

Longitudinal Study of Adjustable Workstations

by

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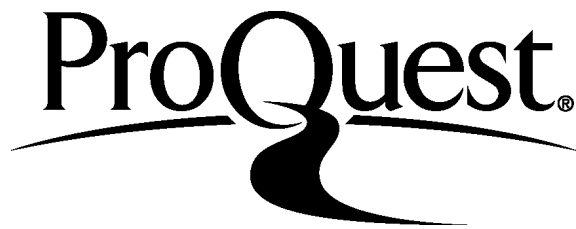
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Dedication

To Ernest Moyer, the mentor in my life that has taught me it is not only acceptable to ask questions but imperative.

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Abstract

Workplace interventions to reduce discomfort and sedentary time have been studied in a variety of settings. Adjustable workstations are one type of ergonomic intervention that is used to potentially reduce occupational sitting time, negative health impacts, and to increase productivity. This investigation compared two types of ergonomic interventions, as well as contrasting behavioral interventions among workers with and without adjustable workstations. Seventy-two sedentary office workers were selected to participate in a longitudinal study to evaluate interventions for a reduction in occupational sitting time, to understand the effect on productivity and to evaluate musculoskeletal pain and behaviors. Workers were randomly placed into four different intervention groups and observed over 14 weeks. Group assignments were: control group, employees trained on behavioral interventions, employees given adjustable workstations and the final group had both ergonomic and behavioral interventions. During the study, there was a decrease in discomfort scores and fatigue for the adjustable workstation users. Standing time was increased in groups that had the adjustable workstations and frequency of workstation use remained constant throughout the 14 weeks. There was sufficient evidence to suggest that adjustable workstations will decrease sitting time and decrease all over body discomfort in

occupations that typically involve long hours of sitting. More research is needed to determine the health benefits of less occupational sitting.

Chapter One:

Introduction

As technology improves, the way we spend time at work has changed drastically in the past few decades. More time is spent on computers and we require less active roles in the workplace. According to the Bureau of Labor Statistics in the next ten years the fastest growing jobs include categories such as customer service representatives, management and statisticians, which can be expected to include primarily sedentary work (1). The amount of time that Americans spend in sedentary activities is thought to be approximately 7.7 to 10 hours out of 15 waking hours a day (2).

The human body was designed to move and research indicates that, limiting this movement to static postures for long periods of time, can have unfavorable health outcomes if interventions are not used to break up sedentary work (3). Several interventions are available that potentially could reduce static or poor postures for those who work at computers for the majority of the day. Ergonomic engineering interventions include ways to increase movement such as adjustable desks, treadmill type workstations and pedaling foot rests. Ergonomic behavioral interventions consist of educational and motivational types of information on proper stretching techniques

and goals including mini-breaks, stretches and education on postural and office setups for better workstation designs. Various factors can affect how a person will respond to an ergonomic intervention such as physical health, workload and other psychosocial aspects within an organization. Understanding the variations and limitations between the interventions are important for employers to maintain healthy productive employees. As more research and options are available to employees, it is a sensible next step to understand how the intervention can work within organizations and to select interventions that personnel will use to obtain the maximum benefits without decreasing productivity.

The use of adjustable workstations in the workplace is becoming more widespread. There are limited investigations of the psychosocial, physical and economic benefits of adjustable workstation use. Adjustable workstations allow the user to raise or lower their work surfaces to support either a seated or standing posture by manually or electronically raising/lowering the surface. Employees can easily reduce their sitting time by using an adjustable desk and this has been shown not to have a negative impact on productivity (4, 5). Research studies on adjustable workstations have reviewed a variety of outcomes such as a decrease in worker discomfort and absenteeism, an increase in productivity and worker engagement, and improved health outcomes (5-11). During evaluation of the literature on adjustable workstations it was determined that there was a reduction in both occupational sitting time and musculoskeletal discomfort in most studies. However, there is insufficient evidence to determine whether the use

of adjustable workstations was also associated with a decrease in adverse health outcomes (4-6). Employees tend to feel more alert and productive while using these workstations yet investigations seem to differ on the association of increased productivity (5, 12-14). During physiological measurements in behavioral types of research, there is a suggestion of increased alertness from use of adjustable workstations (5). The encouraging results that were reiterated throughout the behavioral studies signify, that productivity and alertness may increase but have not been found to decrease with adjustable workstation use (5, 14, 15).

A variety of modifiable workstations are available including those that are placed on top of an existing desk, those that require more installation time onto existing desktops and whole desks that electronically or manually raise and lower the work surface. The variations of sit-stand workstations allow employers to choose the model that is most appropriate for their workforce, their processes and their work environment.

This paradigm shift of occupations becoming more sedentary and requiring less energy expenditures for workers, leisure activities trending towards less physical activity, and commutes to work becoming longer, brings into focus the need to increase physical activity in settings where interventions can be applied (6, 16-18). Research suggests that sedentary work independently, may have a negative impact on personal health, even in settings where physical activity guidelines are met (2, 10, 19). Adjustable workstations

plus behavioral interventions have the potential to reduce the negative health outcomes associated with sedentary time during a large portion of an employee's day (7).

As Lockheed Martin employees learn more about the outcomes of adjustable workstation studies which emphasize the negative impacts of sedentary jobs, they are requesting to have modifications made to their workstations which facilitate them varying their posture throughout the day. This study examined behavior and training interventions and collected information that can be generalized to other groups of employees that utilize computers for long hours. Once the benefits and limitations of the interventions are better understood for the population of employees, employers may be better able to help reduce the potential for musculoskeletal injuries by diminishing postural fatigue and to increase worker health and productivity.

Public Health Significance

The increase in sedentary occupations, commuting time and inactive leisure interests have brought into focus the need for research efforts into public health interventions that will reduce their negative impact on health. Negative health outcomes such as obesity, cardiovascular morbidities and other health related issues are associated with a sedentary lifestyle (2, 7, 20-23). The medical costs associated with the health consequences of inactivity are estimated at \$76 billion in the United States in 2000 (24). As our population shifts towards more sedentary activities while not meeting the recommended guidelines for physical activity, decreasing sedentary time in our

occupations affords us the opportunity to address some of these morbidities at a place where we spend a significant amount of our time and where we have the potential to impact a large amount of people. The workplace is a crucial setting for healthy interventions. In 2002 the Current Population Survey estimated that there were 145 million in the United States work force (24). Some publications estimate the amount of occupational sitting time to be up to 75% of an employee's total workday (4, 15, 17, 25, 26). As variable workstations become more common, it may be useful to understand the benefits and limitations to the devices and to recognize if education can increase the benefits of adjustable workstation utilization for the 45,000,000 computers in the U.S workplace and the one million people who have absent time due to treatment or resting from musculoskeletal pain (27-29).

A historical exploration into the etiology of increased obesity rates has indicated that more sedentary hours spent watching TV is positively correlated with higher body mass indices (BMI) in all persons (2, 28, 30-33). There are varied factors that cause adults and children to be overweight. These include genetic factors and physical activity. However, research findings have confirmed that even if physical activity guidelines are met, the more sedentary a person is, the more likely he or she is to have a higher BMI (2, 10, 30). Worldwide obesity rates have doubled in the past 35 years. There are approximately 1.9 billion adults, aged 18-64, who are overweight and at the same time physical activities are declining in many countries (34, 35). The four leading risk factors associated with global mortality (percentage of deaths) in order are: high

blood pressure, tobacco use, high blood glucose and physical inactivity (35). Further it has been found that physical inactivity can lead to cancers, heart disease, diabetes and depression (35). The global health focus has been to increase physical activity over the next few years to aid in the prevention of noncommunicable diseases (34, 36). The World Health Organization's 25x25 campaign is to help reduce premature mortality from noncommunicable diseases by 25% before the year 2025 (37). There is a potential for the use of adjustable workstations to reduce cardiometabolic risk as part of other health promotion objectives.

The significance of this research is to understand if workers will continue to use the ergonomic interventions and which interventions (or combination of interventions) result in sustained use, decreased discomfort and little or no negative impact on productivity. Once that is established we can then continue to research ways to increase physical activity and thus decrease the negative health impacts of too much inactivity. In the long run, it would be beneficial as these types of interventions may help to reduce healthcare costs as a result of improved worker health.

Purpose of the Study

The purpose of this study is to provide three variations of interventions to a sample of employees who work six or more hours per day at a computer and to collect data on measures of discomfort, and behavioral differences between the types of interventions. To accomplish this goal, the study was designed to answer the following questions:

1. Do employees continue with ergonomic or behavioral interventions over time?
2. Is there a change in self-reported musculoskeletal discomfort for sedentary employees who are given training interventions, adjustable workstations or both types of interventions?
3. Do ergonomic or behavioral interventions impact productivity during computer use?

Chapter Two:

Literature Review

The purpose of this research was to understand the utilization of adjustable workstation use and training interventions in a population of software engineers. The outcomes to be assessed were discomfort, productivity and frequency of intervention use over a 14 week period.

The literature review was conducted using PubMed, Google scholar and EMBASE search on the following keywords: “adjustable workstations”, “sedentary work”, “sit-stand workstations” and “ergonomic interventions”.

Health Effects

Upper musculoskeletal disorders (MSDs) can be a result of high repetition tasks, forces on the body or awkward postures. Postural fatigue caused by static improper postures at computer workstations and long hours associated with certain occupations, can result in musculoskeletal discomfort (5, 11, 38). The more time spent in sedentary work, the more likely and severe the symptoms of MSD pain will be (39). The consensus in the current literature, that observed discomfort as a dependent variable in

interventions, has shown a correlation between less pain and frequent movement during the day (11, 17). MSD injuries are contributing to a large number of occupational illnesses in the U.S. (40). In 2013, ergonomic injuries for upper extremities accounted for 33% of all of the reported injuries and illnesses to the Bureau of Labor Statistics (41). Typically up to ten hours a day is spent in sedentary activities for most adults, with workplace sitting accounting for the bulk of that inactive time (2, 42, 43). A possible root cause to the numerous upper extremity injuries, is long hours of occupational sitting and a more modern lifestyle that promotes physical inactivity. The sedentary time spent sitting at work oftentimes continues into the employee's leisure activities.

In U.S. households over 92% of those employed also have computers at home (44), which may signify more time spent in sedentary activities after the workday is finished. Both leisure time activities that are sedentary and occupations that require a large amount of seated time result in the majority of a person's day being spent in sedentary behaviors, predominantly prolonged sitting (22). Understanding how to alter sedentary time at a location where a large percentage of individuals spend their time would be supportive of a healthier lifestyle and musculoskeletal system (11). Also employee health programs at work should incorporate education on the health effects of too much sitting and should focus on interventions that increase movement in a workday (37).

Current guidelines from the World Health Organization and other global recommendations advocate for 150 minutes of moderate to vigorous physical activity (MVPA) for those 18-64 years of age each week (35, 43). However, even when people achieve the guidelines, the adverse health outcomes from prolonged sitting may not be reversed (22). Current research is evaluating what types of physical activity guidelines best combat the negative effects of sedentary occupations and lifestyle, as well as trying to understand the relationship between time spent sitting and adverse health effects. As researchers examine what type of exercises and breaks are necessary to alleviate sedentary time, they have observed different work-rest regimens. The work-rest cycles considered ranged from attaining physical activity guidelines of 30 minutes per day with a normal 8 hours of sitting at a computer workstation, to a 5-10 minute stretch and walk after every hour of occupational sitting, to a quick 2 minute walk during every 30 minutes of sedentary time plus the global recommended exercise guidelines of 30 minutes of physical activity. These studies have found the latter to be healthier for decreasing the cardiometabolic risk potential (21, 22, 39, 45). However, other research indicates that the more micro breaks utilized the less discomfort, eyestrain and fatigue a person will encounter without a negative effect on overall productivity(39).

Correlation has been observed between long durations of occupational sitting time and weight gain and obesity in previous studies (2, 10, 30, 46). Investigations indicate that increased sitting time may produce outcomes such as obesity or weight gain regardless of obtaining the required amounts of physical activity (30, 42, 47, 48). Extended periods

of sitting are connected to higher mortality rates even when BMI is within a healthy range (19). Postural changes from sitting to standing and moving inside of an office space is considered light activity and can add energy expenditures to an individual's total energy consumption (37). Although adjustable desks have not yet been shown to increase energy expenditures enough to lose weight, future research in this area continues (37, 49). Magnetic Resonance Imaging (MRI) results did show an increase of fat liver adiposity, total adiposity and visceral abdominal fat with moderate correlations to sedentariness (50).

Cardiovascular disease, type 2 diabetes, cancer and all-cause mortality in various populations have been studied and an increasing amount of evidence is suggesting that there may be a relationship to these noncommunicable diseases and sedentary time (2, 10, 15, 17, 42, 46, 51, 52). Physical inactivity in the United States results in 200,000 to 300,000 deaths each year (24). A dose-response relationship between sitting time and mortality has been shown in that there are more deaths associated in groups with heavier periods of sitting however there are no recommended guidelines as to how much sitting is unhealthy or has the potential to increase the risk of noncommunicable diseases (19).

One of the cardiometabolic disease risks occurs when there are substantial amounts of sedentary time is due to the skeletal muscle lipoprotein lipase (LPL) activity that is inhibited during these prolonged inactive periods (3, 7, 53-55). LPL inhibition can cause

higher levels of free fatty acids and triglycerides in circulation (3, 7, 53-55). The increase in fatty acids and triglycerides produces excess reactive oxygen species that can cause cardiometabolic health issues (7, 23, 46). Researchers have reported that small changes in behaviors such as, more standing time versus sitting, can reduce LPL activity suppression (25, 42, 56). In two short 3-month studies, high density lipoprotein was shown to decrease with an increased use of a sit-stand workstation (15, 25).

Interrupting sitting time at work more frequently may help decrease the risks of cardiovascular disease and type 2 diabetes compared to persons who spend the same amount of time sitting but meet the physical activity guidelines of 30 minutes of physical activity after a long period of sedentary time (8, 21). Cardiovascular risk has also been observed in populations that received the recommended amount of activity set forth by various organization's guidelines; yet spent a lot of time sitting at work and at home (21). The recommendations from previous studies do not indicate to change the guideline levels of physical activity, instead they encourage guidelines to be established for a dose response relationship for sitting time (21, 37).

There is a strong link between postprandial glucose levels and the possibility of cardiovascular issues after prolonged intervals of seated time (23, 57, 58). In lab based studies interrupting sitting time with standing or 90 seconds of walking have been associated with decreases in postprandial glucose and insulin excursions due to

ergonomic interventions such as adjustable workstations or added movement through the use of micro breaks (15, 21).

Recent literature has suggested that as sitting time increases inflammation, this may affect the function of telomeres. Telomeres are related to aging and cancers since progressive shortening of these protein structures, found in our deoxyribonucleic acid (DNA), can cause the destruction of our cells (59). As we age, telomeres will become shorter and certain lifestyle factors such as being overweight, smoking and lack of exercise, can contribute to progressive telomere shortening (59). Advanced telomere shortening is associated with cardiac issues, cancers and diabetes (59). Investigations into telomere size, demonstrates that exercise can actually lengthen telomeres (8, 60). Being able to identify which types of exercise can help to reverse the shortening of telomeres, in future research, will be beneficial as workplace behavioral interventions add education for healthy movements and techniques. These interventions will also have a possibility to encourage a healthier workforce and simultaneously reduce absenteeism and unproductive employees.

Diet, physical activity and drug therapies can all combat cardiovascular risk (23, 30, 53). Hopefully future research will identify the level of physical activity required to minimize the effects of our present sedentary routines. Investigational consideration of the relationship between sitting time and the length of breaks as well as the frequency of breaks required to combat the damaging health consequences is significant. Once

those dose- response relationships are more clearly defined they can be set as further global guidelines alongside current physical activity guidelines (53). Global guidelines now incorporate suggestions to reduce sitting as much as possible but are unable to recommend how much sitting versus active time should occur (43). A recent consensus statement in 2016 gave guidelines for 2 to 4 hours a day of standing or moving around during work time that is necessary to decrease the potential for noncommunicable diseases and musculoskeletal discomfort (37). However it is still unclear what amount of moderate to vigorous physical activity is required to combat periods of sedentary time. Research has shown that greater than 7 hours a week of MVPA failed to fully mitigate risk of mortality from too much sitting time (2). It is clear that reducing physical inactivity for a person's total day is as important as meeting the guidelines for daily physical activities (37).

