PREDICTORS OF MUSCULOSKELETAL SYMPTOMS AND IMPROVEMENT OF HEALTH OUTCOMES VIA COMPUTER SOFTWARE

A Dissertation

by

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ABSTRACT

According to the Bureau of Labor Statistics, musculoskeletal disorders (MSDs) account for 30 percent of overall Nonfatal Occupational Injuries and Illnesses. Every year employers spend 20 billion dollars in direct workers' compensation costs and five times as much in indirect costs. Risk factors from computer work have been contributed to MSDs from repetitive movements, awkward static postures, and working for long hours without rest breaks. The problem remains to find a valid method to evaluate and reduce MSDs while performing computer work. Two studies on Remedy RSI Guard data and OES data (subjective) were conducted utilizing a computer desktop software that objectively measures computer behaviors of participants to determine if any predictors variables from the OES data demonstrate musculoskeletal discomfort, which can lead to MSDs.

Study 1 (Remedy Data) had 13,672 participants from an oil and gas company who had Remedy RSIGuard® on their computer for 1-year. This software was collected continuously during the workday, monitoring participants' computer activities, work patterns, and behaviors. This Remedy data was used to compare the OES seven-question body part discomfort survey by regression analysis. However, many of the odds ratio results were 1.0, indicating no association between body part discomfort and the predictor variables.

Study 2 (OES Data) involved the same participants as the Remedy RSIGuard® data. The OES questionnaire was collected at the beginning of the study and compared to the OES seven body part discomfort questions using regression analysis. Document

Holder and Stress predictor variables had associations in all seven regression analyses when compared to the body part discomfort questions. The variable Breaks had associations in five regression analyses. The variables Bitrifocals and Properly Working Equipment were found to have associations in four regression analyses.

Overall, the subjective data from the OES data resulted in several variables that predicted musculoskeletal symptoms, whereas only a few predictor variables from the objectively measured Remedy data predicted musculoskeletal symptoms. However, the conundrum of determining the most effective way of recognizing discomfort before MSDs occur is still under study.

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I am grateful I have finished this dissertation. I did not know when I started this process how long it would take and how hard the journey. It is a great feeling to be able to say I actually did it!

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CHAPTER I

INTRODUCTION

Problem of Musculoskeletal Disorders

Computer desktops have been in our everyday lives for several decades (Jomoah, 2014). Musculoskeletal symptoms are still reported by computer users, despite the interventions and numbers of studies that have been performed to determine causality (Andersen et al., 2011; Cho et al., 2012; Esmaeilzadeh et al., 2014).

Although MSDs are the most common occupational injury in the U.S., the overall trends are decreasing. However, the rate of MSDs are still around 30 cases per 10,000 full-time workers, and MSDs still account for almost 30 percent of overall Nonfatal Occupational Injuries and Illnesses Requiring Days Away From Work according to Bureau of Labor Statistics (BLS) (BLS 2011; BLS 2014; BLS 2015). Each year MSDs cost employers approximately 20 billion dollars in direct workers' compensation costs and as much as five times on indirect costs. (US Department of Labor, 2017). There have been numerous ergonomic accessories such as ergonomic keyboards, ergonomic mice, ergonomic chairs, and ergonomic desktop interventions to correct postures; however, the number of MSDs remains high (Lanhers et al., 2016).

Repetitive movements, which include keystrokes, mouse clicks, mouse movements, and awkward static postures for long hours without adequate recovery time, are risk factors from computer work that contribute to MSDs (Douwes et al., 2007; Taylor & Green, 2006). Also, keyboard, mouse, and screen arrangement have been an established risk factor for musculoskeletal symptoms due to the non-neutral postures in the wrist and neck (Kim et al., 2010). Barbieri et al. (2015) reported that the reason implicated for the development of MSD is prolonged static muscle posture with little variation in the upper extremity muscles. Self-reported findings have shown that musculoskeletal symptoms are more likely when workers use computers more than four hours per day (Ellahi et al., 2011; Homan & Armstrong, 2003). Eltayeb et al. (2009) reported the four top predictors for neck and shoulder complaints were awkward head and body positions, challenging tasks, daily computer work hours, and previous neck, shoulder, or arm complaints. Psychosocial stressors, such as perceived high stress, high workload, little work control, little support from colleagues or supervisor, boredom, over-commitment, and little to no rewards, have been associated with neck and upper extremity pain (Eijckelhof et al., 2014).

Muscle fatigue has been studied to understand the mechanisms of the exposure-response relationship to MSDs (Chang et al., 2009). Chang et al. (2009) tested the hypothesis that keystroke duration measured by typing performance using software on the participant's computer may be an indicator of muscle fatigue. Hence, it may be possible to measure keystroke duration and muscle fatigue to identify and prevent MSDs (Chang et al., 2009). A study by Kim & Johnson (2012) validated digital signals from the keyboard compared to individual keystroke forces and then compared them to the computer software measured keystroke durations. The software was determined a valuable tool for a non-invasive, low-cost exposure assessment of muscle fatigue during computer work.

Several studies have shown that musculoskeletal symptoms were associated with mouse use, which predicted acute pain in the neck and shoulder (Andersen et al., 2008; Filgueiras et al., 2011). The systematic review by Ijmker et al. (2007) reported that there were more positive associations between mouse use and hand-arm symptoms than evidence for the neck and shoulders. A study by Kiss et al. (2012) revealed several variables that contributed to neck and shoulder complaints. A one-year study by Kiss et al. (2012) determined that working over an average of 25 hours per week on a computer, working more than one hour continuously without a break, along with mouse reaching, space issues, and forearm support were the most relevant variables.

One solution proposed to reduce MSDs, was the introduction of rest breaks, such as macro-breaks (ten minutes or longer), instead of micro-breaks (short breaks or rest pauses) using existing break software (Dekker et al., 2015). Mathiassen (2006) suggested ‘active breaks’ that result in different muscle activations and postures, i.e., the biomechanical variation of muscles as well as diversity. In these ‘active breaks,’ the muscles would have difference exposures, which were needed to reduce MSDs. Other studies only weakly support this suggestion.

Similarly, an in-situ field test by Henning et al. (1997) on breaks with stretching indicated short breaks, i.e., three minutes versus 30 minutes were more favored. However, no improvement in productivity was seen. McLean et al. (2001) determined that breaks at 20-minute intervals were sufficient to relieve the discomfort to the upper extremities and lower back. Furthermore, a study by Morris et al. (2008) showed that workers preferred micro rest breaks, 20-second breaks every five minutes. In this study, the software monitors the keyboard and mouse activity to optimally break, rather than disrupt at pre-set intervals. However, other parameters, such as a digital calendar, could be incorporated into the software to optimize breaks.

Productivity defined by several studies is the total word count typed minus errors (Nakphet et al. 2014; Van den Heuvel et al., 2003). Concerns about the effect on productivity from rest breaks have not been realized or instead resulted in a positive outcome for productivity (Henning et al., 1997; McLean et al., 2001).

Several studies have evaluated stretching during computer work breaks to determine if they were a valuable tool for reducing symptoms of MSDs. The systematic review by da Costa and Vieira (2008) reported that breaks could be beneficial. However, stretching was necessary but it needs to be specific for reducing and preventing MSDs and should not aggravate any existing conditions. Even though rest breaks have been studied and determined to reduce symptoms of MSDs, there was no consensus in the literature on the amount or frequency of rest breaks needed to reduce work-related MSDs.

