to participate, and you can withdraw from the research study without any penalty if you change your mind later.

Who will know about my participation in this research study?
This study is confidential and the records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely and only Texas A&M Researchers Parag Sharma and Dr. Mark Benden will have access to the records.

IRB NUMBER: IRB2016-0577D
IRB APPROVAL DATE: 07/19/2017
IRB EXPIRATION DATE: 07/18/2018

Whom do I contact with questions about the research?
If you have questions regarding this study, you may contact Dr. Cynthia Hernandez (cynthiah@vpsa.tamu.edu) Parag Sharma (psharma@sph.tamhsc.edu) or Dr. Mark Benden (mbenden@sph.tamhsc.edu).

Whom do I contact about my rights as a research participant?
This research study will be reviewed by the Human Subjects' Protection Program and/or the Institutional Review Board at Texas A&M University. For research-related problems or questions regarding your rights as a research participant, you can contact these offices at 1+ (979) 458-4067 or irb@tamu.edu.

STATEMENT OF CONSENT
TEXAS A&M UNIVERSITY HUMAN RESEARCH PROTECTION PROGRAM
INFORMED CONSENT DOCUMENT

I agree to be in this study and know that I am not giving up any legal rights by signing this form. The procedures, risks, and benefits have been explained to me, and my questions have been answered. I know that new information about this research study will be provided to me as it becomes available and that the researcher will tell me if I must be removed from the study. I will be able to ask questions at any point of this study. I understand I must fully participate to receive compensation for this study. A copy of this entire consent form will be given to me.

__________________________ __________________________
Participant's Signature Date

__________________________ __________________________
Printed Name Date

INVESTIGATOR'S AFFIDAVIT:
Either I have or my agent has carefully explained to the participant the nature of the above project. I hereby certify that to the best of my knowledge the person who signed this consent form was informed of the nature, demands, benefits, and risks involved in his/her participation.

__________________________ __________________________
Signature of Presenter Date

Printed Name

Date

APPENDIX B

Texas A&M University Division of Student Affairs Sit-Stand Study Survey Questions

1. Do you have a table-top, height adjustable sit-stand desk at your workstation?

   Yes
   No

2. How long have you been using your sit-stand desk?

   1 year
   2 years
   3 years

3. Do you ever use your table-top, height adjustable desk in a standing position?

   Yes
   No

4. Do your co-workers' habits with their sit-stand desk have an influence on the way you use your sit-stand desk?

   When we discuss our sitting/standing habits
   When I see them using their sit-stand desk
   Both of the above
   No

5. In which way do they influence how often you stand using your desk?
   Motivates me to stand more
   Makes me feel like I want to stand less

6. In which way do they influence often you move the desk into different positions? (sitting to standing/standing to sitting)

   Motivates me to change positions more often
   Makes me feel like I want to change positions less often

7. Which of the following do you possess at your workstation?
   Footrest
   Standing pad/fatigue mat
   Neither of these

8. How often do you use a footrest when standing?
   Never
   Sometimes

Frequently

9. How often do you use a standing pad/fatigue mat when standing?
    Never
    Sometimes
    Frequently