Overall adding more movement into a workday reduces the risk of noncommunicable diseases (37, 58). Therefore employers should look for ways to increase healthy movements where possible and understand what types of interventions will work within their organizations. Interventions that can increase movement and decrease negative health outcomes have the ability to benefit the employee as well as the employer with potential changes in productivity, fewer sick days at home from work, more productivity and in the long run the possibility of decreased healthcare costs (37).

Previous Studies

Longitudinal studies on adults using adjustable workstations, that collected data for longer than one week, reported a decrease in overall sitting time ranging from forty minutes to one hundred and forty minutes each day (6, 14, 15). Recent systematic reviews of height adjustable workstations found that occupational sitting time was reduced but findings on other measurements of health and psychosocial outcomes have been inconclusive. Few studies have reported a decrease in musculoskeletal discomfort (4, 5, 11, 14).

Research that focused on training interventions illustrated differences in MSDs, eye discomfort, increase in standing time and overall MSD risk awareness/prevention (27, 39, 61, 62). The training interventions varied and those studies that had a statistical significance or an association to a positive behavior or measured outcome, consisted of in-depth training sessions with portions that were “hands on” and ranged from 90 to 270 minutes (7, 17, 29, 62). Training intervention topics ranged from learning the risk factors of musculoskeletal disorders, how to properly set up a workstation, increasing micro breaks during a workday and stretching exercises (39). All of the training interventions attempted to measure several outcomes such as mood disturbances, discomfort, eyestrain and productivity (5, 11, 62). Some studies showed an increase in productivity while others showed no difference after training interventions were put in place (6, 11, 15). The persuading finding of the investigations consistently established when an intervention is put in place it does not decrease productivity, even when more

time is spent on micro breaks and stretching (39). This may reassure employers of the benefit of investigative research for application of various interventions including the use more frequent microbreaks during a workday. Overall research reveals, that there is an increase in productivity and a decrease musculoskeletal symptoms as the number breaks that are taken during a workday increase (39, 63-66). Repeatedly, investigations reported more productivity and less discomfort with micro breaks, whether or not the participants complied with the stretching exercise interventions, which suggests that the adjustable workstation breaks are sufficient to alter psychophysiological arousal (5, 39, 65). Training coupled with an ergonomic intervention often produced the most positive outcomes on decreased discomfort and most productivity (26, 67). Another study showed that education plus an additional prompt to take a break resulted in more of a decrease in seated time over education alone which may indicate that self-paced or web-based education may not be adequate for ergonomic/physical activity interventions (68). There were investigations that looked at training and behavioral interventions which noted that individuals often times do not perform the recommended healthy movements and stretches (29, 39, 69). As research progresses into the psychosocial aspect of these interventions studies, it would be prudent to consider gender and skill set differences among populations and potentially adapt strategies that are targeted to the specific population being addressed (70).

Many studies explored mood states or presenteeism and a higher percentage of those investigations reported improvements in fatigue, tension, confusion and vigor (5, 17,

71). Presenteeism is when employees come to work, not feeling well and are therefore less productive than others, or have a decrease in productivity from their own baseline (71). Although this study did not review mood, most participants mentioned they felt happier, more energetic and engaged throughout the 14 weeks. Physical activity has been shown to improve mental health and is normally a goal of employer health promotion campaigns (37, 71). Studies indicate that the financial expenditures of presenteeism often cost 2 to 5 times more than the cost of absenteeism (71). Symptoms that accompany presenteeism are depression, anxiety and lethargy (71). Even though physical activity and improved mood states have a strong correlation, understanding the connection between physical activity and employee presenteeism is recently gaining awareness. The more sedentary an employee is the more likely they will report higher levels of presenteeism (69).

The design of adjustable workstation research varied among investigators. Studies were primarily longitudinal with a control group or crossover in design (4, 6, 17). The majority of the studies did not select their participants randomly (4, 6, 17). The number of participants fluctuated between 11 and 60, and the intervention periods lasted between 1 day to 52 weeks (4, 6, 7, 15, 17). On average the investigations had 30 participants over a 3-month period (4, 6, 17). Outcomes assessed with sit-stand desks were mood, BMI, insulin levels, cholesterol levels, time spent standing, minutes of physical activity and productivity (4, 6, 17).

Time spent in sedentary activities was measured either with self-report questionnaires, inclinometers or types of accelerometers (57, 72). Self-reported measures tended to not alter behaviors during use and can either be a single question or summation of responses for different categories of activities (57, 73). Self-reported time of activities was often captured with questionnaires/tools that have shown test retest reliability and correlation to accelerometers and inclinometers (72). The stronger reliability of these self-report measures are detected behaviors that are done as a routine such as television watching or sitting at work (57). Self-reported tools are important to larger studies where the cost of accelerometers may be prohibitive to gather information on sedentary activities (74). The two self-reported questionnaires found in literature most frequently during this study were: *Total Sitting Questionnaire (TSQ)* and *The Occupational Sitting and Physical Activity Questionnaire*. The TSQ is the short version of the *International Physical Activity Questionnaire*. There were approximately a dozen various self-report activity questionnaires that have been shown to have moderate test-retest reliability when compared to accelerometers, and used in some of the research settings that could be found using the English language (4, 17, 75). The *Occupational Sitting and Physical Activity Questionnaire (OSPAQ)* showed moderate validity correlations when compared to accelerometers for walking, sitting and standing (76). Some of the self-reported sedentary time questionnaires have a seven-day recall of activities for the study participants (76). Self-completion of questionnaires is the more common method of measurement in sedentary studies due to researchers understanding the domains of behavior and due to financial limitations (56, 74, 77, 78). The *Past-Day Adult's Sedentary*

Time (PAST) questionnaire recalls the participant's past day activities rather than the end of the week questionnaires asking for 7 days of information and could possibly be less affected by recall bias (78). However, one report showed that the 7 day recall using the domain specific questionnaire improved the approximation of daily sitting times by summing up different domains because it was easier for some people to recall time spent in specific behaviors rather than one activity all day long (57, 74). Domain specific questionnaires had higher sensitivities for weekdays compared to weekends (74, 79). It is recommended to use both a self-report measure of activities along with an accelerometer to understand the most about the data collected (57).

Two types of activity meters mentioned in sedentary time studies are ActivPALs® and the ActiGraph®. Both meters are considered accelerometers and can count steps and sedentary time, but only the ActivPALs® can give you standing and seated time based on position (72, 77). Both are useful in assessing activities during the day; however, they do have their biases and concerns. ActiGraph®'s limitation is the placement of the device either on the hip or waist, making it unable to distinguish between sitting, lying down and standing (74, 80). ActivPALs® requires users to wear the device for longer than 10 hours a day, or more than 80% of their waking day (57, 78). Even when device based measurements record activities, users would still need to recall the past day to account for times that the meters were not used (79). Wear time of an accelerometer will vary and missing data can look like sleeping due to lack of counts (57). Activities are recorded on accelerometers as counts. The counts are added over a period of time.

Accelerometers should not always be considered the correct standard of sedentary measurement based on their limitations and that more research is necessary to understand which cut points are the best representative of sitting time and what the minimum wear time from the user is appropriate (72, 77, 78, 81). They are more useful and representative of analyzing a user's physical activities and studies that relate to physical activities (77).

A recent consensus statement, by an international group of experts published in the British Journal of Sports Medicine, presented a few key concepts on sedentary time in the office (37). After their review of intervention and epidemiological studies their recommendations were as follows:

- “During full time work an employee should try and stand or engage in light physical activity for 2 hours a day, gradually increasing up to 4 hours a day
- Adjustable desks are recommended to break up seated and standing time in an office. Neither prolonged static postures should occur for long periods of time and should be broken up periodically
- Health promotion goals of a corporation should include education on increased risk of cardiometabolic and premature mortality from sedentary lifestyles.”

Workplace physical activity interventions vary among self-initiated activities from educational topics or onsite facilities or activities that allow employees to engage in

physical activities at the worksite. It is a benefit to having physical activity programs at the job since employees spend a large part of their day at work and that should make it easier for individuals to meet the guidelines for physical activity (16, 82). Physical activities at the workplace can affect productivity by decreasing absenteeism, lowering job stress and increasing job satisfaction and worker health (82). More research is needed to understand which physical activity programs work best and determine the economic impact of the programs.

This research utilized some tools found in the literature review such as self-reporting questionnaires for accountability of activity times, Likert scales for self-reporting of discomfort, the selection of the vendor used-Ergotron and the attempt to capture presenteeism for indication of productivity changes during the study.

Chapter Three:

Methodology

This study was approved by the University of South Florida's Human Research Ethics Committee in August of 2015. The study identification number associated with the study is Pro00023149 (Attachment 1). All study participants were given a copy of the informed consent document for this research during the first week of September. Only those participants who signed the form were able to join the research investigation.

A longitudinal study was conducted at Lockheed Martin Mission System and Training (LMMST) in Orlando, FL. LMMST Orlando sits on 253 acres with a footprint of 1067.2 kilosquare foot. Software and system engineers at the Orlando, FL LMMST campus comprise over forty percent of the total employee population. The sample of software engineers selected for this group were pursued due to the long hours and sedentary nature of their work and that they were located in same area, under the same management team.

Employees that had the job title of software engineers were selected to compare various interventions within similar types of employees and work environments. The intent of the investigation was to provide a clearer understanding of the differences between

various interventions and to assist in selection of a common ergonomic intervention process for the organization. The results of this study can assist different business areas in determining the appropriate type of office ergonomic training or adjustable workstations to meet the needs of a majority of the population at Lockheed Martin or to assist in areas that require an ergonomic intervention. The results can also be used to inform interventions among larger populations of employees outside of Lockheed Martin.

The data points collected during the study were discomfort scores, frequency of workstation use and productivity based on fatigue indications and overtime/lost time total days before and during the study.

Seventy-four employees were randomly placed into one of four groups. Each group completed two baseline questionnaires to collect initial scores for discomfort and behaviors and then continued to answer questionnaires five other times during the following twelve weeks of the study. Demographic data was collected in the first baseline questionnaire.

All information was captured by a software program called ErgoSuite or self-reported within ErgoSuite. ErgoSuite version 3.5.7 was installed on the participant's computers. ErgoSuite software has been used as an enhancement to the Lockheed Martin macroergonomics program for several years. This program alerts employees once a

certain amount of computer work has been accomplished to proceed with a micro break, assists employees to self-assess posture and aids in ergonomic education. The software was used to capture discomfort level, region of discomfort and behavioral aspects of the study (Figure 1).

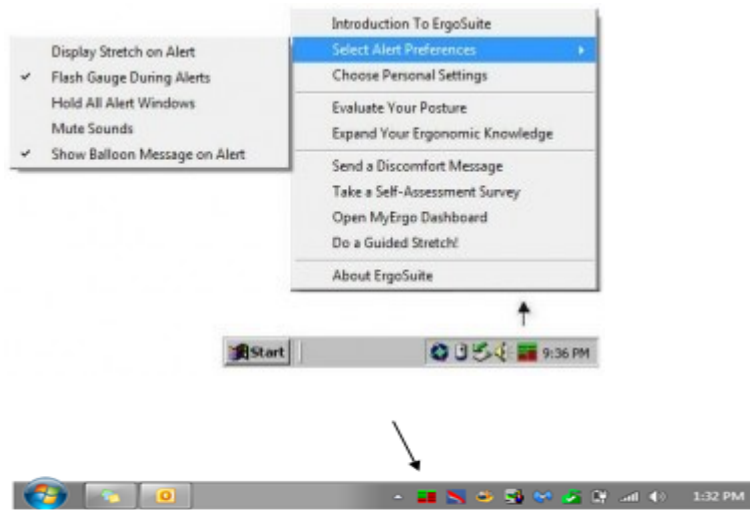


Figure 1- ErgoSuite Icon Available for Users 24/7

Self-reported discomfort level ratings were reviewed seven times within the study (Figure 2). Scores were captured twice prior to the introduction of interventions and then additionally five times throughout the remaining 12 weeks. The discomfort regions are pictorially categorized by: head, eyes, jaw, neck, trunk, shoulders, chest, upper back, lower back, arms, elbow, hands, wrist, fingers, upper legs, knees, lower legs, ankles and feet (Figure 3). Discomfort level groups are slight, moderate and severe. Each are assigned a Likert type scale of 1-3, with 1 = slight, 2=moderate and 3 = severe (Figure 4). This Likert type of questionnaire is useful in longitudinal type studies

for self-administration of surveys as shown in the Nordic pain questionnaires and is commonly used in research when capturing subjective perceived pain (15, 20). The employees would select the area of the body that they felt discomfort and score it using the 1-3 scale and push send to confirm their selection (Figure 4). The scores were collected in ErgoSuite and reports were reviewed to compare seven times during the study.