Studies on computer usage monitoring software

Several studies have validated computer usage monitor software by video recording compared to the gold standard of observations with statistical correlations (Blangsted, Hansen, & Jensen, 2004; Ijmker et al., 2008). The typical variables reported in the validation studies were daily computer usage time, keyboard time, and mouse time (Blangsted, Hansen, & Jensen, 2004; Ijmker et al., 2010). Comparison studies showed recorded computer usage as 2 to 2.5 hours per day when the self-reported values ranged from 4.1 to 5 hours. The keyboard time for recorded versus self-reported was 0.3 to 1.6 and 1.8 to 3.6 hours per day, respectively. Lastly, for mouse usage, time ranged from 0.6 to 1.4 hours per day for recorded time to self-reported time ranges of 1.4 to 3 hours (Heinrich et al., 2004; Homan & Armstrong, 2003; Mikkelsen et al., 2007). These times likely vary due to the varying range of occupations studied. As a result of these studies, computer usage monitoring software has been determined to be an acceptable method to achieve objective measurements (Chang et al. 2008; Douwes et al., 2007; Heinrich et al., 2004; Homan & Armstrong, 2003).

Most research on musculoskeletal symptoms regarding computer users has focused on self-reported surveys, which do not reflect actual usage time or actual breaks (Blangsted, Hansen, & Jensen, 2004). Self-reported surveys for computer usage, especially for actual time spent at the computer, will generally produce overestimates (Ijmker et al., 2008). Usage times are overestimated by 1.8 hours for computer usage with reported musculoskeletal symptoms and 1.5 hours overestimated with no musculoskeletal symptoms reported (Gerr & Fethke, 2011; Heinrich et al., 2004). Two studies reveal that on self-reports, musculoskeletal symptoms are reported when working over 4 hours per day (Ijmker et al., 2011; Mikkelsen et al., 2007). The study by Ijmker et al. (2011) indicated that there was no association found between computer and mouse use with neck and shoulder complaints from the computer usage recorded data. However, from the self-reported data, there was a significant association with neck and shoulder symptoms. Explanations for the discrepancy between self-reported data and recorded data could not be determined, but self-reports have the potential for nondifferential exposure misclassifications (Ijmker et al., 2008). However, comparing the two studies, there were fewer recorded data participants than self-reported data and the same physical and psychosocial factors were not measured in both studies.

Purpose of Current Study

One of the purposes of the current study is to compare the mean values of the RSIGuard® variables used in the evaluation to mean values found in a literature search. Also, there will be an evaluation of the variables in the RSIGuard® data with the OES self-reported body part discomfort survey. Finally, there will be an evaluation of the OES dataset to determine if there are variable(s) that predict self-reported musculoskeletal symptoms.

Current research gaps

1983 was the birth of human-computer interaction (HCI) and the launch of the Apple Macintosh, the first personal computer (MacKenzie, 2012). At this time, we began to see the study and research of integrating technology and human interaction (MacKenzie, 2012; Woo, White, & Kai, 2016). Also, in 1983, American National Standards Institute (ANSI) and Human Factors Society (HFES) established an ergonomics standard with guidelines for computer workstations. This ANSI document developed guiding principles for workstation design leading to improved ergonomic product design and better user interfaces (Woo, White, & Kai, 2016).

Even though the discipline of HCI began around the same time as the first personal computers, HCI was in its infancy. In that regard, and with the many changes and improvements in technology, workers still reported problems working on a computer. Even with many studies and research that have improved posture, equipment, and rest breaks while working at a computer, today, there are still a multitude of issues reported regarding computer workers and MSDs.

Software technology has allowed for development of ergonomic desktop software that monitors individuals while working at a computer. This software objectively records an individual's computer behaviors such as hours on a computer, hours on a mouse, keyboard strokes, breaks taken, and breaks skipped. The software technology used in this research was RSIGuard® (Cority Enviance). This software has a unique algorithm considering an individual's computer activity and inactivity, breaks taken, keystrokes, and mouse activity, all analyzed in an intelligent model to individualize the timing of breaks. This unique algorithm intended to suggest a break at the least intrusive time, so the user is likely to take the break rather than skip it.

Numerous studies using desktop software have been performed. Ijmker et al. (2011) performed a study using desktop software compared to self-reports to determine computer use that could predict participants with severe arm, wrist, hand, neck, and shoulder pain. The research result showed that self-reports showed an association with musculoskeletal symptoms, where the software recorded data did not have any associations. Mikkelsen et al. (2012) performed a study with 2,146 participants using computer desktop software and a self-reported baseline body discomfort questionnaire with a 1-year follow-up. Computer work was not found to be associated with prolonged or chronic pain, but mouse use showed a weak association with acute distal arm pain.

Lanhers et al. (2016) performed a study using desktop software with active breaks on participants with and without symptoms of MSDs; results indicated the intervention group with the active breaks reported minor symptoms of MSDs.

The limitations in the previous studies have been that many studies have been subjective (self-reported), but even if the study was objective, the studies have not been able to determine associations, except weakly, to symptoms of MSDs. One of the limitations of this study also allowed participants to disable the features of BTEnabled, FMNEnabled (ForgetMeNots), and Mircobreak Compliance. Unfortunately, these features were disabled by the users approximately 50 percent of the time. These features were critical components to measure rest breaks in the software. Breaks were demonstrated in many research studies, as an essential component for reducing MSDs. This study also did not have a follow-up OES questionnaire at the 1-year follow-up to evaluate changes in MSD symptom status.

The objective of these two research studies was to determine if there were any predictor variables (independent variables) that indicate body part discomfort (dependent variable), commonly referred to as symptoms of MSDs. The occupational health benefits of this research were to be able to predict symptoms of MSDs before they become a health issue for occupational computer workers. A thorough understanding of how MSDs occur while working on a computer will lead to recognition and prevention of MSDs and, subsequently, reduction of occupational MSDs.

CHAPTER II

DESCRIPTIVE STATISTICS OF REMEDY DATA

Occupational Overview

Computers are used nearly everywhere in today's global world. The use of computers has grown significantly throughout the 21st century, especially in terms of work-related situations. It is not uncommon in today's workplace for employees to sit at computers for hours. Employees who work on computers commonly have awkward postures, engage in repetitive movements, and do not take sufficient rest breaks. These issues, as mentioned above, regarding working on computers, can result in employees experiencing symptoms of MSDs or actual diagnosed MSDs.

This study used objectively measured data collected when participants worked on computers to examine computer behaviors and patterns that can contribute to symptoms of musculoskeletal disorders. The findings of this study, regarding the variables explored, are inconsistent with that of other studies. These contradictory findings may be due to the large data set (n = 13,762) of this study. The results of this study demonstrate that the two compliance features (e.g., BreakTimer and ForgetMeNots), which were used to reduce strain (which can result in musculoskeletal disorders or symptoms), were not enabled by approximately 50% of computer users, thus potentially impacting the findings of this study.

Technical Summary

Background: Computers are used in all aspects of work and personal life. The use of computers has grown tremendously over the last several decades. Workers spend

many working hours at computers engaging in awkward static postures, performing repetitive movements, and without breaks. Since employees spend many working hours at computers, they are at an increased risk of developing musculoskeletal disorders (MSDs). ***Purpose***: To evaluate a data set using descriptive statistics, specifically examining predictors variables, to determine if any variables indicate musculoskeletal discomfort. Furthermore, this research compared the findings of this study to other peer-reviewed research studies. ***Methods*****:** The study included 13,762 participants that were from a secondary de-identified data set, which was provided by Cority Enviance. Data was gathered using the RSIGuard® desktop software over a period of 364 days. ***Results*****:** The study reported a mean (SD) total computer use hours per day of 3.14 (1.28) with mean (SD) mouse hours per day of 2.79 (1.2) and mean (SD) keyboard hours per day of 1.04 (0.57). MouseClicks' highest mean (SD) was in MouseLeftClicks per day at 2298.43 (1296.6). The mean (SD) BreakTimer (BTEnabled) and ForgetMeNots (FMNEnabled) features were at 54.27 % (47.14) and 47.53 % (47.23) respectively. MicroBreak compliance mean (SD) recorded 20.06% (35.80). OverallBreakCompliance mean (SD) resulted 90.86% (16.31). ***Conclusions*****:** The outcomes in this study were higher compared to averages presented in previous studies. However, these higher outcomes could be due to the large sample size (n = 13,762) in this study or due to a similar, yet different software used in the other studies. Additionally, the differences denoted might be due to the industry/occupation in which participants were studied. The features (BTEnabled and FMNEnabled), which were user enabled, were only used by approximately 50% of participants, which may have affected the results. The outcomes

presented here can be an example for future studies of this type and size to determine solutions to musculoskeletal disorders or symptoms while working at a computer.