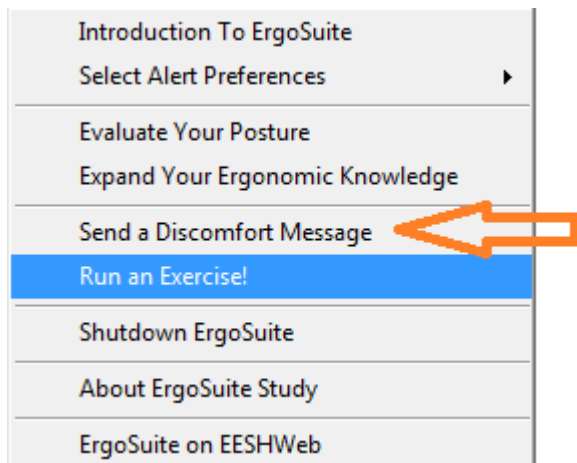


Figure 2-ErgoSuite Discomfort Notes

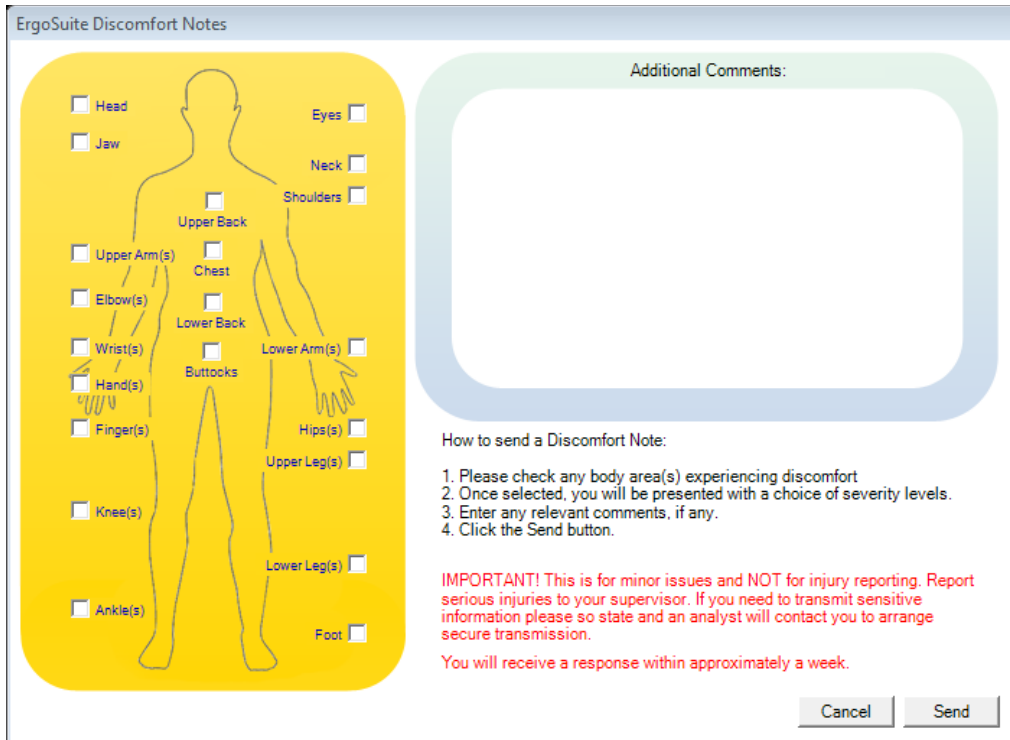


Figure 3-ErgoSuite Discomfort Note Region of Body

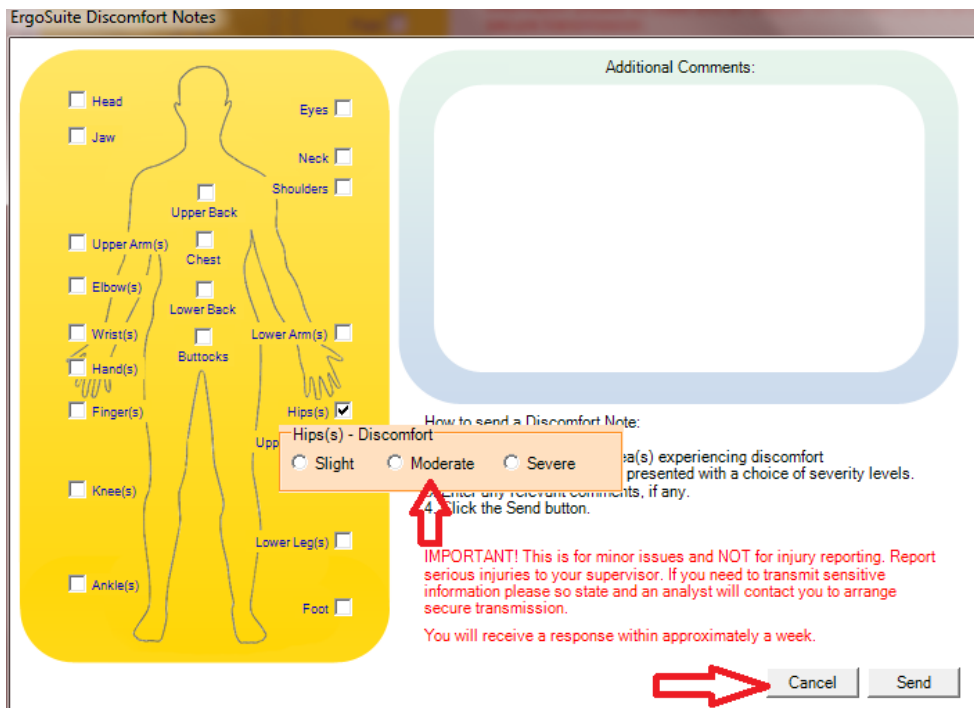


Figure 4- ErgoSuite Discomfort Note Likert Scale

Productivity was assessed by comparing three measures: total keystrokes, sick time and overtime taken during the study period, and fatigue indicators. Total keystrokes is the sum of all keystrokes for any time period needed to be observed. In this study total keystrokes were reported for weeks 1, 2, 3, 4, 6, 10 and 14. ErgoSuite summed all keystrokes taken for the particular week and produced a weekly average for all participants of the study. ErgoSuite also captured fatigue indicators by counting the number of alterations and comparing that total to the total keystrokes, for the same weeks 1, 2, 3, 4, 6, 10 and 14 (Figure 5).

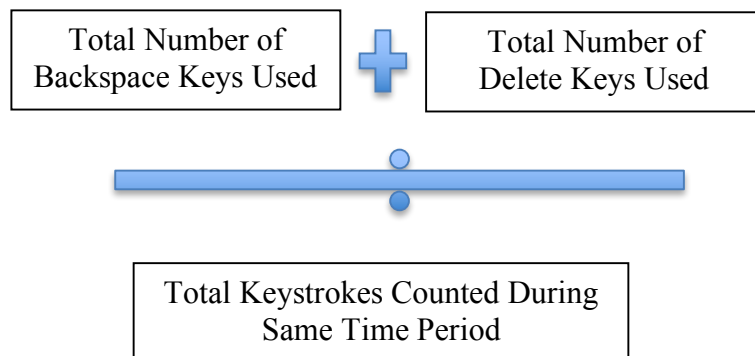


Figure 5- ErgoSuite Fatigue Indicators Calculation

Measuring the use of alteration keys can illustrate an association of an effective intervention that benefits from enhanced productivity in an organization.

Productivity was also assessed for all groups in this study by the number of days absent (Personal Illness or Personal Business) other than vacation or holiday time and the number of hours worked in overtime for 3 months prior to any interventions and for 3 months after the interventions were instituted. Absent time and overtime was collected through the finance and human resource department and compared to the three month

period prior to the study to the three month period during the study for all groups as well.

The frequency of adjustable workstation use and training on healthy movements and stretch interventions were demonstrated in the weekly self-reported hours spent standing, walking or seated throughout the workday. This information was collected periodically throughout the 14 -week investigation.

The employees were randomly placed into one of four groups. Group one included the employees that did not receive any of the three interventions. This group served as the control group for the study. Employees in this group were involved with all steps of the processes including capturing time spent in sitting, standing and walking activities. The second group consisted of employees that were trained on healthy movement tools and techniques (HMTT). The intervention for this group was primarily focused on instilling practices of movement during their workdays. This additional training occurred after the two baseline questionnaires were completed. The brief education was developed for those who worked in office environments and included specific ways to incorporate additional movement into each workday. This was administered by a five-minute video developed in house. Three tools were emphasized during the video: stretch, stand and walk. When the ErgoSuite software determined it was time for a break, employees were taught three injury prevention techniques for the following parts of their body: chest, back and wrists. The video explained when and how to

include these prevention techniques during the day. These interventions were selected and developed by Duffy Rath Physical Therapy System©. The ErgoSuite icon in the bottom right hand corner of the user's computer monitor displays a square made up of horizontal bars that are green when breaks are being taken and will turn red with increasing number if the employees do not take the recommended pauses from their computer work. Group two participants were advised to stretch when 50% of the bars are red. They were encouraged to stand during phone calls or virtual/teleconferences. Another recommendation to increase standing time was introduced by teaching employees to walk to co-workers workstations that were in the nearby vicinity rather than sending an email or instant message to them. Walking was the next motion encouraged in the video. It was suggested to these employees that they could use the treadmill computer station, located in the Imaginarium-a common area that employees use to take a break away from their office space, during slower paced work such as reviewing email, during long teleconferences or while taking training certifications. The video also reviewed "walking meetings" when only discussing work with one or two employees, if possible.

Group three included employees who received an adjustable workstation and training for proper use and adjustment of the unit through Ergotron. No HMTT training was delivered to this group; however, they did participate in the periodic questionnaires.

The fourth group of employees was given an adjustable workstation and training for proper use and adjustment of the unit through Ergotron, along with HMTT training.

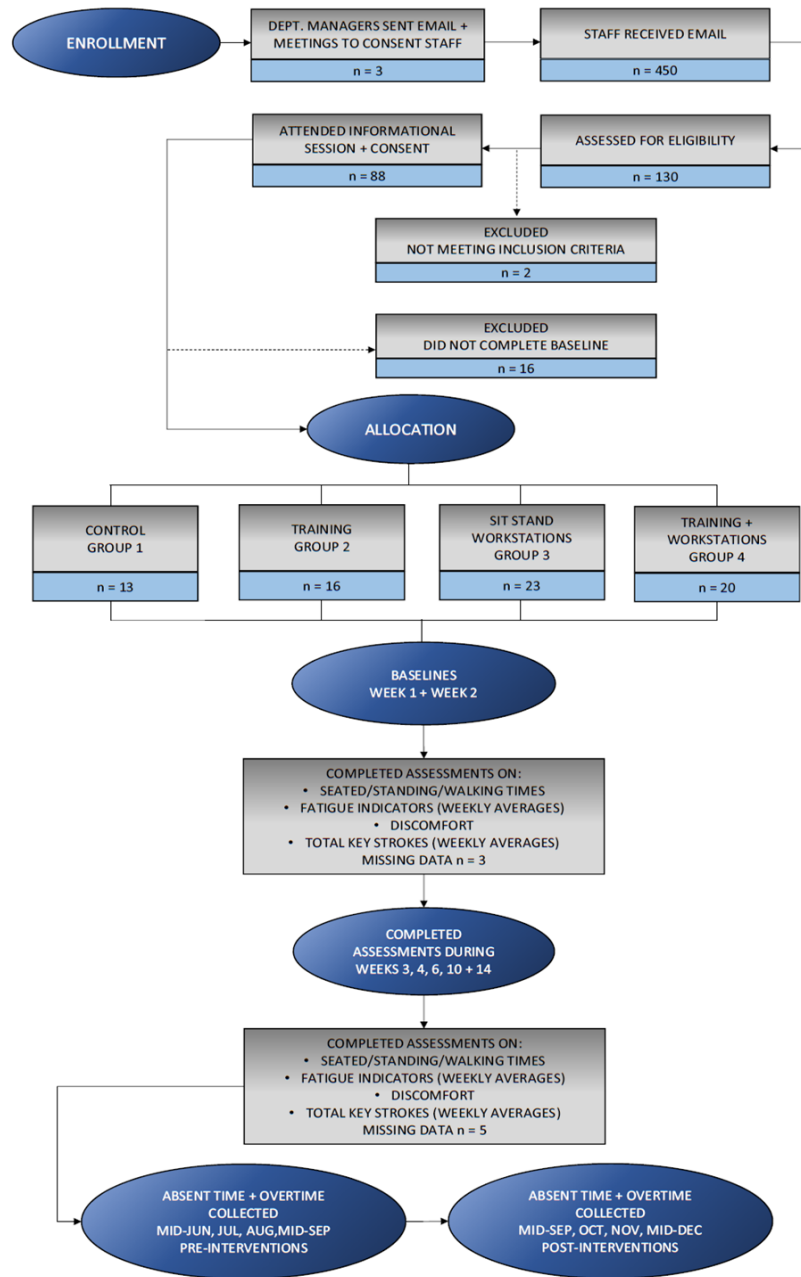


Figure 6: Flow Diagram of Study Setup and Data Collection over Time

Selection Process

The LMMST business unit primarily develops software solutions and training / simulation technologies for both civil and commercial markets. At the time of study development, there were approximately 2500 full time employees with 388 various job titles at the Orlando facility. Approximately 90% of these employees had occupations requiring sedentary computer work for a large percentage of their workday. About half of the population fell into one of two job titles: system engineers and software engineers. Both job functions are among those requiring sedentary computer activities for a majority of the workday. Whether at their primary desks or working on computers in a lab, both sets of engineers performed computer based work for nine to ten hours a day. A standard workday at this facility is nine hours but many of those salaried employees work more than the mandatory 9-hour day. Typically personnel take a 30-minute lunch break at the cafeteria or at their desks. The site is set up for a 9/80 workweek which is four 9-hour days followed by an 8 hour Friday with every other Friday as an off day. The type of work conducted by system and software engineers is similar to other sedentary computer based roles at the Orlando site as well as the rest of our workforce population within Lockheed Martin worldwide. Some of the Lockheed Martin workforce engages in active manufacturing, maintenance or other types of non-sedentary work; so this was representative of introducing prevention opportunities to employees performing computer based sedentary tasks across the entire corporation. Information gathered from the study will facilitate the development of ergonomic protocols to be employed throughout the corporation. In addition, this

information may be generalizable to other office based occupations that are of a sedentary nature, not just in the United States but globally as well.

The software engineer group was selected as the potential research group because they comprise a substantial percentage of the Orlando LMMST population and their job responsibilities are primarily sedentary computer work. Software engineers vary in level (1-5) of expertise and years of experience, but they all have the same responsibilities to plan, conduct, and coordinate software development activities and also design, document and test software that contains logical and mathematical solutions to business issues in computer language by means of data processing equipment. Meetings were held with the software engineering management to explain the goals of the study and to gain approval to proceed. The Human Resource department provided a list of software engineering employees and their specific level within their titles. An email notification was sent to 450 employees who had the title of software engineer. Those employees who wanted to learn more about the study emailed the principal investigator (PI) to sign up for one of six informational sessions held in the onsite auditorium. Senior level employees with a director or manager title were excluded from the study so that those who were new to the company or early career individuals would not feel obligated to participate. Other exclusions to the study were those who were not full time or did not work six plus hours a day on a computer, were non-ambulatory or pregnant, and those who were not willing to participate from mid-September to mid-December 2015. Employees who did qualify and wanted to

volunteer to participate for the study joined one of the information sessions held in the on-site auditorium. The meeting provided details about the research in both video and instructor led format. Prospective participants were able to ask questions during and after the presentation. Written consent forms were collected from the employees who agreed to participate in the workstation study.

After employees had indicated they would like to be involved for the project, they were listed out in Excel and randomly placed into one of the four groups: group 1-control, group 2-training, group 3-desk and group 4-training+desk. 130 employees attended an information session and the PI received 88 signed informed consent forms. During the two baseline questionnaires 74 employees participated in the study as designed. 74 subjects participated for the first two months but 2 employees left the study during the last month.

Participants

After the employees were selected for the study, the next phase ensured all participants had the same level of office ergonomics awareness and training prior to any baseline questionnaires being sent out. A training report confirmed that all employees had completed the LMMST Office Ergonomics course (course code 055291WPL0A).

Seventy-four employees were randomly grouped into one of four categories: group one had no interventions and was considered to be the control group, group two had education on healthy movement tools and techniques, group three received an

adjustable workstation and training on the use of the workstation, and group four received an adjustable workstation, training on how to use the workstation and the healthy movement tools and techniques training.

Interventions

Ergotron was selected as the vendor for the study based on the ability to work with customer service in person at the study location, the number of buyers allowed to be utilized through Lockheed and the varying number of products offered. Two different types of adjustable workstations were selected based on the variability of sizes and number of monitors used at engineers' desks within the Orlando site. An Ergotron vendor completed an assessment of the workstations of those forty employees, in groups 3-desks and 4-training+desks, who would be receiving an adjustable workstation within the first few weeks of the study. A third party assessment determined which equipment was most appropriate for the workspace due to existing space and shape of office or cubicle areas. Employees were not instructed to use the sit-stand workstation for any particular intervals. All adjustable workstations were installed over the weekend of September 25, 2015. The guidance given to workstation users was to start out slow and gradually build their tolerance for standing. There were no guidelines given to employees, other than for them to do what is most comfortable and try to change postures when prompted by the ErgoSuite computer generated reminder for breaks. Employees were free to ask questions. Some employees

specifically asked what was typical for standing use the vendor replied that the typical standing use was approximately 2- 4 hours a day.

Two types of Ergotron products were purchased and installed: WorkFit model T and model S. The model T was designed as an easy method to modify existing spaces without maintenance or installation costs (Figure 7). It has the ability to hold one or two monitors and up to 35 pounds of weight. A laptop can also be used easily with the WorkFit-T. The WorkFit-T takes approximately 30 minutes to install with two monitors. It can hold two monitors with the typical base mounts or two monitors that can be attached to an independent arm secured to the back of the WorkFit-T unit.

The WorkFit--S has a variety of attachments as well and can hold up to 29 pounds (Figure 8). The model S has more adjustability; however, it requires installation by a trained technician. This will require more of a financial investment from a business in order to conduct the installation. The average time to install a single monitor WorkFit--S is around 75 minutes. For those engineers who were over 6'1" a tall user kit was installed to increase the height variability on the adjustable workstation. Engineers who had a third monitor were also given an extra adjustable third arm that could be moved up and down manually after placing the workstation at the desired height.



Figure 7-Ergotron WorkFit- T



Figure 8-Ergotron WorkFit- S (Single and Dual)

Healthy movement tools and techniques training was released through an email with a training video on September 26, 2015, which was week 3 of the study. Healthy movement tools and techniques used were based on 3 simple principals: stretch, stand and walk. These movements were selected by two physical therapists. The video was reviewed by groups 2-training and 4-training+desks during the participant's own time starting on September 26th. At week 6 of the study another reminder for the same 3 principles reviewed in the previous video were put into a one slide PowerPoint

presentation and emailed to all those in groups 2-training and 4-training+desks. Some suggestions to increase movement were to: 1) Standing when the ErgoSuite prompted it was time for a break and to stretch at that time. The breaks are calculated by duration and keystrokes including alterations keys possibly indicating fatigue. 2) Conducting in-person conversations rather than emails or instant messaging, to increase movement. 3) walking meetings, 4) Using the treadmill workstation located in a common area.

Data Collection

The majority of Lockheed Martin employees performing computer based tasks have a version of ErgoSuite on their primary computers. ErgoSuite is used as an additional tool in the education about and prevention of musculoskeletal disorders that can be aggravated or brought on by poor postures and long hours of computer work.

ErgoSuite is able to measure active hours on a computer, fatigue indications and assists in self-paced education on office ergonomics. All participants were upgraded to ErgoSuite version 3.5.7 prior to collection of information.

Baseline information was collected via two questionnaires completed before the installation of the adjustable workstations or prior to training on healthy movements tools and techniques training. Data was also collected during weeks 1, 2, 3, 4, 6, 10 and 14 of the study. All information was entered through a link on ErgoSuite or via email to the principal investigator.

Activity was self-reported for collection of seated time versus standing time 7 times during the 3-month study. Thursdays were selected as the day to submit data on activity during weeks 3, 4, 6, 10 and 14 of the research period after the interventions were put into effect on week 3. If an employee knew ahead of time they would be out of the office or not available on a Thursday they would send information the day before or the day after. Those who were on vacation for the entire week were not asked to submit data. Employees were reminded to submit their data on the ErgoSuite link through Microsoft Outlook calendar invites and through email reminders during the week of a collection period and the day of data collection. This type of self-reported activity has shown significance in a variety of studies and is comparable to those studies that used accelerometers (measures a person's activity) against self-reported activities typically within a short duration of 7 days or less (20, 25, 47, 54, 83-86).

Questionnaires were submitted by each participant using ErgoSuite software and included: seated/standing activity (Appendix 3) and two baseline questionnaires (Appendix 4). These two appendices provide the questions that the study group was asked to address; however, the format was setup on the ErgoSuite software. The first baseline questionnaire asked more about demographic information. Subsequent questionnaires asked about seated/standing activity. Self-reported discomfort and activities were selected based on: 1) financial limitations for the study, 2) that accelerometers cannot distinguish positions between sitting and standing 3)

Table 1 – Outcomes Collected During the Study

Measurements	Groups	How Often Information Was Gathered	Period	Outcome
Discomfort level (ErgoSuite discomfort message)	1, 2, 3, 4	7	week 1, 2, 3, 4, 6, 10, 14	Differences in pain scores change over 3 months
Body Region(ErgoSuite)	1, 2, 3, 4	7	week 1, 2, 3, 4, 6, 10, 14	Does the area of pain change
Fatigue Indicators (ErgoSuite)	1, 2, 3, 4	7	week 1, 2, 3, 4, 6, 10, 14	Increase/decrease/same in fatigue indicators
Total Keystrokes	1, 2, 3, 4	7	week 1, 2, 3, 4, 6, 10, 14	Increase/decrease/same in productivity
Lost time (LM human resources)	1, 2, 3, 4	2	Mid June-mid Sept & mid Sept – mid December	Increase/decrease/same in productivity
Overtime (LM finance)	1, 2, 3, 4	2	Mid June-mid Sept & mid Sept – mid December	Increase/decrease/same in productivity
Hours Walking (self-report)	1, 2, 3, 4	7	week 1, 2, 3, 4, 6, 10, 14	Increase/decrease same number
Hours Sitting (self-report)	1, 2, 3, 4	7	week 1, 2, 3, 4, 6, 10, 14	Increase/decrease same number
Hours Standing (self-report)	1, 2, 3, 4	7	week 1, 2, 3, 4, 6, 10, 14	Increase/decrease/same number

inclinometers must be worn for a minimum of 10 hours. The study participants are only required to work a 9-hour day; therefore, the inclinometers were not appropriate for this test. Accelerometers are a good choice for studies that focus on activity but would not be useful for looking a use of a sit-stand station. The following table is the information that was collected during the study.

Statistical Analysis

Measures were compared for change at various time periods using paired sample t-tests and analysis of variance (ANOVA) models. Analysis was conducted using statistical analysis system (SAS) version 9.4. Measures were established on the pain scores, total keystrokes, fatigue indicators, hours of standing, seated and walking times, and overtime/lost time within for each group at the start of the study and at various times throughout the study. For all statistical analysis, statistical significance was defined by a p-value <.05.

Differences between the groups and within the groups, over time was further evaluated using a mixed model repeated measures analysis with a factorial design where subjects within each group were considered random effects. Each week of data and the 4 groups were considered fixed effects.

For discomfort scores a generalized estimation equation was used to understand the continuous outcomes and if there were interactions between groups considered statistically significant.

The following are the aims of the study:

- 1) Do employees continue with ergonomic or behavioral interventions over time? This was assessed by self-reported activities collected over 14 weeks. Comparison of the interventions between groups 1-4 over 14 weeks to understand which changes are statistically significant and which interventions may be useful at Lockheed Martin with further investigations.
- 2) Is there a change in self-reported musculoskeletal discomfort for sedentary employees who are given training interventions, adjustable workstations or both types of interventions? Observation and analysis of self-reported pain over time to understand the differences between the interventions and which interventions reduce discomfort scores over the study period.
- 3) Do ergonomic or behavioral interventions impact productivity during computer use? Evaluation of absences from work, total keystrokes over a week and fatigue indicators during a week helped in identification of the best intervention fit from the study.

Chapter Four:

Results

Out of the 130 interested software engineers, 88 submitted informed consent forms (Figure 6). The participant rate was 82% after 72 employees continued with the study throughout the 14 weeks. Two employees left the study at week 4 and 8 no longer wanting to participate. This resulted in a response rate of 97% for both males and females. Table 2 describes the population by sex, age and job level according to title. The average age and BMI of the participants was 37.2 (9.4) years and 26.9 (4.4) kilograms per square meter, respectively.

Discomfort scores for 4 regions of the body were collected for each of the groups 1-4 during the study. The body regions included: head, arm, trunk and lower body. Self-reported discomfort was established using a Likert scale of 0-3: 0= no pain, 1=slight, 2=moderate and 3=severe. The discomfort Likert scores were collected on weeks 1, 2, 3, 4, 6, 10 and 14.

Table 2- Demographic Characteristics of Study Participants

Demographic	Control (N=13)	Training (N=16)	Adjustable Desks (N=23)	Training and Desks (N=20)
Job Title (n)				
Associate	6	1	4	3
Engineer	3	3	3	1
Engineer Sr.	1	6	7	9
Engineer Stf.	1	2	6	6
Engineer Sr. Stf.	2	4	3	1
Marital Status (n)				
Single	6	6	9	5
Married	7	10	16	14
Divorced	0	0	1	1
Age in years (Mean (SD))	37 (9.5)	37.1 (9.2)	37.3 (9.6)	37.3 (9.3)
Weight in pounds (Means (SD))	187.4 (96.4)	187.7 (96.4)	188.7 (97.2)	187.3 (96.6)
BMI (Means (SD))	26.8 (4.4)	26.9 (4.4)	27.12 (5.15)	27.03 (5.30)

Discomfort in the head region was consistent for the control group over time (Table 3). Head discomfort for group 2-training had an increase at week 4 (Figure 9). The line graphs show decreases for groups 3- desks and 4-training+desks, after weeks 1 and 2 once the interventions began. There was a very slight increase in head discomfort rating for group 3-desks near the end of the study. In group 3-desks two individuals reported discomfort. The moderate discomfort for the head region was reported by a group 3-desks and a group 4-training+desk participant towards the end of the study.

Table 3: Mean Head Discomfort Rating

Mean rating	Control (n = 13)	Ergonomic training (n = 16)	Adjustable desks (n = 23)	Ergonomic training + Adjustable desks (n = 20)
Week 1	0.27	0.08	0.24	0.31
Week 2	0.20	0.27	0.56	0.23
Week 3	0.27	0.20	0.14	0.27
Week 4	0.18	0.46	0.20	0.21
Week 6	0.18	0.14	0.00	0.06
Week 10	0.18	0.13	0.00	0.00
Week 14	0.20	0.00	0.17	0.06

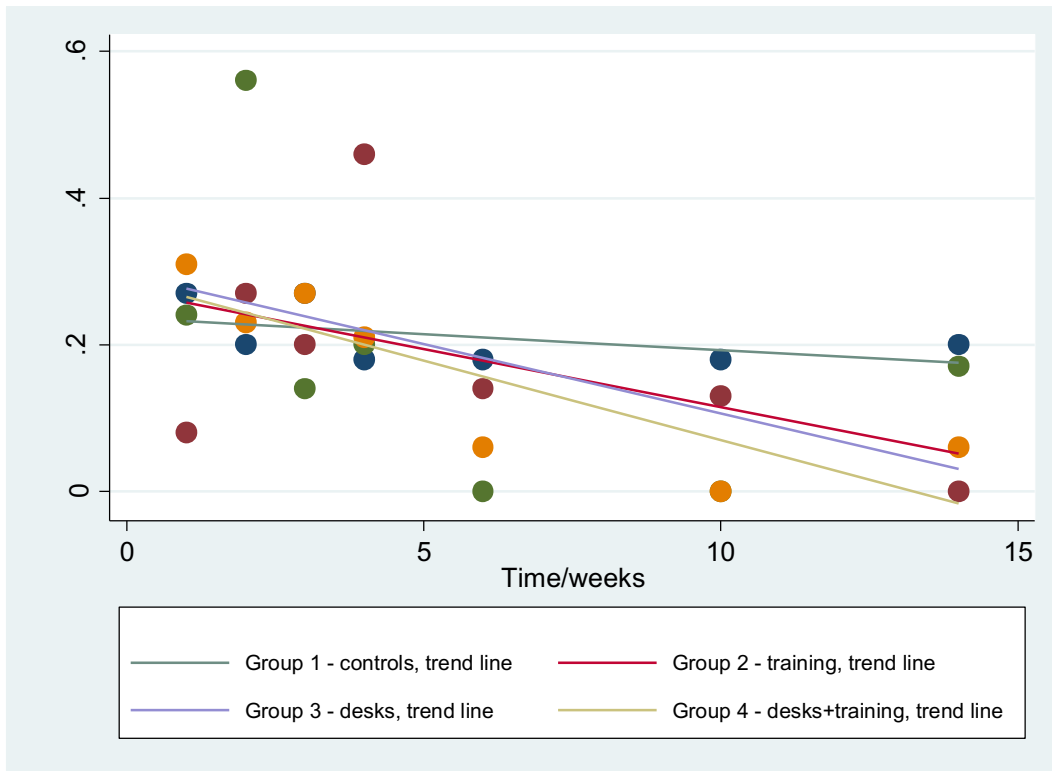


Figure 9: Linear Trend of Mean Head Discomfort Rating for Each Group

Group 1-control was fairly consistent in trunk discomfort scores for all 14 weeks (Table 4). Groups 2-training, 3-desks and 4-training+desks showed a decrease in torso discomfort after the interventions were introduced; however, group2-training had a higher level of trunk discomfort than all 3 other groups for the duration of the study (Figure 10). Eight out of 15 individuals in group 2- training reported some level of discomfort especially during weeks 2 and 4. Group 3-desks and group 4-training+desks continued to report higher levels of discomfort in the trunk region through week 4 and decreased levels at week 6. Week 6 was four weeks after the interventions had been implemented. Between group 3-desks and group 4-training +desks, there were 9 people at week 4 who reported some level of trunk discomfort. Review of group 3-desks and group 4-training+desks self-reported standing times showed that the range of standing during week 4 was an average of 2.2 hours and week 6 they stood an average of 2.4 hours yet only 3 participants had trunk discomfort. Groups 3-desks and 4-training+desks reported a mean standing time of 2.35 hours per day through the final week of the study with a continual decline of lower body pain from week 6 through 14.

Table 4: Mean Trunk Discomfort Rating

Mean rating	Control (n = 13)	Ergonomic training (n = 16)	Adjustable desks (n = 23)	Ergonomic training + Adjustable desks (n = 20)
Week 1	0.45	0.69	0.53	0.56
Week 2	0.40	1.08	0.44	0.46
Week 3	0.36	0.73	0.29	0.40
Week 4	0.36	0.85	0.40	0.50
Week 6	0.18	0.50	0.13	0.13
Week 10	0.27	0.47	0.06	0.06
Week 14	0.30	0.31	0.00	0.13

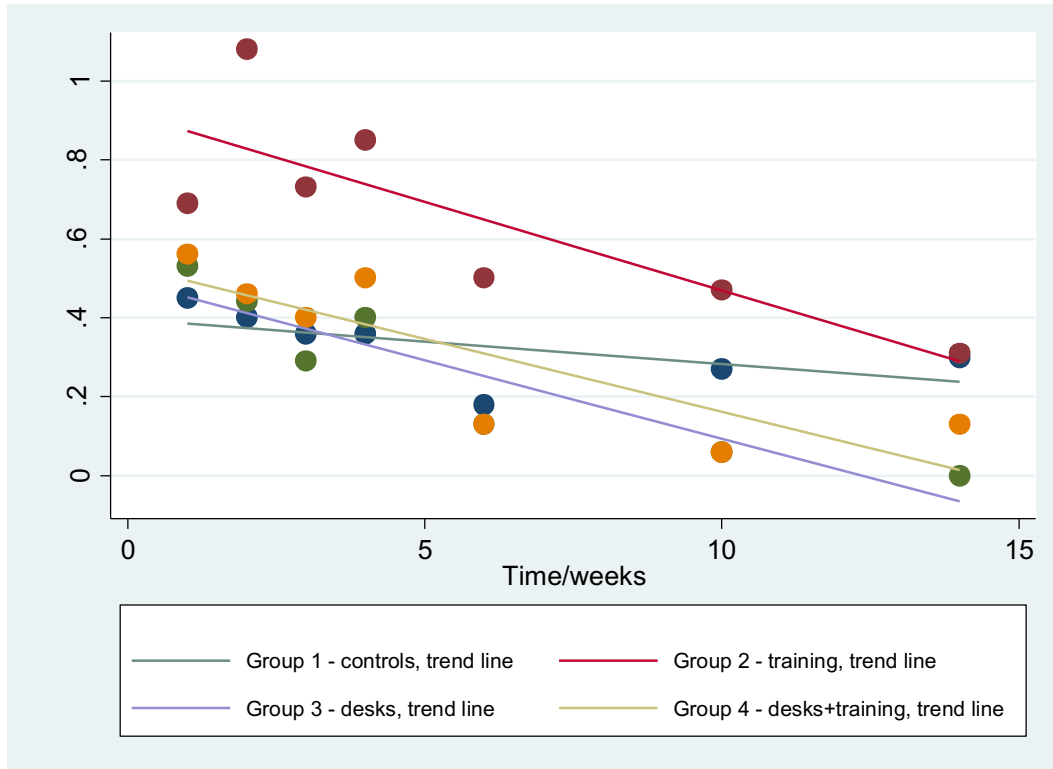


Figure 10: Linear Trend of Mean Trunk Discomfort Rating for Each Group

Discomfort of the arms did not show a considerable difference over time between the groups (Table 5). There was a decrease in discomfort of arms reported for all groups at week 6 (Figure 11).