Introduction

Computers are ubiquitous; they are used in the workplace, schools, and at home (Calvin College, 2005). Ciccarelli, Straker, Mathiassen, and Pollock (2011) indicated that the number of computers used in the U.S. workplace had grown substantially since the first decade of the 21st century. Coenen et al. (2019) noted that the increased utilization of computers in the workplace, in which employees have self-reported working between four to six hours per day, can lead to symptoms of musculoskeletal disorders (MSDs). Musculoskeletal discomfort is caused by repetitive movements, awkward postures, and a lack of sufficient breaks when working on computers (Coenen et al., 2019). Since computers are used everywhere, for many hours, there is a need to study computer usage as it relates to musculoskeletal discomfort.

Considerable research has been conducted on workers for concerns with computer interaction and musculoskeletal complaints (Aaras, Fostervold, Ro, Thoresen, & Larson, 1997; Cooper & Straker, 1998; Johnson, Dropkin, Hewes, & Rempel, 1993; Karlqvist, Hagberg, & Selin, 1994; Powers, Hedge, & Martin, 1992; Smith, Cohen, Stammerjohn, & Happ, 1981). A seminal study conducted by Smith et al. (1981) utilized a questionnaire given to computer users who identified computer-related musculoskeletal discomfort when evaluating health complaints. In 1992, Powers et al. noted that 50 million Americans worked on computers daily. Due to the prevalence of computer utilization, Powers et al. (1992) recognized the need to evaluate keyboard configurations, specifically to reduce musculoskeletal discomfort among computer users. Powers et al. (1992) found that a negative-sloping keyboard system aided in reducing wrist extension among computer users, allowing individuals to display a more neutral posture, which assisted in reducing musculoskeletal symptoms.

In 1995, Fogleman and Brogmus explored workers' compensation claims for cumulative trauma disorders. They noted that due to the increase in graphic user interfaces, the researchers recognized that computer mouse use increased. The increased prevalence of mouse usage was significant, especially since mouse use can result in musculoskeletal symptoms (Johnson et al., 1993). Cooper and Straker (1998) and Karlqvist et al. (1994) both found that mouse use resulted in static muscle shoulder loading, which increased one's risk of neck and upper extremity problems. Additionally, Aaras et al. (1997) determined that forearm support reduced the load on both trapeziuses for sitting computer work versus no forearm support, leading to muscle strains and potentially MSDs.

Various methods (e.g., video-recordings, electromyography [EMG] muscle testing, and self-reports) have been used in research studies to determine the duration and load impact of computer use in relation to symptoms of MSDs (Chang et al., 2010; Hwang, Chen, Yeh, & Liang, 2010). Computer users, who completed the self-reported surveys, often overestimated their computer-use duration and were more likely to report symptoms of MSDs (Chang et al., 2010; Coenen et al., 2019; Ijmker et al., 2011; Mikkelsen et al., 2012). Hwang et al. (2010) reported that video-recording, which used to be the standard evaluation tool, approximated software-recorded data. As a result of this validation, studies could now be verified using software-recorded data. Evaluation of the desktop software, like in this research, was performed by statistical analysis of the data files collected by the DataLogger feature of the software (Cority Enviance, Inc., 2018). This software feature makes it simple and very cost-effective (Chang et al., 2010) for evaluation, whereas video recorded analysis involves a lot of time and resources (Mathiassen, Liv, & Wahlstrom, 2013).

Davis and Kotowski (2014) and Nakphet, Chaikumarn, and Janwantanakul (2014) explained the importance of computer users taking rest breaks. The researchers noted that taking rest breaks during computer use can result in a reduction in musculoskeletal discomfort. Given the importance of rest breaks, the RSIGuard's BreakTimer feature is incorporated into the RSIGuard® Software.

The results obtained from self-reported studies have revealed that muscular discomfort often occurs in the forearms, hands, and wrists, and in the upper extremities, which was due to daily computer usage (Delp & Wang, 2013; Ijmker et al., 2011; Mattioli, Violante, & Bonfiglioli, 2015). Musculoskeletal discomfort is a significant workplace topic, specifically because approximately 28% of all industrial injuries are musculoskeletal (US Department of Labor, 2017). In the United States, in 2014, employers spend roughly $20 billion in direct workers' compensation claims (US Department of Labor, 2014). Furthermore, US employers spent approximately $100 billion in indirect costs related to workers' compensation (US Department of Labor, 2014), thereby reinforcing the importance of reducing MSDs.

The primary objective of this study is to provide a summary of Cority Enviance data, which is characterized using descriptive statistics. The information presented is significant because it summarizes the variables analyzed from a large sample size data.

Methods

Data Information

In 2015, Cority Enviance, Inc. provided Texas A&M University with a secondary data set. This data set is reflective of participation from 13,762 employees who worked, from 2013 to 2015, for an oil and gas company. The data set was de-identified and did not provide details regarding demographic variables (e.g., gender of participants or job classification), agreed upon by Cority Enviance's clients when the study was initially conducted. No information about experimental design, informed consent, or any specifics of the data collection is known. In March of 2016, Texas A&M's Institutional Review Board approved this study.

Data Collection

The software used in this study was Cority Enviance RSIGuard® Version 3. RSIGuard® is an ergonomic desktop software that monitors an individual's workplace computer activities, work patterns, and behaviors (Cority Enviance, 2014). The purpose of monitoring these specific factors is because each factor can contribute to MSDs and/or body part discomfort. What makes this software different is that it has a unique algorithm that uses "accumulated strain" of the keyboard and mouse, in addition to examining one's natural rest breaks, to calculate a non-intrusive time for each user to take a break (i.e., the BreakTimer feature).

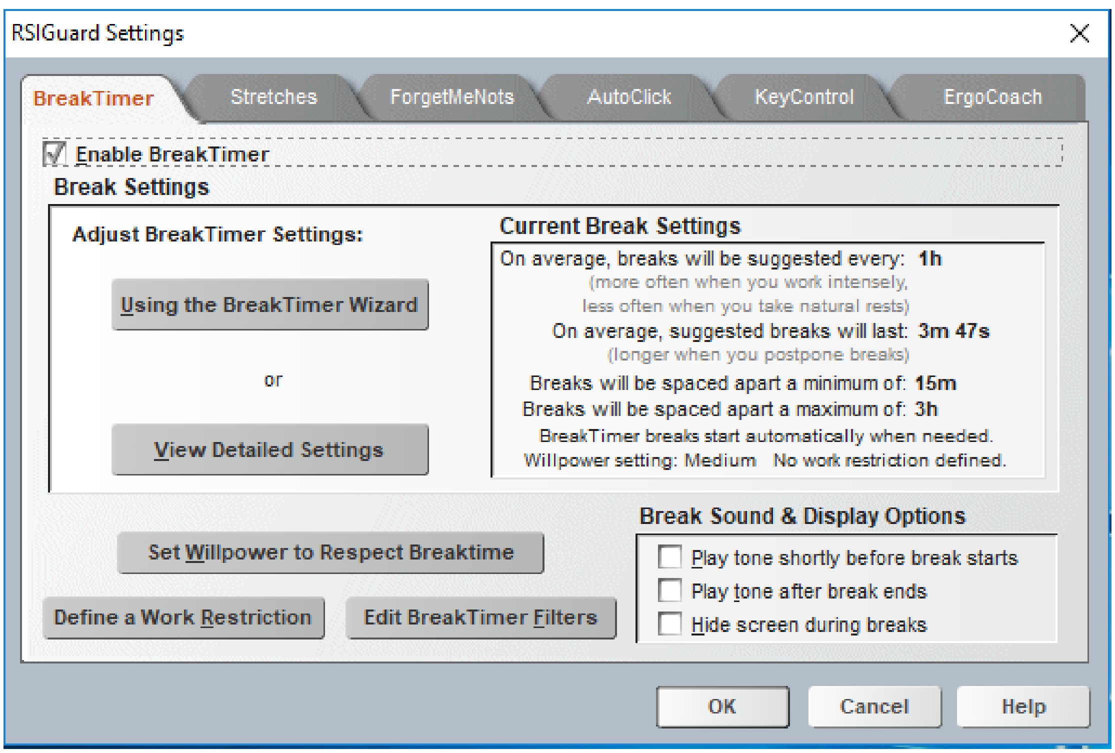
When examining an individual's computer strain measurements, it is important to note that these measurements are two-fold. An individual's physical strain, regarding how hard the person presses the keys, is measured. Secondly, muscle strain, which is required for mouse activities (differs from clicks to drag and drop functions), is examined. Previous surface electromyography (EMG) studies were conducted to establish the strain measurements used in the BreakTimer algorithm (Cority Enviance, Inc., 2014).