Table 5: Mean Arm Discomfort Rating

Mean rating	Control (n = 13)	Ergonomic training (n = 16)	Adjustable desks (n = 23)	Ergonomic training + Adjustable desks (n = 20)
Week 1	0.09	0.15	0.24	0.00
Week 2	0.10	0.25	0.19	0.00
Week 3	0.09	0.20	0.21	0.00
Week 4	0.18	0.23	0.00	0.00
Week 6	0.00	0.00	0.00	0.00
Week 10	0.00	0.20	0.12	0.00
Week 14	0.00	0.23	0.00	0.00

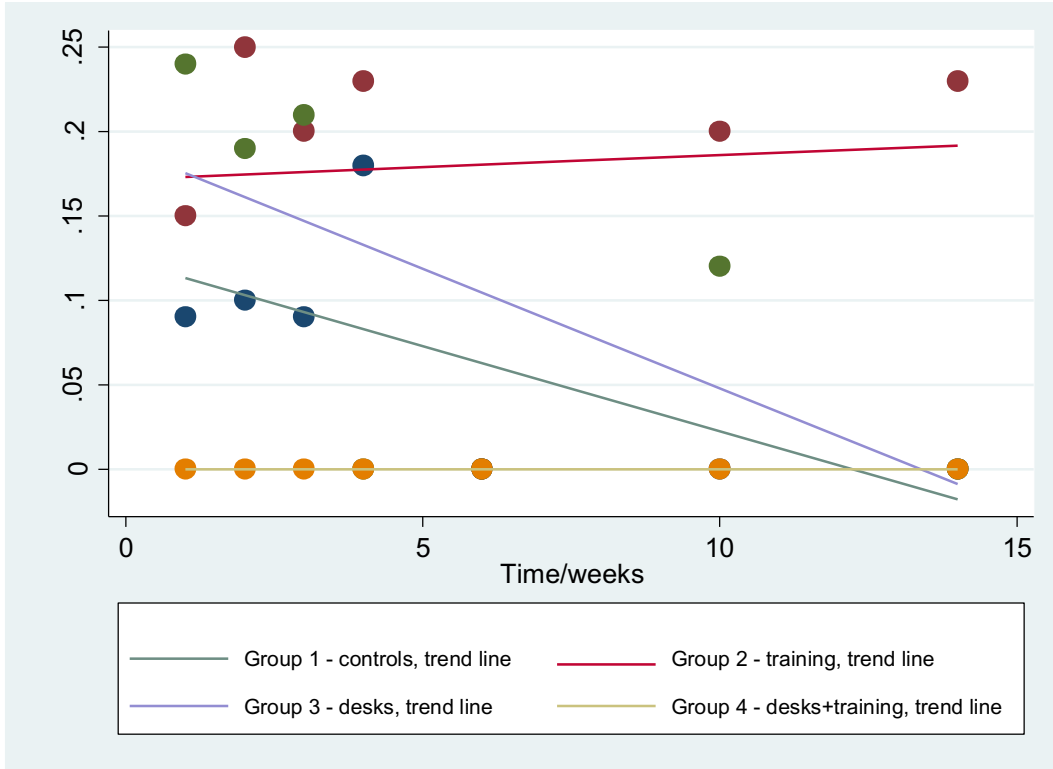


Figure 11: Linear Trend of Mean Arm Discomfort Rating for Each Group

Group 1-control reported minimal lower body pain during the study and reported no discomfort towards the end of the study period (Table 6). Participants in groups 3-desks and 4-training+desks who reported lower body discomfort reported standing times between 1-3 hours on week 4. During week 6 when the lower body pain rating displayed a marked decrease, participants reported standing times between 2.5-8 hours, during which they also reported experiencing lower body discomfort. There was an increase in the reported lower body pain for participants in group 2-training that was unexpected towards the end of the study from week 10 through week 14.

Table 6: Mean Lower Body Discomfort Rating

Mean rating	Control (n = 13)	Ergonomic training (n = 16)	Adjustable desks (n = 23)	Ergonomic training + Adjustable desks (n = 20)
Week 1	0.18	0.23	0.65	0.19
Week 2	0.20	0.17	0.19	0.46
Week 3	0.18	0.27	0.43	0.33
Week 4	0.27	0.46	0.40	0.21
Week 6	0.00	0.07	0.06	0.13
Week 10	0.00	0.27	0.06	0.13
Week 14	0.00	0.31	0.00	0.06

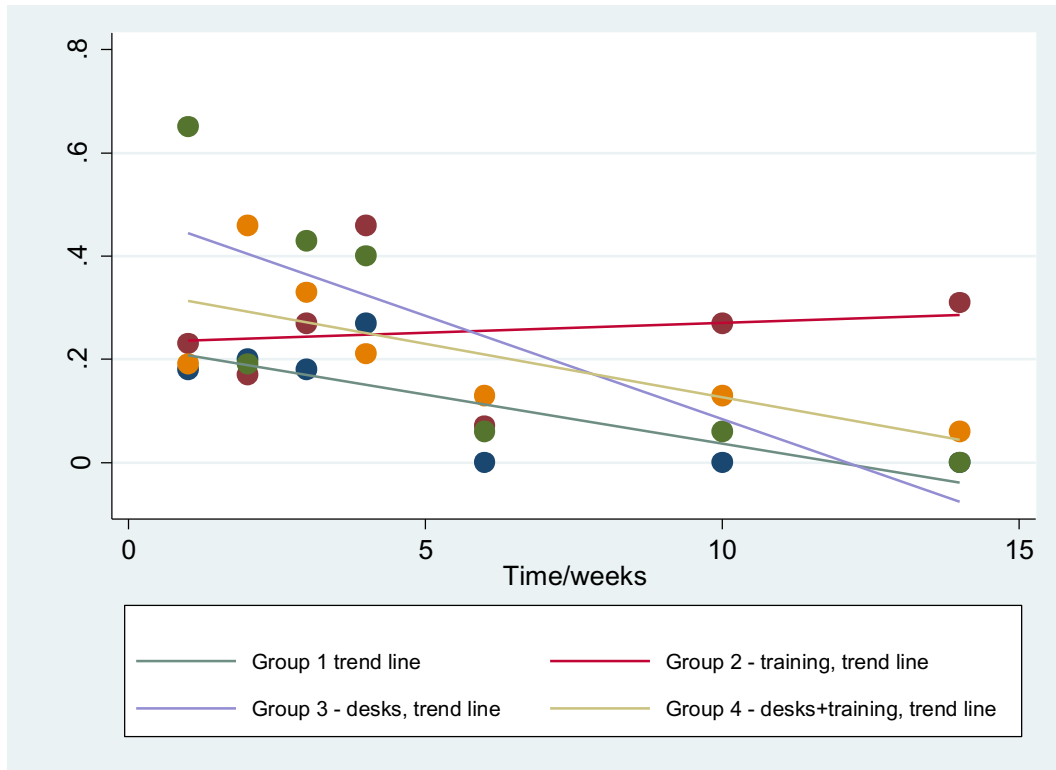


Figure 12: Linear Trend of Mean Lower Body Discomfort Rating for Each Group

Formal Statistical testing of paired data was conducted to understand any changes within each group over the 14-week period. An ANOVA was performed to see if there were changes between the groups.

A generalized estimation equation was used to estimate the parameters of linear repeated measures with possible correlations between the outcomes. The results are presented as odds ratios with 95% confidence intervals. The regression analysis model adjusted for age, sex and body mass index. Odds ratios describing discomfort are displayed in Table 7 through Table 10. The tables reflect changes in discomfort for the four body regions: head, arms, trunk, and lower body, over the course of the study.

Table 7: Odds Ratios of Arm Discomfort

Factor	Odds Ratio	95% C.I.	p-value	Interaction p-value
Training	0.2	.62-8.01	0.087	Training x Workstation p=.301
Workstation	0.56	.05-6.83	0.65	Training x Time p=.038*
Time Trend	0.72	.58-.90	0.004*	Workstation x Time p=.436

*p<.05

There is a decrease in odds of arm discomfort of only 5% per week for the training group, which is significantly less than the workstation group. The odds of arm discomfort decreased by 28% per week for the adjustable workstation groups.

Table 8: Odds Ratios of Head Discomfort

Factor	Odds Ratio	95% C.I.	p-value	Interaction p-value
Training	2.23	.03-1.26	0.221	Training x Workstation p=.766
Workstation	1.74	.49-6.14	0.391	Training x Time p=.418
Time Trend	0.89	.74-1.07	0.212	Workstation x Time p=.592

*p<.05

There were no statistical significant differences for interactions or trends over time for head discomfort.

Table 9: Odds Ratios of Trunk Discomfort

Factor	Odds Ratio	95% C.I.	p-value	Interaction p-value
Training	1.22	.53-2.84	.641	Training x Workstation p=.331
Workstation	1.74	.40-2.77	0.908	Training x Time p=.826
Time Trend	0.82	.68-.98	0.009*	Workstation x Time p=.763

*p<.05

During the study over time, there was an 18% decrease in reported trunk discomfort each week for all groups.

Table 10: Odds Ratios of Lower Body Discomfort

Factor	Odds Ratio	95% C.I.	p-value	Interaction p-value
Training	.31	.10-.90	.031*	Training x Workstation p=.179
Workstation	1.52	.47-4.99	0.486	Training x Time p=.008*
Time Trend	0.66	.53-.82	<0.001**	Workstation x Time p=.760

*p<.05, **p<.001

Lower body discomfort was showed a 13% decrease for the training group, which is significantly less than the adjustable workstation groups. The odds of reporting lower

body discomfort decreased by 34% each week for adjustable workstations groups over the study time period.

The mean hours standing reported for each group are shown below over the 3 months (Table 11). A repeated measures analysis (age, sex and BMI adjusted) was conducted to understand how the participants' standing times would change over the study period (Table 12).

Table 11: Mean Time Spent Standing per Day by Group

Mean time/ 9 hour work day	Control (n = 13)	Ergonomic training (n = 16)	Adjustable desks (n = 23)	Ergonomic training + Adjustable desks (n = 20)
Standing				
Week 1	1.01	0.85	0.84	0.93
Week 2	0.89	0.78	0.75	0.90
Week 3	0.62	0.54	3.22	3.6
Week 4	0.94	0.53	2.97	3.2
Week 6	0.76	0.59	3.18	4.03
Week 10	0.97	0.64	3.09	3.91
Week 14	0.34	0.86	3.15	3.55

Table 12: Repeated Measures Analysis of Standing Time

Linear (on log scale) trends over study period	Beta (% change per week)	p value	Interaction p value
Training	0.315 (37.0)	0.324	Training x Workstation p=.560
Workstation	1.358 (288.4)	<.001*	Training x Time p=.533
Time Trend	-0.005 (-.5)	.825	Workstation x Time p=<0.001**

*p<.05, **p<.001

The use of adjustable workstations increased standing time by about 10% each week compared those groups not using an adjustable workstation. The use of adjustable workstations had a dramatic effect on time spent standing during the study and there were no statistically significant interactions.

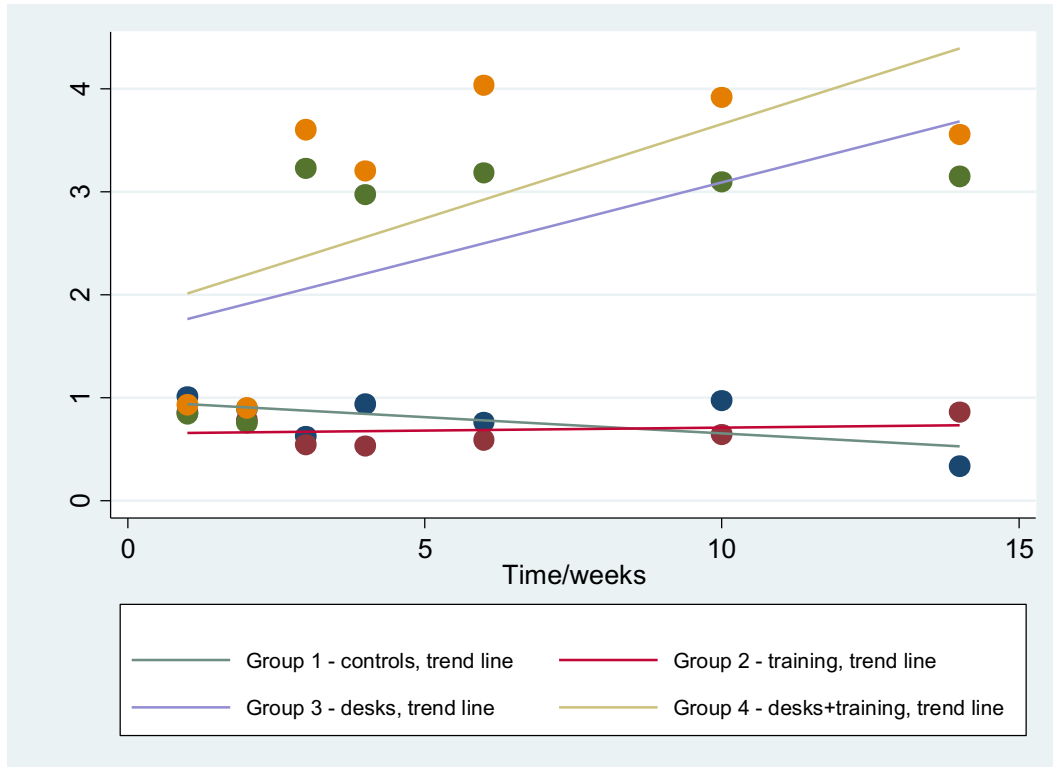


Figure 13: Hours Spent Standing by Group over Time

Group 1-control reported less than an hour of standing each week and did not appear to change over time (Figure 13). Group 2-training was similar to group 1-control in that the reported standing time was less than an hour for all weeks. Group 3-desks was similar to groups 1-control and 2-training until week 3 when the adjustable desks were installed. Group 3-desks continued to use the adjustable desks for 3 hours each day over the remaining 11 weeks. Group 4-training+desks reported standing times that

were even greater than those for group 3-desks, of 3.5 hours a day at week 3 and continued to use the desks throughout the study.

Group 1-control sat for most of their 9 hour workday and had a 40 minute per day increase of sitting over the 14 weeks (Table 13). Group 2-training sat for approximately 20 minutes less each day for the duration of the study (Figure 14). Group 3-desks had a noticeable decrease in sitting time at week 3 and the trend continued for the length of the study. Week 3 was the time period in which the adjustable workstations were installed. Group 3-desks had a reduction of sitting time of approximately 2.5 hours per day (Figure 14 and Table 13). Group 4-training +desks also decreased their sitting time at week 3 and continued to reduce their sitting time by about 2 hours per day according to Table 13. Seated time was reduced in all 3 intervention groups. Group 3-desks had the largest reduction in sitting time. Group 4-training+desks did spend more time walking each compared to group 3-desks only. The use of workstations decreased seated time by 1.39 hour per week compared to those not using a workstation (Table 14).

Table 13: Mean Time Spent Sitting per Day by Group

Mean time/ 9 hour work day	Control (n = 13)	Ergonomic training (n = 16)	Adjustable desks (n = 23)	Ergonomic training + Adjustable desks (n = 20)
Sitting				
Week 1	7.95	8.17	8.48	8.28
Week 2	8.6	8.23	7.89	7.86
Week 3	8.01	7.34	5.56	6.03
Week 4	7.96	8.18	5.89	5.99
Week 6	8.49	7.41	5.87	5.31
Week 10	8.39	7.71	5.67	5.9
Week 14	8.89	7.75	5.73	6.25

Table 14: Repeated Measures Analysis of Seated Time

Sitting Time (no log transform)			
	Beta (Hours per Week)	p value	Interaction p value
Training	-0.229	0.610	Training x Workstation p=0.331
Workstation	-1.436	0.024*	Training x Time p=0.830
Time Trend	0.022	.553	Workstation x Time p=0.002*

*p<.05

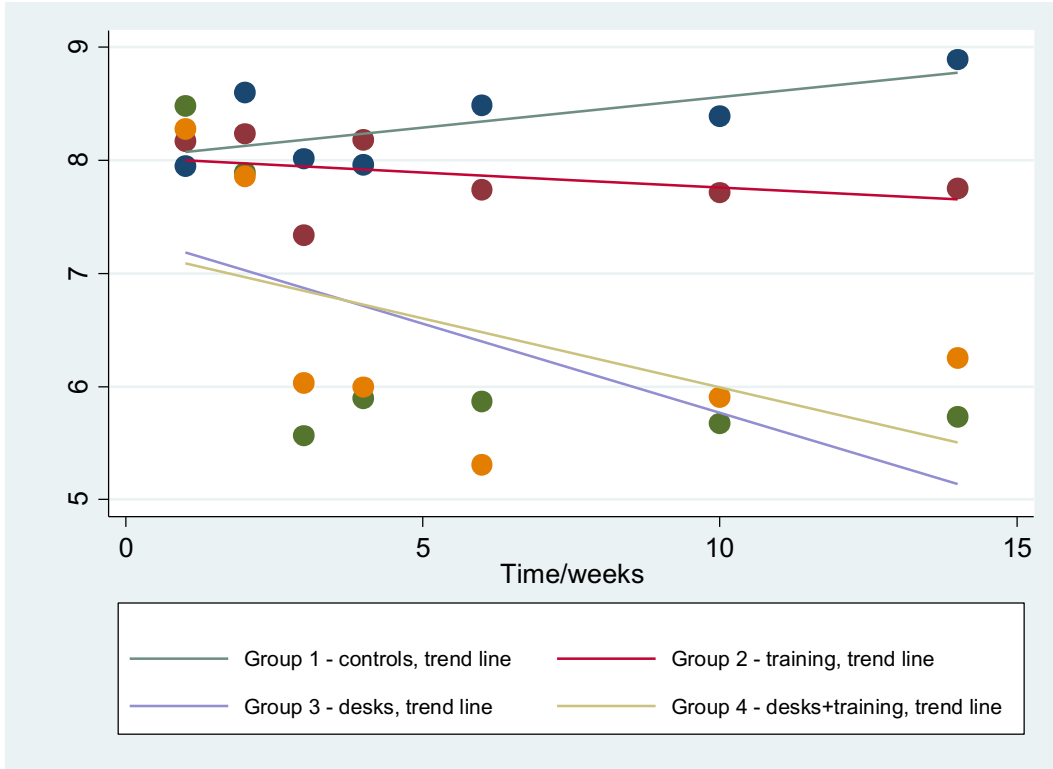


Figure 14: Hours Spent Seated by Group over Time

Walking time was measured to determine if healthy movement tools and techniques training would help increase movement into the workday. Group 1-control reported consistent walking times of approximately 30 minutes of walking time daily (Table 15). Two self-paced guidance/training materials were sent to the participants in groups 2-training and group 4-desks+training during weeks 3 and 6. Group 2-training and group 4-training+desks did increase walking time slightly during the weeks 3 and 6 when the two training interventions were distributed to the two groups. Group 2-training and group 4-desk+training had a drop in walking time at week 4. There is a possibility of more lab work during this point in the study and that would require

seated positions within a lab that were not equipped with adjustable desks. Group 4-training+desks reported increases in walking time at week 6 and this trend continued for the duration of the study with additional walking. Group 2-training decreased their walking time after week 6 through week 14 (Figure15).

Table 15: Mean Time Spent Walking per Day by Group

Mean time/ 9 hour work day	Control (n = 13)	Ergonomic training (n = 16)	Adjustable desks (n = 23)	Ergonomic training + Adjustable desks (n = 20)
Walking				
Week 1	0.57	0.50	0.52	0.55
Week 2	0.47	0.54	0.41	0.53
Week 3	0.45	0.54	0.47	0.58
Week 4	0.44	0.40	0.52	0.40
Week 6	0.39	0.48	0.41	0.66
Week 10	0.42	0.37	0.43	0.65
Week 14	0.53	0.37	0.43	0.56

Table 16: Repeated Measures Analysis of Walking Time

Walking-Linear (on log scale)				
	Beta (% Change per Week)	p value	Interaction	p value
Training	0.190 (20.9)	0.310	Training x Workstation	p=0.141
Workstation	0.050 (5.1)	0.798	Training x Time	p=0.562
Time Trend	-0.013 (-1.3)	0.357	Workstation x Time	p=0.266

*p<.05

Walking time was reduced by 1.3% each week over time for all groups, this was reduction was statistically significant. There was a larger increase in walking for those groups with HMTT training but no changes or interactions were statistically significant.

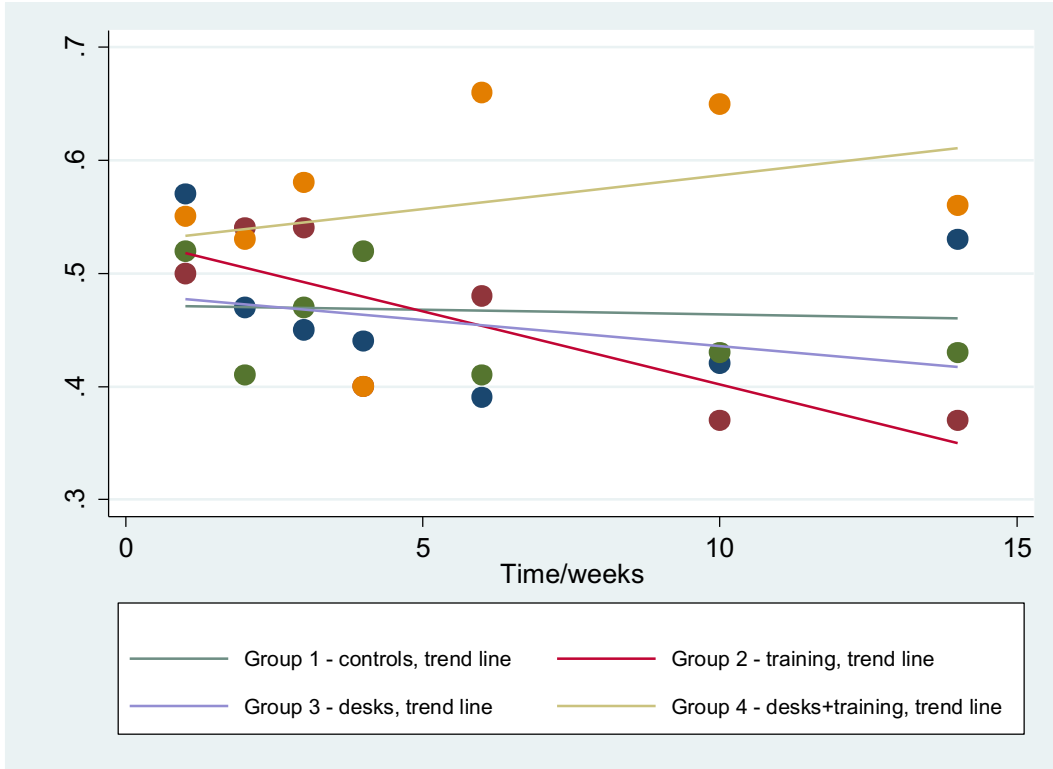


Figure 15: Hours Spent Walking by Group over Time

Productivity was measured by looking at overtime and absences, number of keystrokes and use of alteration keys over a total day. Keystroke measurements were examined to ensure that interventions did not decrease productivity. To decrease variability, weekly averages were looked at for each group during assigned data collection weeks. Formal Statistical testing using paired t tests and repeated measures analysis were conducted. All 4 groups displayed a decrease in keystrokes over the 14 week period. Group 1-control reported a decrease of 4.2% per week, group 2-training had a decrease of 1.1% per week, group 3-desks had a decrease of 3.9% per week and group 4-training+desks had a decrease of 3.7%, these estimates were all statistically significant. The decrease in

keystrokes cannot be explained for group 1 at this time. No group interactions concerning keystrokes between group 1-controls were statistically significant. There was no observed statistical significance between group 2-training with group 4-training+desks for total keystrokes. Total keystroke data are possibly underestimated and not applicable do to using other computers not equipped with ErgoSuite.

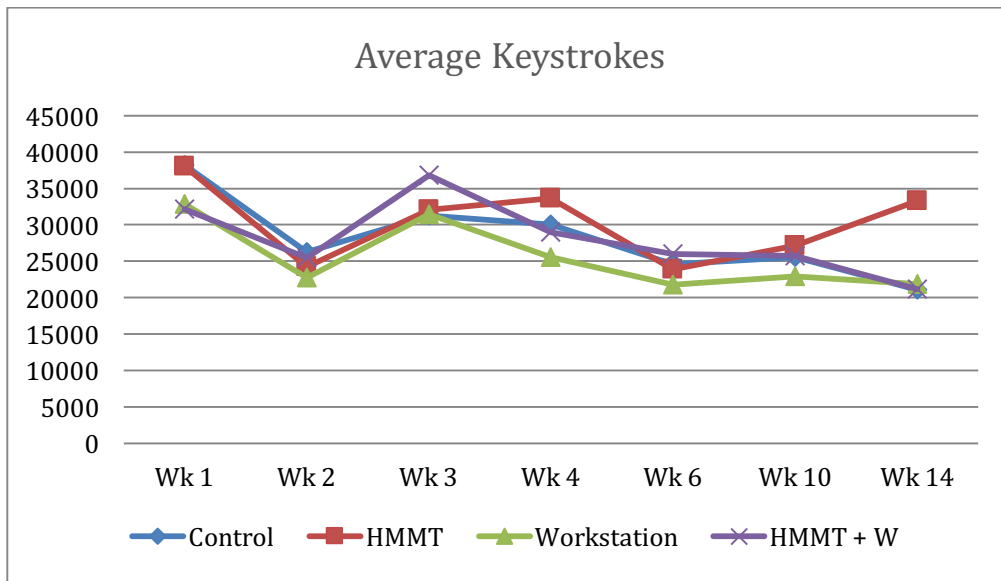


Figure 16: Weekly Average Keystrokes by Group over Time

Table 17: Mean Keystrokes by Group over Time

	Group 1- Control (n=13)	Group 2- Ergonomic Training (n=16)	Group 3- Adjustable Desks (n=23)	Group 4-Ergonomic Training+Adjustable Desks (n=20)
Keystrokes				
Week 1	33891	35463	34630	35985
Week 2	23635	24607	23959	24812
Week 3	32425	33638	32840	34032
Week 4	27623	29433	28212	29129
Week 6	22195	24607	23731	24588
Week 10	24347	25534	25472	26369
Week 14	23512	24578	24225	24891

Table 18: Repeated Measures Analysis of Keystrokes

Keystrokes-Linear (on log scale) trends over 7 week period			
	Beta	p value	Interaction p value
	(% change per week)		(Test of equality of group trends)
Group 1	-0.041 (4.2)	0.015	Group 1 vs Group 2 p=0.156
Group 2	-0.011 (1.1)	0.645	Group 1 vs Group 3 p=0.817
Group 3	-0.038 (3.9)	0.034*	Group 1 vs Group 4 p=0.847
Group 4	-0.036 (3.7)	0.044*	Group 2 vs Group 4 p=0.410

*p<.05

Fatigue was measured by counting the number of alteration keys over total keys typed in a day and comparing to total keystrokes multiplied by 100, resulting in a fatigue factor (Figure 5). All 4 groups displayed a reduction in fatigue over time. This is similar to a reduction in productivity measured by average keystrokes per week, since the total number of keystrokes is used in the formula to calculate the fatigue indicator. Only groups 1-control and 3-desks were statistically significant. There was a difference in fatigue indicators for group 1 compared to group 2, group 1-control had a 3.1% decrease compared to group2 having a .7% decrease in fatigue. During the study, a few participants mentioned the use of backspace keys while writing code as part of their job function. Use of backspace keys on purpose would not indicate fatigue and therefore this analysis will be used with caution.

Table 19: Mean Fatigue Indicators by Group over Time

	Group 1-Control (n=13)	Group 2-Ergonomic Training (n=16)	Group 3- Adjustable Desks (n=23)	Group 4-Ergonomic Training+Adjustable Desks (n=20)
Fatigue				
Week 1	36.16	36.14	36	36.4
Week 2	30	30.1	30	30.4
Week 3	38.65	38.54	38.6	38.5
Week 4	32.7	32.4	32.3	32.5
Week 6	29.2	29.8	29.4	29.6
Week 10	29.3	29.6	29.5	30.2
Week 14	28.18	28.6	28.1	27.9

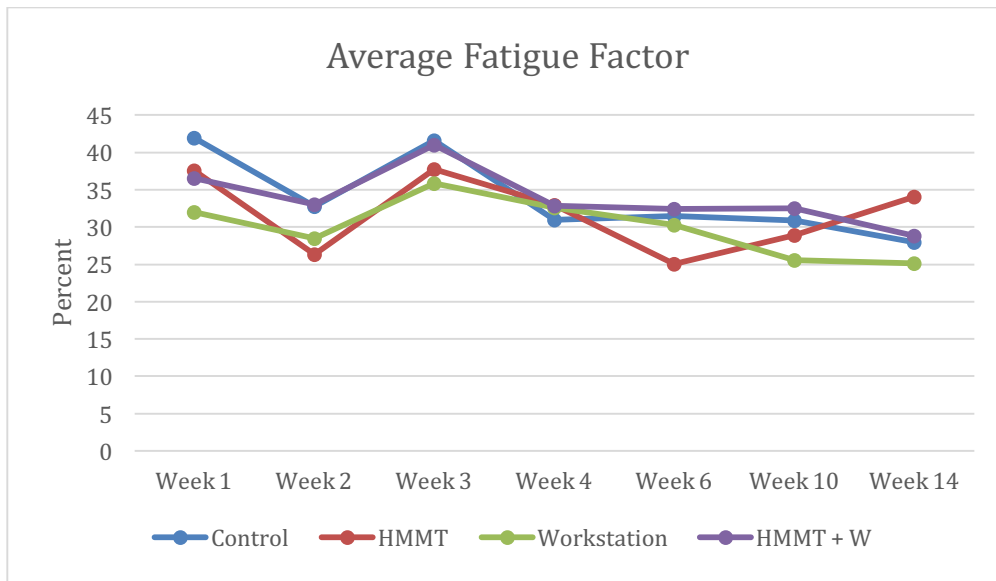


Figure 17: Weekly Average Fatigue Indicators over Time for Each Group

Table 20: Repeated Measure Analysis of Fatigue Indicators

Fatigue-Linear (on log scale) trends over 7 week period			
	Beta	p value	Interaction p value
	(% change per week)		(Test of equality of group trends)
Group 1	-0.031(3.1)	0.027*	Group 1 vs Group 2 p=0.023*
Group 2	-0.007(.7)	0.594	Group 1 vs Group 3 p=0.968
Group 3	-0.029(2.9)	0.014*	Group 1 vs Group 4 p=0.626
Group 4	-0.017(1.7)	0.069	Group 2 vs Group 4 p=0.557

*p<.05

Working overtime hours and any absenteeism other than vacation were considered at pre and post intervention and compared at 2 three month intervals. June through August compared to post intervention time frame of September through December. Groups 2-training and 3-desks were less likely to work overtime while group 4-training+desks was more likely to work overtime, however their results are not statistically significant.

Table 21: Mean Difference in Overtime and Lost Time for Intervention Groups

Group	Mean Difference (95% Confidence Interval)	
	Overtime	Absences
1 - Controls	0 [reference]	0 [reference]
2 - Ergonomic training	18.54 (-16 - 53.18)	15.54 (-6.63 - 37.71)
3 - Adjustable desks	-3.76 (-36.62-29.11)	.96 (-18.9 - 20.82)
4 - Ergonomic training + adjustable desks	26.79 (-7.41-60.99)	5.75 (-15.53-27.03)

Chapter Five:

Discussion

Sedentary behaviors and physical inactivity are terms that have been used to describe the lack of motion in societies. More recent studies use the word sedentary to describe those jobs requiring large portions of time spent seated (6). In other words, anyone can be physically active but obligated to a sedentary role at work. The effects of sitting for seven or more hours per day, has the potential for negative health outcomes even if a person adheres to the recommended physical activity guidelines provided by global and national organizations (9, 19, 28, 46, 57). Office based work is on the rise and is vastly inactive, making this study a practical observational investigation into adjustable workstation use.

During the work week the majority of individuals spend time commuting to work, where they potentially spend 8-9 hours sitting at a computer and can therefore end up having 10 or more hours a day of sedentary time (48). Within this particular sample of software engineers, the average workday was 9.4 hours. Hobbies and physical activity vary between employees, but decreasing sitting time where possible may assist in combating the potential negative health outcomes from too much sedentary time. The most commonly stated reason among people concerning physical inactivity is lack of

time (6). If employers can incorporate ways to increase physical activities during a workday without losing productivity, this would be the beginning of solution aimed at increased physical activity and potentially increasing worker health. The workplace is a suitable location to instill physical activity interventions, as most persons spend a large portion of their waking day at work and workplaces encompass a substantial portion of the population (70). Leisure time activities only contribute to one-third of a person's daily sitting time; therefore more focus should reside in areas that represent larger portions of a person's sedentary time (47). The reasons that employers should investigate the introduction of healthy movement into each work day is that individuals who have higher levels of physical activity display lower risks of developing cancers, obesity, metabolic syndromes and mental health issues (9, 28, 46, 48, 83, 87-89). Also those who have higher levels of activity show more productivity and less absenteeism and presenteesim in the office (5, 6, 71, 82). This pilot study's methods offer low cost interventions to an actual office based environment that is similar to other companies and sedentary professions.