The data was collected using RSIGuard®'s DataLogger, a feature that gathers ergonomic usage data (daily computer statistics). This ergonomic usage data includes computer time, keyboard and mouse time, the number of keystrokes, mouse time, mouse clicks, mouse distance, break information, words typed, keyboard errors, and details regarding a participant's compliance with the software features (e.g., FMNEnabled; MicroBreakCompliance; BTEnabled; Cority Enviance, Inc., 2014).

Daily statistics were collected based on active computer use. RSIGuard® documentation noted that "keyboard use" occurs when the first keystroke begins and extends until there is a 30-second keyboard break (Cority Enviance, Inc., 2018). This duration of time is considered the "keyboard-active state," which is added to the "keyboard use time."

"Mouse use" or "mouse-active state" references an individual's mouse activities (e.g., mouse moves, clicks, or when the mouse wheel-spin first occurs) until the user takes a break that is longer than 30-seconds. The "mouse active state" is added to the "mouse use time" accumulator (Cority Enviance, Inc., 2018). Similar to "mouse-active state," time on the computer is a measurement of how much time the user is in the "active state." This "active state" denotes when the user is either in the "keyboard-active state," "mouse-active state," or in both states. According to Cority Enviance Inc. (2018), total computer time is not necessarily keyboard time plus mouse time added together because if the two are used together, these are considered a single period of time (e.g., five minutes of keyboard and five minutes of mouse used together equals 5 minutes total). Keyboard time, mouse time, and computer times are considered good indicators of computer postures; thus, these factors are indicators of an individual's risk for MSDs. These factors are captured by the variables of HoursK, HoursM, and TotalHours.

Figure 1. RSIGUARD® Settings for BREAKTIMER.

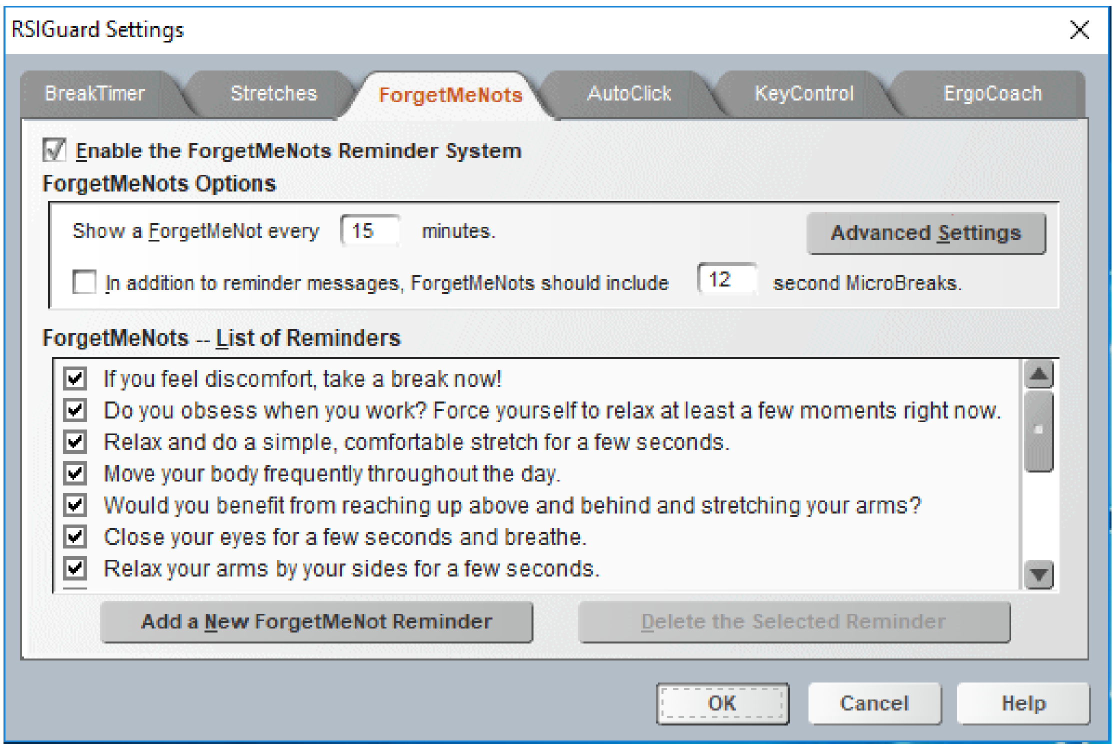


The BreakTimer feature (Figure 1), which was previously described, pauses the computer for a length of time (default equals 3 minutes, 47 seconds), as dependent on the setting. The BreakTimer feature can be enabled or disabled by the user, tracked by the BTEnabled variable. Another feature of the BreakTimer function, which was evaluated, was the BreakTime. The BreakTime captures the amount of time in breaks to see if the suggested break time was taken or shorten. BreaksSkipped is a measurement that denotes if users take the suggested break or not. AvgTimeBetweenBreaks is tracked to determine how long, on average, the user is postponing suggested breaks. OverallBreakCompliance provides information regarding BreakTimer compliance in consideration of natural breaks and delayed breaks.

Other BreakTimer statistics that were evaluated included the NumNatBreaks15secs, NumNatBreaks60secs, NumNatBreaks4min, and NumNatBreaks16min features. These are all-natural rest break statistical features, which explain how often the users take breaks. This data is considered in the algorithm for the BreakTimer breaks to skip a break prompt if the user has recently taken a natural break. Natural breaks indicate a user’s rest break considering behaviors and may indicate one’s likelihood for risks, especially since some users disable the BreakTimer feature.

ForgetMeNots (FMN; Figure 2) is a feature that provides awareness reminders. FMNs use screen pop-ups (e.g., “If you feel discomfort, take a break now!,” “Notice your posture relative to your computer,” and “Are your shoulders and arms relaxed as you type?”), which are displayed every 15 minutes (by default). Within the FMN settings, there is an option for microbreaks, when the FMN reminders messages appear, that pause the computer (for 12 seconds by default), thus allowing individuals to rest briefly. The microbreak feature is tracked by two variables MicroBreaksTaken, which counts the number of microbreaks taken, and the number of microbreaks skipped (MicroBreaksSkipped).

Figure 2. RSIGUARD® Settings for FORGETMENOTS (FMN).



The FMNFrequency variable provides the statistical average for the time between FMNs. The MicroBreaksLength variable is the FMNs setting for the length of microbreaks. FMNEnabled and MicroBreaksEnabled explain if the user has enabled this feature; results are given as a percentage. MicroBreakCompliance provides the user's compliance feature percentage. The FMN and MicroBreakCompliance features can also be enabled or disabled by the individual user.

The Mouse statistics reviewed in this data set included MouseDistance, MouseDoubleClicks, MouseLeftClicks, MouseRightClicks, and MouseScrolls. Each of these statistical variables assigns a “strain” value from previous EMG testing, which is considered contributing risk factors that can result in potential MSDs due to computer usage. These values are used in the BreakTimer suggested break feature.