Our study focus did not show a statistically significant decrease in absenteeism in all groups. Also, there was no difference in productivity measured by total keystrokes or fatigue levels between groups. These findings are in agreement with current literature, that reported increases in productivity while using adjustable desks or studies that reported consistent levels of productivity; but decreases in productivity were not found (17, 39). Adjustable workstations may confer health benefits without having

detrimental effects on worker productivity as shown in this study and others in current literature (6, 15, 17, 62). Some measures of productivity used in comparable investigations observed counting of particular data, whether it was keystrokes or number of documents handled via copy or fax. When outcomes such as fatigue or accuracy were measured there was a statistically significant increase or decrease for groups that had adjustable workstations compared with control groups that did not have adjustable workstations (6, 15, 17, 62). One issue with measuring keystrokes and fatigue to understand productivity in this study was that sometimes software engineers would be assigned to write code for computer programs for a few hours. This was estimated to be approximately 25% of the time. When engineers write code, they use intentional backspace and delete keys and this could overestimate fatigue for the group. In order to address this, the average weekly fatigue indicators were selected for data collection. Analyzing an entire week's worth of keystrokes and alteration keys gave a clearer picture of an engineer's workweek with regards to productivity. Data collected for 7 weeks of the study indicated a decrease in keystrokes in all 4 groups for each data collection period but only the estimates for group 3-desks and group 4-training+desk showed statistical significance. ErgoSuite was used to capture the number of keystrokes from computers used in unclassified areas. However, after the study was underway it was learned that no computers in classified labs had ErgoSuite therefore some work (keystrokes) may not have been accounted for. However, the decrease in keystrokes for group 3-desks and group 4-training+desks can be indicative of increased

activity to complete end of year projects. This typically means additional lab based computer work on a computer that was not utilizing ErgoSuite.

The decrease in keystrokes also could mean that productivity was affected by the use of workstations. However, since our control group also showed a statistically significant decrease over the study period, it is believed that the groups were working on computers that did not capture keystrokes through ErgoSuite.

Pain and Discomfort

Adjustable workstations allow users to change postures easily once they become uncomfortable. Self-reported pain did decrease in most regions of the body for all groups over time, which is consistent with most literature (5, 17, 39, 61, 62, 64, 66, 90). Discomfort in the head region was consistent for the control group over time (Table 3). Head discomfort for group 2-training had an increase at week 4 (Figure 9). It is unknown what could have caused an increase in head discomfort for group 2-training during week 4. Group 2-training worked a typical length workday and no participants had reported anything unusual. Both individuals who reported higher discomfort scores of 2 (moderate discomfort) during week 4 were not on pain meds and did not mention anything unusual for that week. This was the only time during the study where there was an obvious increase in pain for group 2-training, the rest of the study group 2 reported decreases in head discomfort over the remaining weeks. The line graphs show decreases for groups 3- desks and 4-training+desks, after weeks 1 and 2

once the interventions began. There was a very slight increase in head discomfort rating for group 3-desks near the end of the study. This discomfort was reported by two individuals in group 3-desks. One of these individuals worked an 11.5 hour day. Only one person from group 4-training+desks reported any discomfort in the head region. This person had worked a 13.5 hour day when he self-reported his discomfort level. This slight increase of discomfort in the head region for group 3-desks and group 4-training+desks near the end of the study, was possibly due to a longer workday during that time than the participant average 9.4 hour workdays. Increased hours and work demands is not uncommon close to the holidays in order to complete projects and end of year proposals. After Christmas employees are encouraged to use vacation time for that remaining week of the year. This is called a “soft shutdown” of the facility allowing for refurbishment of buildings, deep cleaning of office spaces and other facility related projects to have less interference with a fully occupied workplace. Employees might have worked longer to finish things up before the shutdown.

Group 1 was consistent with reported trunk discomfort during the length of the study. Fifty percent of individuals in group 2- training had some level of discomfort in the torso area, especially during week 2 and 4. It is unclear why group 2-training had the most discomfort, there were no reported injuries, pain meds or increase above average hours worked. However, figure 13 shows more seated time for group 2-training. This could indicate that the healthy movement tools and techniques training was not adequate to help decrease discomfort in the sample. Groups 3-desks and 4-training+desks experienced an increase in pain at week 4. They subsequently reported

decreases in pain even with increased standing time at week 6. Week 6 was four weeks after the interventions had been implemented. This is beneficial information gained, as guidelines may be interpreted for future adjustable workstations users to recognize that it could take 2-4 weeks for the body to adjust to standing more frequently throughout the day. Groups 3-desks and 4-training+desks continued to reported a mean standing time of 2.4 hours per day through the final week of the study with a continual decline of lower body pain from week 6 through 14. Overall there was an 18% decrease of trunk discomfort for all groups each week during the study.

In the lower body region group 1-control had minimal lower body pain during the study and had no discomfort towards the end of the study period yet groups 3-desks and 4-training+desks showed increases in lower body discomfort once the adjustable desks were installed. At week 6, the increases in lower body discomfort were resolved (Figure 12). The soreness in the lower body is to be expected during a period of adjustment as seen in other adjustable workstation studies measuring pain (37, 90). In groups that had workstations, it appeared that discomfort in the lower body resolved after four weeks. Groups 3-desks and 4-training+desks that experienced lower body discomfort were standing between 1-3 hours on week 4. During week 6 when the lower body pain ratings decreased noticeably, groups 3-desks and 4-training+desks participants were standing for approximately 2.5 to 8 hours at times when they experienced any lower body discomfort. This decrease in pain yet increase in standing time could be due to the body becoming adjusted to intermittent standing through the

day. For group 2-training the rise in discomfort of the lower body was unexpected at week 10 through week 14. This could also be due to the fact that reminders to move presented by ergonomic training, were not being employed consistently. It is also possible that this increase was due to two employees who had experienced non-work related injuries of their ankle and foot.

The arm discomfort ratings did not show a considerable difference over time between the groups and there was a decrease in arm discomfort for all groups at week 6 (Figure 11). The decrease in arm discomfort at week 6 could be due to a decline in active time on the computer and keystrokes during week 6 for all groups. Group 2-training had an unexplained increase in arm discomfort, records do not indicate any significant findings from group 2 correspondence that would explain the increase in arm pain. The phenomenon could again be evidence that while ergonomic training may instruct persons to move at various points during the day, they may not move consistently. This may cause increases in discomfort. For those with workstations (groups 3 and 4) there was a 28% decrease in arm discomfort each week. This decrease in arm discomfort in groups with workstations versus groups with training was found to be statistically significant.

Movement

This study provided special attention to workplace physical activity interventions in the forms of self-paced materials periodically throughout the three months. Well-trained

employees that understand the risk factors of MSDs and preventative strategies are likely to use the workstations more than those minimally trained on MSD prevention (27, 62). Consequently it is important to train employees as part of an overall strategy for prevention of MSDs in conjunction with adjustable workstations (25, 67).

A few of the HMMT in this study were: 1) to incorporate walking meetings, 2) include stretching and brief 2 minute walks for every 30 minutes of desk work, 3) to stand while on a teleconference, 4) to encourage less “instant messaging” between co-workers and more face to face conversations and 5) to use the treadmill workstation for checking emails, during live meetings or doing simple tasks such as online mandatory training. The use of HMMT was measured by how much a group increased their walking time and standing time.

Utilization of the healthy movement intervention and the adjustable workstation intervention were measured in self-reported number of hours of sitting, standing and walking times (Appendix 3). If the healthy movement interventions were used there would be an increase in standing and walking times compared to the control and baselines of group 2-Training and group 4-Desks +Training. Self-reported physical activity has been used in historical adjustable workstation and physical activity research. It has been proven to be reliable when compared to accelerometers and is useful in larger studies (42, 72, 79). The *Total Sitting Questionnaire*, which is an abbreviated version of the *International Physical Activity Questionnaire, Occupational Sitting and Physical Activity Questionnaire* were the most commonly found in during this literature review of adjustable workstation studies. These questionnaires ask

respondents to recall the time spent in sedentary and active roles during the past 7 days, whereas this study had fewer questions asking about time spent seated, standing and walking. In addition to this participants were asked about the amount of time spent in these activities for the same day, which would have less potential for recall bias. The three questionnaires mentioned above reported less recall bias on the weekdays versus the weekends (42, 72, 79). This is possibly due to having a scheduled structured day during work hours. The participants of this study are accustomed to strict time charging policies as government contractors. Participants are familiar with recalling the number of hours spent on specific programs for an entire work day in order to align with the company's labor policies. Employees are required to complete their time cards by the end of each day and charge their time to multiple charge numbers in ten minute increments as part of their employment.

There was a 20% increase in walking for groups that had training, although no interaction was statically significant, the group 4-training+desks was closer to statistical significance than those with training or desks alone. This type of behavioral result is consistent with other studies in that concomitant strategies of workstations plus training resulted in more of a reduction in seated time and discomfort (7, 17, 25, 64, 67). Self-paced material may not have been effective for persons to incorporate more walking movement into the workday and the delivery method will need to be further evaluated as this is a common practice in larger corporations to deliver training materials. Prospective research should attempt to understand why training

interventions alone do not result in altered behaviors to increase standing and including movement into employee's workdays. This same issue of employees not performing stretches and movement was found in expanded the National Institute for Occupational Safety and Health (NIOSH) research (39). The research on training that did report decreases in discomfort was very time intensive. For a larger corporation economically this may not be as widely accepted for the types of results that can be expected. The training that reported differences between groups that were trained and groups that were not trained were conducted in large groups and were not self-paced (11, 27, 29, 62). One systematic review discussed the types of interventions in studies to determine if they were effective at reducing sitting time. This review found that all of the interventions they reviewed focused on physical activity primarily and a reduction in sitting time at work would be a result of increased physical activity (91). The interventions identified were focused on: individual fitness counseling, fitness testing, pedometers and tips to increase incidental walking (91). Some studies focused on participants taking micro breaks and identifying how long these breaks needed to be in order to have a positive impact on an individual such as, increases in vigor and improved concentration. Identifying the influences for employee to adhere to micro breaks and stretching regimens will enhance the worker health overall by improving mood states, decreasing fatigue, decreasing discomfort and often increasing productivity (39). The adjustable desk use may be comparable to taking micro breaks which supports the findings of a 2-year study by Ferreria that found that hourly 10 minute breaks reduced MSD injuries in employees (45). It is possible that the

combination of micro breaks and the postural changes that challenge the static muscle work in adjustable workstation users is the best intervention to decrease musculoskeletal discomfort. Getting employees to utilize any type of break with stretches or healthy movement has been a challenge as reported in previous research (29, 39). Walking time and seated time were used to understand if the behavioral interventions such as break reminders and behavioral training were being applied during the study. This study sought to understand if training interventions alone were enough to increase employee awareness to develop more healthy movements into each workday. As seen by the almost consistent standing time, sitting time and the decrease in walking time for groups 2-training; training intervention do not appear to be sufficient to sustain health movement into each workday. Group 4-training+desks displayed increases in standing and walking times and decreases in sitting time, provide additional evidence that interventions need to go beyond training and provide the infrastructure to easily facilitate changing positions during the workday.

There were few previously published studies that utilized adjustable workstations. One aim of this study was to understand the use of the workstations over time in a non-lab based everyday office setting. Often, the perception is that employees do not use the adjustable workstations in the standing position. If employees receive workstations ensuring that they will continue to use them in a way that has the potential to be significant was an important next step. The significance of understanding adjustable workstation use is to provide evidence to address the perception that employees will

not use the device given to them, thereby wasting money or other resources. The two groups that received workstations continued to use them for about 2.5 hours per day. This is consistent with other studies that found if alternative workstations were made available they would be used (26, 92). Previously published studies reported more frequent use of electronic adjustable desks compared to the manual adjustable desks. It has also been reported that the use of sit-stand stations were able to decrease sitting time from 1-2 hours a day (4, 17, 26, 93). Our study could have produced an increase in the number of hours standing based on the minimum 9 hour required workday and on average the employees in this population worked an average of 9.4 hours per day. An interesting next step for potential research would be to provide greater insight into understanding the role that sedentary occupations have on other health outcomes such as body composition and cardiometabolic disease (26, 67). This longitudinal study provides evidence to suggest that employees will continue to use their adjustable workstations and secondly, if employees continue to use their adjustable workstations over long periods of time, they can decrease discomfort possibly due to breaking up long periods of inactivity.

Each intervention group displayed an increase in standing time when compared to the control group by looking at the mean trend lines. The use of an adjustable workstation alone increased standing time by 10% each week. Training + desks also increased standing time more than training alone. This information can be used in future studies or implementation to ensure the appropriate training will accompany an ergonomic

intervention such as an adjustable desk. Standing times increased at week 3 when the adjustable desks were installed. The line graphs on Figure 13 and Table 8 show a mean of approximately 3-3.5 hours for groups 3-desks and 4-training+desks.

Results of the repeated measures analysis indicate that group 3-desks had the largest reduction in seated time compared to group 4-training+desks and group 2-training only. Since group 3 has a larger reduction in seated time, it might indicate that group 4 used their HMMT training to walk more versus sitting or simply standing. To support concomitant strategies a repeated measures analysis compared walking times between groups with training and with workstations and found that those groups with training walked more.

Strengths

This study maintained strong internal validity due to randomization of group placement, which reduced the effects of job levels/titles as possible confounders. This randomization produced results that are generalizable to a larger population of computer users due to real-world applicability.

The self-reported activities were documented at the end of the work shift, which likely reduced recall bias. While previous research indicates that certain accelerometers display strong test-retest reliability when compared to self-report questionnaires, this they may not be able to distinguish standing from sitting (79). Further accelerometers

are generally used for at least 10 hours per day and the typical workday in this study was less than 10 hours. Using self-report also had the advantage of reducing missing data over accelerometers. This would occur in the event that employees forgot to wear their accelerometer while at work.

The finding of this study, that using adjustable workstations was not associated with a reduction in productivity and that they help to reduce discomfort is consistent with previously published (5, 15, 61) Findings that training alone is not sufficient to cause an increase in movement at work and that training along with an adjustable workstation provided the greatest reduction in seated time and discomfort is also consistent with previously published (27, 29).

Most employees were extremely satisfied with their adjustable desk and mentioned increased energy levels and improved mood states which was consistent with other studies that showed improvements in categories such as fatigue, vigor, tension, confusion and depression (5, 12, 14, 90). Out of the entire 72 participants only one employee asked to have the workstation removed and did not want to use another model. Another employee did not like the model that they initially received and asked for a different model after the study began. The WorkFit- T model was better accepted overall and fit into existing workstations more often than the WorkFit- S.

Another strength of this study was that it took place in an actual work environment and that it used a control group to compare intervention use to. This provides additional evidence that adjustable workstations are simple to implement which can improve employee health.

This longitudinal study is one of the largest randomized investigations to date and has the potential to be extended into future research including measurement of health outcomes (4, 17). When looking at our population and the company's principal health care costs, we may be able to slowly work at creating a workplace where we can reduce employee injuries/healthcare costs and hopefully improve worker health.

Future Research

Further research possibilities: 1) to understand further the assessment of what influences sedentary behavior and how to vary those long periods of inactivity, 2) the dose response relationship with occupational sitting time and the association between sedentary behavior at work, BMI and other relevant health outcomes and 3) to assess the economic impact of improved worker health and cost of adjustable workstations.

The interventions were used consistently during the 3 month period. In the future there should be research to better understand the dose-response relationship to sedentary time and the amount of physical activity and breaks required to combat negative health outcomes of too much sitting at work.

Limitations

Self-entered daily activity logs were conducted by each of the study volunteers, as a method to track activity through the study. Research has demonstrated that self-reported inactive time compared to device measured inactive time can be similar in results, but the stronger association exists in groups that have organized daily activities or similar daily work tasks (7, 42, 79). This study could not use an accelerometer or inclinometer due to: 1) budget limitations 2) the focus of the study was work related activities and the device based measurements require 10 hours of wear time

Not all computers used by the software engineers were on Lockheed Martin Intranet system and therefore lacked ErgoSuite software to record all keystrokes and alteration keys. These computers were in classified labs that cannot often be a part of the normal LM software protocol. At each of the 7 points of time that data was collected concerning keystrokes, the weekly averages were gathered and used in the results to account for days both in and out of those labs. Not having ErgoSuite on all computers used by the software engineering groups could underestimate measures of productivity and fatigue.

Another limitation was determining the power of the study since the number of employees selected for this research was established based on the budget allowed through Lockheed Martin. Since these types of investigations are still novel, it was also difficult to estimate the appropriate number of participants required. Although a

formal power analysis was not conducted due to the lack of literature indicating a reduction in pain and sitting time a sample size of 30 is comparable to other studies on office environments that have reported on statistically significant changes (4, 17). However, for this study the effect size was significant; therefore, the number of participants was appropriate for the research premise that there would be differences between interventions.

While the study did maintain strong internal validity due to randomization of group placement there is the possibility of contamination. Participants from multiple groups could have been seated in the same building and as such persons in the control groups would increase their standing time as they observed participants in other groups standing. In addition to this participants from the different groups could have talked about the study at lunch or in meetings, even when not seated together in their office spaces.

Conclusion

Occupational sitting time was reduced, while standing was increased for those groups who had adjustable workstations. Walking times were increased in groups that received healthy movement tools and techniques. Reported pain scores and discomfort ratings showed an overall decrease in groups that had the adjustable workstation that remained consistent during the 3 month period.

Productivity was not affected and the interventions were used consistently. Adjustable workstations provide a simple solution to reduce sedentary behavior at work improve employee health.

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Appendices

Appendix 1: Institutional Review Board Approval



RESEARCH INTEGRITY AND COMPLIANCE
Institutional Review Boards, FWA No. 00001669
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8/12/2015

Megan Sandy
Environmental and Occupational Health
1360 Pelham Road
Winter Park, FL 32789

RE: **Expedited Approval for Initial Review**

IRB#: Pro00023149

Title: Longitudinal Study of Adjustable Workstations and Other Interventions

Study Approval Period: 8/12/2015 to 8/12/2016

Dear Megan Sandy:

On 8/12/2015, the Institutional Review Board (IRB) reviewed and **APPROVED** the above application and all documents contained within, including those outlined below.

Approved Item(s):

Protocol Document(s):

[IRB.docx](#)

Consent/Assent Document(s)*:

[SB Adult Minimal Risk.docx.pdf](#)

*Please use only the official IRB stamped informed consent/assent document(s) found under the "Attachments" tab. Please note, these consent/assent document(s) are only valid during the approval period indicated at the top of the form(s).

It was the determination of the IRB that your study qualified for expedited review which includes activities that (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the categories outlined below. The IRB may review research through the expedited review procedure authorized by 45CFR46.110 and 21

CFR 56.110. The research proposed in this study is categorized under the following expedited review category:

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval via an amendment. Additionally, all unanticipated problems must be reported to the USF IRB within five (5) calendar days.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

A handwritten signature in black ink, appearing to read 'Kristen Salomon', followed by a horizontal line.

Kristen Salomon, Ph.D., Vice Chairperson
USF Institutional Review Board

Appendix 2: Workfit-T and Workfit-S technical data sheets



Highlights

For Computer Users

- Enjoy standing or sitting as you work, switching positions whenever you choose. This work style encourages healthy movement throughout the day
- Easily and simultaneously lift LCD screens to proper height for unsurpassed ergonomic comfort

For IT and Facilities Staff

- IT deployment friendly—convert most work areas into a productive and complete computer workstation in minutes
- Modify existing office spaces or cubes by simply adding a WorkFit-T/TL to an existing worksurface, without the cost of expensive professional installers; it's also great for corner desks
- Safe and neat routing of cables
- Flexible, open-architecture design is scalable for future computer equipment

For HR and Company Cost Savings

- Promote wellness in the daily work routine
- Provide standing work platforms for employees without having to buy expensive height-adjustable chairs

**JUST
STAND
.ORG**

ERGOTRON®

WorkFit-T/TL Sit-Stand Desktop Workstation



Invigorate your workday with this ultra simple and flexible sit-stand desktop workstation!

This ultra simple standing desk solution quickly converts a tabletop into a healthy sit-stand workstation. Simply place the WorkFit-T or WorkFit-TL on an open surface and you're ready to work!

WorkFit-T and WorkFit-TL save space because they move straight up and down, always staying within the footprint of your desktop. The platform is extremely stable throughout its range of motion—one can freely lean on it while working without worry about tip or height-drop.

Five-year warranty: tested and guaranteed!





Highlights

For Computer Users

- Enjoy standing or sitting as you work, switching positions whenever you choose. This work style encourages healthy movement throughout the day

- Easily and simultaneously lift LCD screens to proper height for unsurpassed ergonomic comfort

For IT and Facilities Staff

- IT deployment friendly—convert most work areas into a productive and complete computer workstation in minutes
- Modify existing office spaces or cubes by simply clamping a WorkFit-S on an existing worksurface, without the cost of expensive professional installers
- Safe and neat routing of cables
- Flexible, open-architecture design is scalable for future computer equipment

For HR/Risk Management and Company Cost Savings

- Promote wellness in the daily work routine
- Provide standing work platforms for employees without having to buy expensive height-adjustable chairs

**JUST
STAND
.ORG**

ERGOTRON®

WorkFit-S Sit-Stand Workstation



Sit-stand for wellness and productivity

Sitting for long hours in front of a computer at work? Presenting Ergotron's WorkFit-S, the first-of-its-kind desktop workstation that promotes proper ergonomic positioning and inspires an on demand sit-stand work routine. This height-adjustable unit offers 18 inches (46 cm) base height adjustment, five inches (13 cm) individual display adjustment and a back-tilt keyboard tray. Designed to help workers counteract the harmful effects of increasingly sedentary life and work styles, the WorkFit-S encourages healthier movement throughout the day.

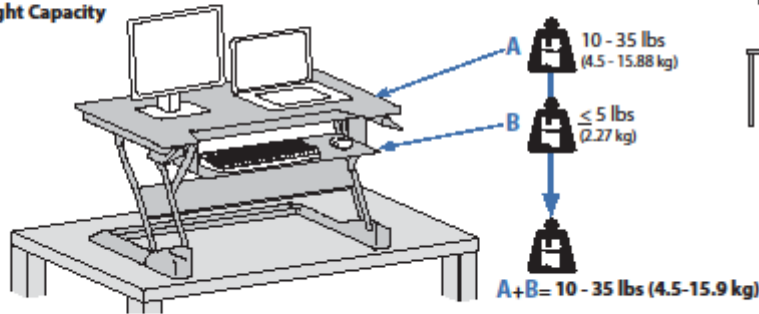
- ① VESA® compliant
- ② Lift range: LCD/keyboard tray adjust 18" (46 cm) in tandem; LCD adjusts 5" (13 cm) independently; maximum LCD height adjustment = 23" (58 cm)
- ③ Designed for use with a separate, external keyboard for proper ergonomics. Keyboard adjusts 18" (46 cm). Optional Tablet/Document Holder (97-558-200) includes lift handle
- ④ Ergonomic back-tilt keyboard tray with left or right mouse tray ensures wrists remain in a neutral position during data entry—avoid repetitive-stress injuries while increasing comfort and productivity. Wrist rest not included, order separately
- ⑤ Desk clamp attaches to surface edge .4–2.4" (10–60 mm) thick

Ergotron®

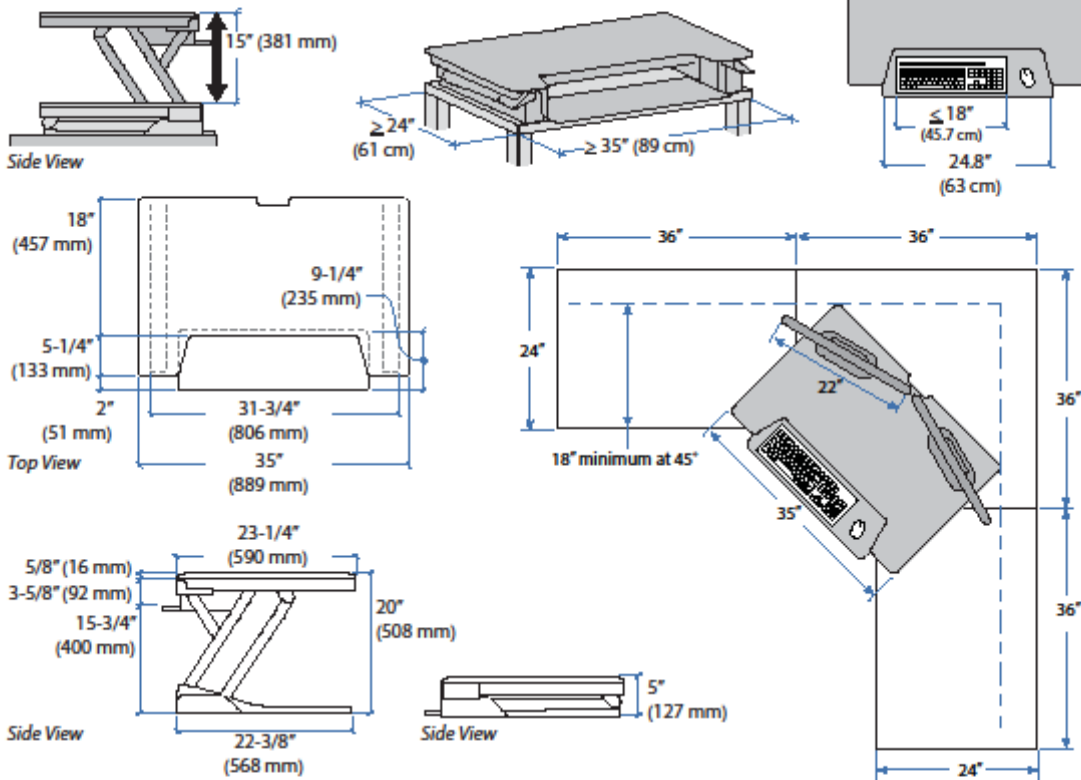
Dimensional Illustrations

WorkFit-T, Sit-Stand Desktop Workstation

Weight Capacity



Dimensions



Shown on a 90° corner work surface.
Top View

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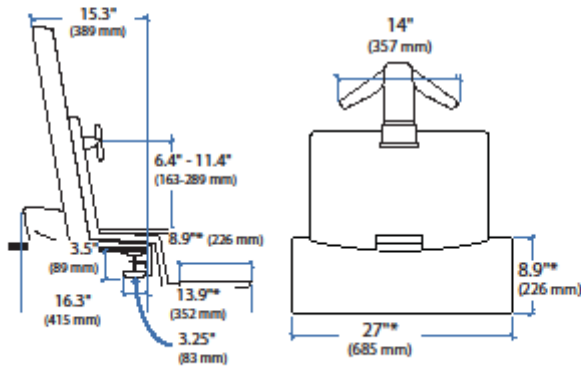
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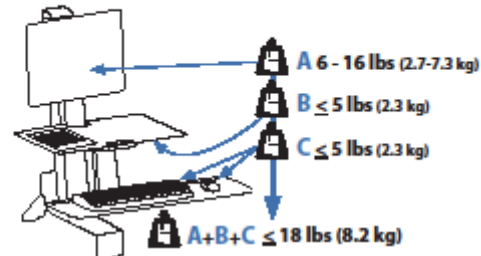
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Dimensional & Range of Motion Illustrations

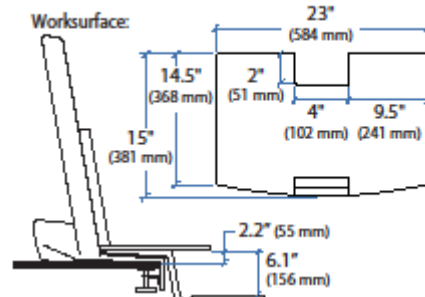
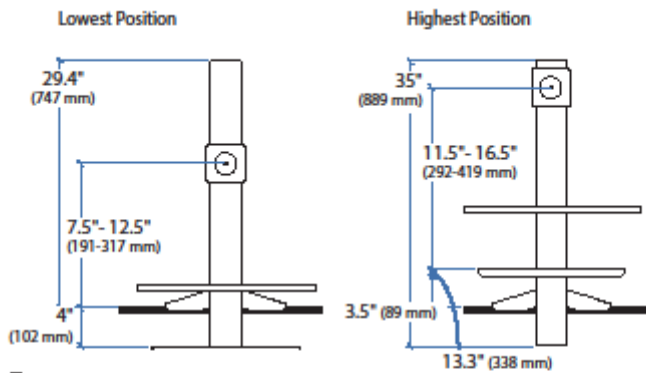
WorkFit-S with Worksurface, Single LCD Mount, LD



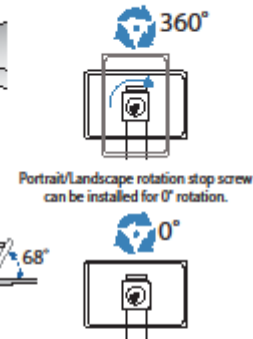
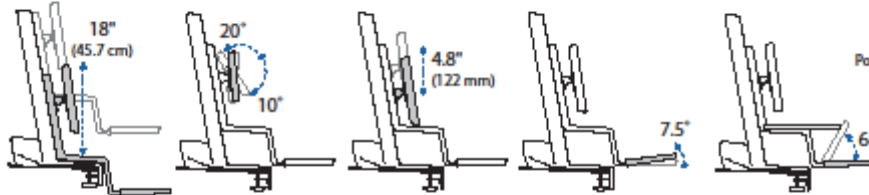
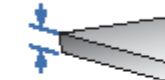
Weight Capacity:



*Keyboard Tray has 9 Mounting Locations - see page 5 for details.



Desk Thickness:
≤ 2.4" (60 mm)



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Appendix 3: Hourly Activity Questionnaire

Daily Activity Time

Date:

1. How many hours were spend seated today at work?
 - a. At desk?
 - b. In meetings?
 - c. At lunch?
 - d. Other, describe and time
2. How many hours did you stand today?
3. Time spent walking?

Appendix 4: Baseline Questionnaire

1. Date
2. Name:
3. Date of Birth:
4. Sex:
5. Height:
6. Weight:
7. Marital status:
8. Any past surgeries or issues concerning MSDs? (yes or no)
9. Any pain meds to manage chronic pains? (yes or no)
10. Current level of absenteeism due to discomfort (doctors apt, physical therapy, massage)
in hours:
11. Please use the ErgoSuite icon and send a discomfort message.
12. How many hours were spent seated today at work?

At your desk?

In meetings?

At lunch?

Other, describe and time
13. How many hours did you stand today?
14. Time spent walking in hours?

Appendix 5: Glossary

ANOVA	Analysis of Variance
BMI	Body Mass Index
HMMT	Healthy Movements Tools and Techniques
LPL	Lipoprotein Lipase
LM	Lockheed Martin
LMI	Lockheed Martin Internal
LMMST	Lockheed Martin Mission System and Training
MRI	Magnetic Resonance Imaging
MSDs	Musculoskeletal Disorders
MVPA	Moderate to Vigorous Physical Activity
NIOSH	National Institute for Occupational Safety and Health
OSPAQ	Occupational Sitting and Physical Activity Questionnaire
PAST	Past-Day Adult's Sedentary Time
PI	Principal Investigator
SAS	Statistical Analysis System
SD	Standard Deviation
Sr.	Senior
Sr. Stf	Senior Staff
Stf.	Staff
TSQ	Total Sitting Questionnaire