The two variables, TodaysBuiltinKbdWorkSeconds and TodaysBuiltinPtrWorkSeconds, were gathered based upon the individual’s computer laptop usage. There are other features of RSIGuard®, which include Stretches, AutoClick, KeyControl, and ErgoCoach, that were not evaluated in this study.

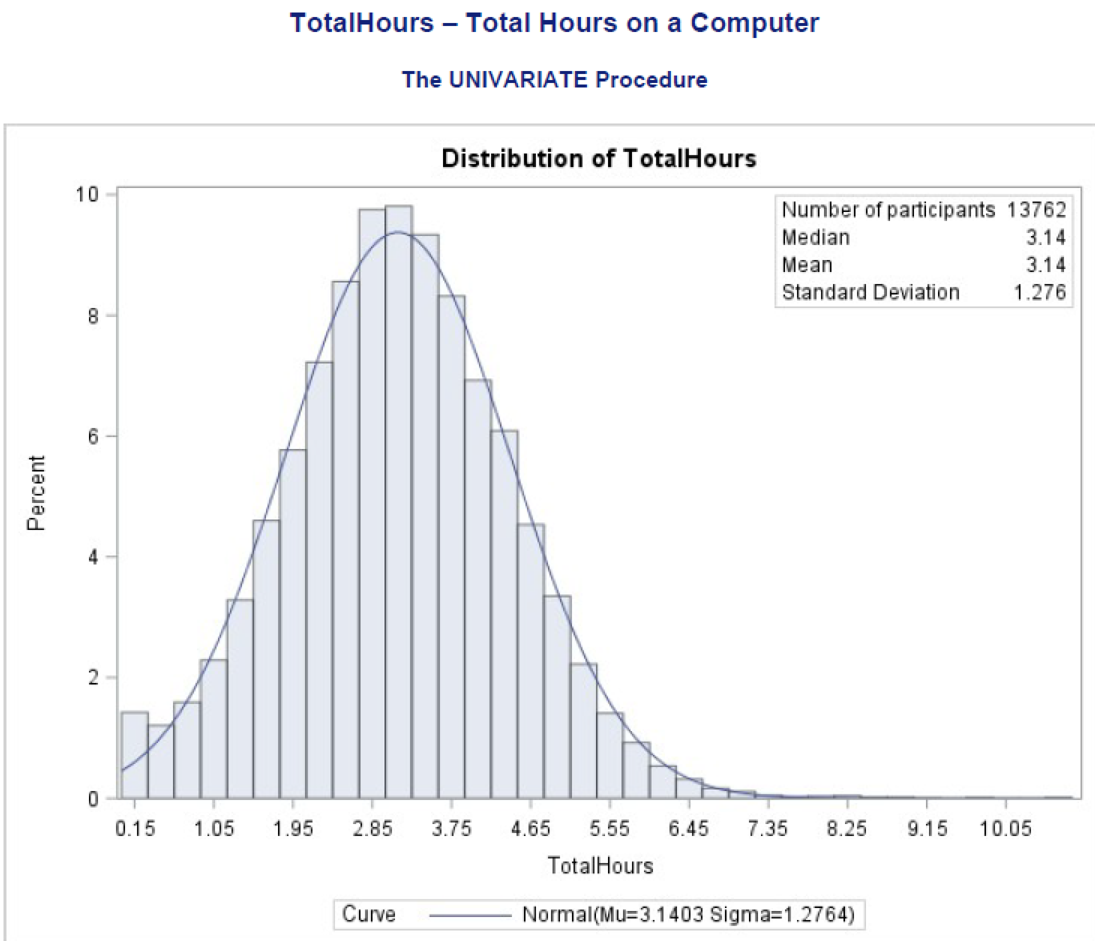
Data & Statistical Analysis

Descriptive statistics were used to summarize the data. The descriptive statistics were analyzed using the proc univariate statement in SAS 9.4. Using descriptive statistics, the researcher analyzed the mean, standard deviation, median, mode, and range of the data. The data results from this study are reflective of an average of an average (i.e., averaged continuously), in which results were measured over 364 days.

Results

On average, participants of this study spent approximately three hours at the computer, which is less than an eight-hour workday (Figure 3). Two-thirds of this recorded time was spent using the mouse, and one-third of this time was spent using the keyboard. A summary of computer user results is presented in Table 1.

Figure 3. Total Hours on a Computer.



Specific mouse information is displayed from highest to lowest count per day and was determined using the following features: MouseLeftClicks, MouseScrolls, MouseDoubleClicks, then lastly, MouseRightClicks.

The user could configure the BreakTimer feature. As a result of this configuration option, approximately half of the users had the BreakTimer feature disabled (BTEnabled). Other variables within the BreakTimer feature included BreakTime, BreaksSkipped, and AvgTimeBetweenBreaks. However, any of the statistics reported should be noted as incomplete data and should be approached with caution, especially given the lack of the feature enabling.

Table 1. RSIGuard® Data. List of Variables.

Variable Name	Mean	SD	Median	Mode	Range
General Variables					
HoursM	2.79	1.20	2.74	0	0-9.99
HoursK	1.04	0.57	0.97	0	0-5.37
TotalHours	3.14	1.28	3.14	0	0-10.70
WordCountAMPM	582.71	420.15	502.00	0	0-4019
KbdErrorsAMPM	176.51	134.33	148.00	0	0-1259
BreakTimer variables					
BreakTime	37.10	189.67	0	0	0-12625
BreaksSkipped	0.07	0.25	0	0	0-4.77
MicroBreaksTaken	1.38	3.53	0	0	0-129.87
MicroBreaksSkipped	0.33	1.34	0	0	0-78.34
BTEnabled	54.27	47.14	82.00	100.00	0-100
AvgTimeBetweenBreaks	36.73	990.02	3780.0	3780.0	0-129690
	(61.23)	(16.50)			
OverallBreakCompliance	90.86	16.31	97.24	100.00	0-100
Other Break variables					
NumNatBreaks15secs	117.19	46.80	114.00	0	0-545
NumNatBreaks60secs	35.70	13.45	35.00	34.00	0-143
NumNatBreaks4min	11.31	4.73	11.00	11.00	0-76
NumNatBreaks16min	2.67	1.43	3.00	2.00	0-13
Mouse variables					
MouseDistance	109347.20	69131	97349	0	0-919993
MouseDoubleClicks	165.58	148.76	133.00	0	0-2536
MouseLeftClicks	2298.43	1296.6	2110.0	0	0-13626

Table 1. (Continued).

Variable Name	Mean	SD	Median	Mode	Range
MouseRightClicks	54.41	71.63	35.00	18.00	0-1775
MouseScrolls	2234.52	2443.6	1696.00	0	0-53634
ForgetMeNots variables					
FMNEnabled	47.53	47.23	29.00	0	0-100
FMNFrequency	18.93	11.73	15.00	15.00	0-120
MicroBreaksEnabled	24.77	41.38	0	0	0-100
MicroBreaksLength	11.36	2.04	12.00	12.00	0-30
MicroBreakCompliance	20.06	35.80	0	0	0-100
Laptop variables					
TodaysBuiltinKbdWorkSeconds	481.06	834.58	99.00	0	0-11256
TodaysBuiltinPtrWorkSeconds	588.06	1184.5	58.00	0	0-15924

A similar feature to BreakTimer is ForgetMeNots (FMN), which includes the MicroBreaks features and FMNFrequency. Like the BreakTimer feature, ForgetMeNots also could be disabled by the participants. Less than 50% of participants enabled the ForgetMeNots feature. FMNFrequency reports an average (18.93) over the default of 15 minutes, which means that users were delaying the FMN messages. MicroBreaks is also a feature that the user could disable. Likewise, less than 25% of the participants who had the ForgetMeNots enabled had the MicroBreaks featured enabled. Like the BreakTimer feature, it is essential to approach this data with caution, given the lack of feature enabling. OverallBreakCompliance had a very high compliance percentage because the user could not adjust this feature. Description of variables with units is shown in Table 2.

Table 2. RSIGuard® Data. Description of Variables.

Variable Name	Description	Units
AvgTimeBetweenBreaks	BreakTimer setting for average time between breaks	Seconds[a]
BreaksSkipped	Number of BreakTimer breaks skipped	Numerical Count[a]
BreakTime	Time spent in BreakTimer breaks	Seconds[a]
BTEnabled	Percentage of time during the day that BreakTimer was enabled	Percentage
FMNEnabled	ForgetMeNots enabled	Percentage
FMNFrequency	ForgetMeNots setting for time between ForgetMeNots	Minutes[a]
HoursK	Keyboard usage hours	Hours[a]
HoursM	Mouse usage hours	Hours[a]
KbdErrorsAMPM	Number of sequences of delete/backspaces keys, combined AM & PM	Numerical Count[a]
MicroBreaksEnabled	Percentage MicroBreaksEnabled	Percentage
MicroBreaksLength	ForgetMeNots setting for length of ForgetMeNots microbreaks	Seconds[a]
MicroBreaksSkipped	Number of ForgetMeNot microbreaks skipped	Numerical Count[a]

Table 2. (Continued).

Variable Name	Description	Units
MicroBreaksTaken	Number of ForgetMeNot microbreaks taken	Numerical Count[a]
MicroBreakCompliance	Percentage of MicroBreakCompliance	Percentage
MouseDistance	Distance mouse was moved	Pixels[a]
MouseDoubleClicks	Number of pointer double clicks	Numerical Count[a]
MouseLeftClicks	Number of pointer left clicks	Numerical Count[a]
MouseRightClicks	Number of right clicks	Numerical Count[a]
MouseScrolls	Number of pointer scroll clicks	Numerical Count[a]
NumNatBreaks15secs	Number of natural 15-second breaks	Numerical Count[a]
NumNatBreaks16min	Number of natural 60-second breaks	Numerical Count[a]
NumNatBreaks4min	Number of natural 4-minute breaks	Numerical Count[a]
NumNatBreaks60secs	Number of natural 16-minute breaks	Numerical Count[a]
OverallBreakCompliance	Percentage of OverallBreakCompliance	Percentage
TotalHours	Total hours on a computer	Hours[a]
TodaysBuiltinKbdWorkSeconds	Number of seconds of activity on the built-in keyboard notebook	Seconds[a]
TodaysBulitinPtrWorkSeconds	Number of seconds of activity on built-in pointer of notebook	Seconds[a]

Table 2. (Continued).

Variable Name	Description	Units
WordCountAMPM	Words typed per day, AM & PM	Numerical Count[a]

[a]Rate in units per day

Discussion

The present study is a synopsis of the descriptive statistics of a large sample size. This large sample of office workers, who engaged in this study over a period of 364 days, is unique. Considering that this study was comprised of 13,672 participants, this study is larger than any other similar study published to date regarding objectively recorded software.

The findings of this study note, that on average, participants engaged in 2.79 hours of daily mouse use, which was twice as high as two reports that used similar software that assessed mouse usage (Davis & Kotowski, 2014; Ijmker et al., 2011). Additionally, this study noted that participants engaged in 1.04 hours of keyboard use per day, which is inconsistent with the average keyboard usage noted in other studies (Davis & Kotowski, 2014; Ijmker et al., 2011). Davis and Kotowski (2014) indicated that participants used their keyboard 1.6 hours per day, while Ijmker et al. (2011) found that participants used their keyboard approximately 0.62 hours per day. When comparing the total time of mouse use, the findings of this data set denote much higher results at approximately three hours per day, which is different from Davis and Kotowski's (2014) research and Ijmker et al.'s (2011) study. Likewise, this data set reported twice the amount of time spent between breaks than the findings by Davis and Kotowski (2014), which denotes half the time between breaks. Lastly, this study reported that total MouseClicks were twice as high as the clicks denoted by Davis and Kotowski (2014).

Each participant in this data set had administrative rights, which allowed users to turn on or turn off several features (e.g., BTEnabled, FMNEnabled, and MicroBreakCompliance). These features were used to reduce strain, which can cause musculoskeletal disorders. Given the graphical results, which the researcher reviewed, it was determined that many of the users opted out of the features. Except for the OverallBreakCompliance component because this feature could not be turned on or off by the user.

The comparison studies (e.g., Davis & Kotowski, 2014; Ijmker et al., 2011) used similar computer software to this study; however, it is important to note that different outcomes may exist due to the software utilized. A possibility of differences may have occurred due to the occupation and industry in which this study occurred (Wahlstrom, 2005). Consequently, given the differences in datasets, locations, industries, the nature of an individual's employment, etc., there is limited research regarding the likelihood of musculoskeletal symptoms when working on computers in the workplace (Ijmker et al., 2011).

The strengths of this research include a large population, the length of time in which data was collected, and the use of software to compile data. The software program used to record patterns and behaviors allowed for objectivity, which is not present when individuals use self-reported questionnaires. The weakness of this study is that the users were allowed to select many of the features that they wanted to disable, thereby impacting the data results, specifically in terms of the prevalence of use and time spent using a feature(s). Another weakness of this study is that the occupation/industry in which the employees worked, who participated in this study, is unknown; thus, the results may not reflect other industries/employment types.

Future studies should explore the same or similar industry participants, require that all software features be enabled, target a large data population, thus allowing for comparison of results.

CHAPTER III

ANALYSIS OF REMEDY RSIGUARD® DATA

Occupational Overview

In today's business environment, computers are indispensable resources. Many employees are likely to sit at a desk, virtually all day, in awkward postures, and without taking sufficient rest breaks. The increased use of computers and lack of rest breaks can cause symptoms of musculoskeletal disorders (MSDs). Computer work has resulted in many physical complaints and issues, including the neck, shoulders, lower back, elbows, forearms, wrists, and hand discomfort, thereby resulting in debilitating injuries.

Data from an ergonomic desktop computer software program called Remedy RSIGuard® was collected objectively and analyzed in this study from an office environment on 13,762 participants. Remedy RSIGuard® gathered information from an individual's computer to measure participant's computer routines. Computer user data was collected. This RSIGuard® data was compared to the self-reported Office Ergonomic Suite (OES) body part discomfort survey data. There were seven body part discomfort questions (e.g., Frequency of Discomfort, Neck and Upper Back Discomfort, Eyes or Head Discomfort, Lower Back Discomfort, Elbow and Forearm Discomfort, Shoulder Discomfort, and Wrist and Hand Discomfort), collected from the OES questionnaire. At the beginning of this study, the OES questionnaire was given to each participant. The findings from this research regarding the variables evaluated were similar to other studies that have been performed using computer software. The study results, which were analyzed by the proportional odds cumulative logit model (logistic regression), revealed that most of the variables, except for two variables, showed no difference between the objectively recorded data and the body part discomfort survey. The two exceptions of variables were BreaksSkipped, noted in the Lower Back Discomfort Model, and the variable of HoursK, which is noted in the Wrist and Hand Discomfort model. The partial proportional odds model (PPOM) is a unique approach to determine musculoskeletal disorders.

Technical Summary

Background**:** In today's office environment, computers are a vital part of the everyday work process. It is common to sit at a computer for many hours without breaks and in awkward postures. Studies have reported that these work conditions can result in workers developing symptoms of MSDs. Most research methods exploring individual computer behaviors use self-reported surveys, whereas this study objectively measured data using a large sample size. ***Purpose*****:** Evaluate the Remedy (Cority Enviance) data set, using the proportional odds model to examine predictors variables and compare those variables to the body part discomfort outcomes to determine if any predictor variables demonstrate discomfort. ***Method*****:** This study used a secondary de-identified data set provided by Remedy (Cority Enviance), which included 13,762 participants. Over a year, data was continuously collected using the RSIGuard® ergonomic desktop software. The RSIGuard® data was compared to the seven discomfort questions in the OES self-reported survey. Body part discomfort status was reported using four levels or five levels (depending on the model) which compared the highest level of discomfort (Constant or Moderate Discomfort) to the lowest level (Never experiences or No

discomfort). A proportional odds model (POM), also known as a cumulative logit model, was utilized since the outcome variables were ordinal. The score test result was examined to determine if there was a violation of proportionality (equal slopes). When a violation of proportionality was noted, a partial proportional odds model (PPOM) was performed. Data were analyzed using SAS 9.4 software, and logistic regression analyses were performed. ***Results***: In the Lower Back POM (no PPOM), the only variable of significance was BreaksSkipped, with an odds ratio of 1.17. The other variable of significance was HoursK, as noted in the Wrist and Hand Discomfort PPOM that resulted in an odds ratio of 1.265. ***Conclusion***: This research study did not produce many significant variables to determine the impact of daily computer work on symptoms of MSDs. However, this research topic is still relevant with the number of musculoskeletal diseases reported each year.

Introduction

Technology and the increased utilization of workplace computers have resulted in more sedentary jobs (Tersa-Miralles, Pastells-Peiró, Rubí-Carnacea, Bellon & Arnaldo, 2020). Today, many workers sit for long periods, in awkward postures, and do not take enough rest breaks (Oha et al., 2014; Sharan et al., 2011). Computer work has long been associated with MSD complaints (e.g., in the neck, shoulders, lower back, wrists and hands; Ardahan & Simsek, 2016; Baker & Moehling, 2013). Baker and Moehling (2013) evaluated anthropometric measurements among predominately female workers with chronic MSD symptoms. The researchers did not find any positive associations between symptoms of MSDs and measurements of postures. Baker and

Moehling (2013) proposed that computer users who report musculoskeletal symptoms were not merely displaying symptoms from nonconforming postures to anthropometric measurements but instead have multiple factors contributing to MSDs. In 2019, the Bureau of Labor Statistics reported that MSDs were the most commonly reported occupational injuries, which costs millions of dollars per year. Given the prevalence and cost of MSDs, it is critical that ongoing MSD research continues in order to reduce occupational exposures (Zakerian & Subramaniam, 2011).

Past research using computer software to determine an individual's computer behavior to evaluate symptoms of MSD has been limited. Mikkelsen et al. (2012) performed research using objectively recorded computer software to compare self-reported pain in acute, prolonged or chronic pain effects. Self-reported pain in the elbow, wrist, hand, and forearm was collected at the beginning of the study, weekly, and at the terminal end of the 1-year study. The results indicated that mouse use time was associated with acute symptoms in all muscle groups of concern. However, the recorded data did not reveal any association with prolonged or chronic pain or associations with symptoms of MSDs. Lastly, Mikkelsen et al. (2012) did not show any associations with keyboard usage.

Ijmker et al. (2011) performed a comparison study between ergonomic software recorded objectively and self-reports of symptoms of MSDs. The self-reports noted positive associations between arm, wrist, and hand symptoms and working on a computer greater than four hours per day. When individuals worked on a computer, using their mouse, for more than four hours per day, neck and shoulder discomfort were reported. However, in this study, the objectively measured data showed no associations between the self-reported results and musculoskeletal symptoms.

Researchers have noted the implications associated with computer mouse use, specifically in terms of the impact on musculoskeletal discomfort in an individual's wrists, forearms, and shoulders (Chen, Lee, & Cheng, 2012; Szeto & Lin, 2011). The amount of time using a mouse, repetitive mouse use, and awkward postures have contributed to musculoskeletal discomfort (Chen, Lee, & Cheng, 2012; Onyebeke, Young, Trudeau, & Dennerlein, 2014; Szeto & Lin, 2011). James et al. (2018) conducted a study of university employees where participants self-reported musculoskeletal discomfort in the neck, lower back, and shoulder. Many participants believe that their musculoskeletal discomfort was work-related. Furthermore, 77% of participants reported using a mouse for a pointing device, which is the potential cause of musculoskeletal discomfort. Onyebeke, Young, Trudeau, & Dennerlein (2014) reported that computer users, on average, use a mouse for up to two-thirds of their total computer time. Lin, Young, & Dennerlein (2015) tested different types of mouse configurations with electromyography muscle monitoring and revealed that using a roller mouse had the most neutral hand posture. For this study, a combination of the roller mouse and the touchpad demonstrated neutral shoulder posture as compared to other pointing devices.

While working at a computer, regular breaks, compared to no breaks, resulted in less reported user pain (Ardahan & Simsek, 2016). Chaikumarn, Nakphet, and Janwantanakul (2018) performed a study on 35 female participants who were divided into three groups: (1) active breaks with stretching, (2) active breaks with dynamic contraction, and (3) passive breaks (control). All participants took a break every 20 minutes for 3 minutes. Neck and shoulder postures of participants were monitored using an infra-red motion analysis camera. The researcher found that active breaks resulted in reduced musculoskeletal discomfort in the neck and shoulders. Irmak, Bumin, and Irmak (2012) and Osama, Jan, and Darain (2015) evaluated rest breaks with exercises to reduce the effects of musculoskeletal discomfort. Both groups completed a self-reported discomfort questionnaire. In both studies, users reported less perceived pain with active exercises during breaks while working at a computer.

Lanhers et al. (2016) implemented a computer software program to suggest the importance of frequent, short breaks. The break reminders were beneficial, as participants who previously reported musculoskeletal discomfort reported reduced musculoskeletal discomfort symptoms after implementing the program. In a study by Nakphet et al., 2014, active and passive rest breaks were studied using a group of female computer workers. The researchers found that those who engaged in active rest breaks reported less musculoskeletal discomfort compared to the passive study group (Nakphet et al., 2014). Furthermore, Lacaze et al. (2010) performed a study involving call center workers. Those who engaged in a well-designed exercise program performed during rest breaks experienced reduced musculoskeletal discomfort symptoms.

In 2003, a study by Van den Heuvel, De Loose, Hildebrandt, and Thé was conducted using a desktop software. Participants were encouraged to take breaks to reduced neck and upper back symptoms. A total of 260 participants with neck and upper limb complaints were randomized into three groups: a control group, a group that had four extra breaks per day, and one group that performed exercises during breaks. The researchers found that the group who engaged in extra breaks experienced more recovery from the MSD symptoms. Douwes, de Kraker, and Blatter (2007) compared self-reports, computer software, and direct observation to validate the accuracy of using computer software. Typically, self-reports were over-estimated. Computer software was accurate estimations of an individual's computer usage, making it the best way to determine computer use time.

Many studies about musculoskeletal discomfort among office workers have been conducted. The majority of studies about musculoskeletal discomfort involve self-reported questionnaires (Ardahan & Simsek, 2016; Ellahi, Khalil, & Akram, 2011; Rehman, Khan, Surti, & Khan, 2013; Sharan et al., 2011). In a study of 395 office workers, Ardahan and Simsek (2016) found that working on a computer seven hours per day or 3 hours without breaks may contribute to musculoskeletal discomfort. Rehman, Khan, Surti, and Khan (2013) conducted a study involving 416 participants. The researchers identified that lower back discomfort occurred when participants worked one to two consecutive hours without breaks. Sharan et al. (2011) performed a study on 4500 information technology professionals. The researchers discovered that the longer a person works on a computer, the more likely pain would occur. Furthermore, Sharan et al. (2011) explained that when computer workers skip breaks, existing musculoskeletal discomfort can be aggravated.

The primary objective of this research study was to identify predictor variables associated with developing musculoskeletal discomfort while working at a computer.

The research was performed using objectively recorded data which was compared to a self-reported body part discomfort questionnaire. The data was analyzed using an ordinal logistic regression model, specifically proportional and partial proportional odds models.

Methods

Data Information

In 2015, Cority Enviance, Inc. provided Texas A&M University with a secondary data set. This data set is reflective of participation from 13,762 employees who worked, from 2013 to 2015, for an oil and gas company. The data set was de-identified and did not provide details regarding demographic variables (e.g., gender of participants or job classification), agreed upon by Cority Enviance's clients when the study was initially conducted. No information about experimental design, informed consent, or any specifics of the data collection is known. In March of 2016, Texas A&M's Institutional Review Board approved the analysis of the Cority Enviance data.

Data Collection

This Cority Enviance RSIGuard® study was collected using RSIGuard® Version 3. RSIGuard® is a desktop ergonomic software that collects participant's daily computer use statistics. These statistics were collected by RSIGuard®'s DataLogger that focuses on computer usage and behaviors which can contribute to MSDs. The DataLogger collects data on the participant's daily computer statistics. The initial statistics collected at the baseline period (initial time study begins for each participant) were essential to monitor participants throughout the study to evaluate changes. This software features a

BreakTimer, ErgoCoach, KeyControl (hotkeys), and AutoClick. These features are optional depending on how they are initially set up by the individual or companies.

During this study, the BreakTimer feature could be configured by the user. In fact, approximately half of the users had this feature disabled. The BreakTimer is a key feature for the RSIGuard® software. BreakTimer promotes rest breaks. Researchers have recommended that rest breaks reduce repetitive movements and were essential in reducing the likelihood of developing work-related MSDs. The BreakTimer, causes the computer to pause and is measured by the variables BreakTime, BTEnabled, BreaksSkipped, AverageTimeBetweenBreaks, and OverallBreakCompliance. A more detailed analysis of all the features of RSIGuard® can be found in the article entitled "A Descriptive Statistics Analysis on Remedy RSI Guard Data," which was authored by Bridges (2019).

In addition to the RSIGuard® data, the OES (Office Ergonomic Suite) questionnaire was utilized. The OES questionnaire contained seven body part discomfort questions (e.g., Frequency of Discomfort, Neck and Upper Back Discomfort, Eyes or Head Discomfort, Lower Back Discomfort, Elbow and Forearm Discomfort, Shoulder Discomfort, Wrist and Hand Discomfort). The OES data was used for comparison purposes in the regression analysis and reflected the dependent variables explored in this study.

Statistical Analysis

The model was built using the seven dependent variables of the OES questionnaire and was analyzed using regression analysis (specifically, a POM). In the original data set, there were around 100 variables. However, for the purpose of this study, only 27 variables were analyzed. The dependent variables have four levels or five levels of dependent variables (depending on the model) associated with them. The dependent variables range from Constant, Frequent, Infrequent, or Never Experiences Discomfort to Severe, Moderate, Minimal, Slight, Never/No discomfort.

The predictor variables were the following:

- HoursM: Mouse usage hours
- HoursK: Keyboard usage hours
- BreakTime: Time spent in BreakTimer breaks
- BreaksSkipped: Number of BreakTimer breaks skipped
- MicroBreaksTaken: Number of ForgetMeNot microbreaks taken
- MicroBreaksSkipped: Number of ForgetMeNot microbreaks skipped
- MouseDistance: Distance the mouse was moved
- MouseDoubleClicks: Number of pointer double clicks
- MouseLeftClicks: Number of pointer left clicks
- MouseScrolls: Number of pointer scroll clicks
- BTEnabled: BreakTimer is enabled
- AverageTimeBetweenBreaks: BreakTimer setting for average break length
- FMNEnabled: ForgetMeNots is enabled
- FMNFrequency: ForgetMeNots enabled
- MicroBreaksEnabled: MicroBreaks enabled

- MicroBreakLength: ForgetMeNots setting for length of ForgetMeNots microbreaks
- NumNatBreaks15secs: Number of natural pauses greater than or equal to 15 seconds
- NumNatBreaks60secs: Number of natural pauses greater than or equal to 60 seconds
- NumNatBreaks4min: Number of natural pauses greater than or equal to 4 minutes
- NumNatBreaks16min: Number of natural pauses greater than or equal to 16 minutes
- OverallBreakCompliance: Break compliance considering natural breaks
- MicroBreakCompliance: Microbreak compliance
- WordCountAMPM: Combined words typed in the AM and PM
- KbdErrorsAMPM: Combined typos in the AM and PM
- TodaysBuiltinKbdWork: Time spent using a built-in keyboard of a notebook computer
- TodaysBuiltinPtrWork: Time spent using a built-in pointer of a notebook computer

SAS 9.4 software was used to conduct the regression analysis, which was performed using proc logistic. When the POM failed to reject the null hypothesis (hypothesis I), a stepwise selection for model fit was utilized with equal slope and unequal slope parameters. A default *p*-value of 0.05 was used to determine what variables were the best fit for the model. A regression analysis, which used a POM that produces a score test, was applied. When the score test result was significant, this indicated a violation of proportionality; thus, the POM fails to reject the null hypothesis. If this is the case, a PPOM was used in the analysis. However, when the score test is not significant, the proportionality assumption was satisfied, thereby indicated that no further analysis was necessary.

The null and alternative hypotheses (Hypothesis I) for proportionality was the following:

H_o = Score test determines there is no proportionality.

H_A = Score test determines there is proportionality.

Proportional and Partial proportional odds model

A POM was used for the response variables because categorical (ordinal responses) data were provided. For this study, the sample size was large, and there were many predictor variables. When a large sample size is present and many predictor variables exist, Hilliard (2017) noted that it is likely that proportionality will be violated. When proportionality is violated, a PPOM must be performed to relax the proportionality assumption and produce different parameter estimates across all response levels for each predictor variable (Hilliard, 2017). A detailed description of a PPOM was discussed in the research article by the title “A Logistic Regression Analysis of OES subjective data compared to a body part discomfort survey,” which was authored by Bridges (2020).

Results

Overview of the hypothesis (Hypothesis II)

The researcher hypothesized that there was no difference between the Remedy (Cority Enviance) predictor variables and musculoskeletal discomfort reported by participants. The predictor variables resulting from the model, which were significant, helped determine if there was an association between the predictor variables and body part discomfort.

The null and alternative hypotheses for the study were as follows:

H_o =There was no association between the predictor variables and musculoskeletal discomfort in computer work.

H_A=There was an association between the predictor variables and musculoskeletal discomfort in computer work.

Results of the Proportional Odds Assumption

The Frequency of Discomfort model was first analyzed with a POM, which resulted in a score test *p*-value of less than 0.0001. The result was significant, and, therefore, the proportionality assumption (parallel lines) was violated. Next, a PPOM analysis was performed, which resulted in an equal slope result of MouseDistance and MicroBreakLength. The unequal slope variables were BreakTime, AverageTimeBetweenBreaks, and WordCountAMPM had significant *p*-values.

A POM was analyzed to explore Neck and Upper Back Discomfort, which produced a score test of 0.0169. However, this result was significant, which means the proportionality assumption has failed to reject the null hypothesis. Therefore, given this failure to reject the null hypothesis, a PPOM was needed. The PPOM resulted in only one equal slope (parallel) variable after model building, produced MouseScrolls, and this variable was significant.

A POM was utilized in the Eyes or Head Discomfort Model and resulted in a score test of $p = 0.0214$. Consequently, this significant result violated the assumption of proportionality, and, therefore, a PPOM was used. The only variables from the analysis that were equal slopes included MouseDistance, BTEnabled, AverageTimeBetweenBreaks, and NumNatBreaks4min.

The Lower Back Discomfort model analysis was performed using a POM, which gave a non-significant score test ($p = 0.0928$). The regression analysis used 27 variables from the original data, but as a consequence of significance, only six variables were significant. The variables of significance were BreaksSkipped, MouseScrolls, BTEnabled, AverageTimeBetweenBreaks, OverallBreakCompliance, and WordCountAMPM.

The score test *p*-value for the Elbow and Forearm Discomfort analysis provided a $p = 0.0048$, which violates the proportionality assumption. Even though a PPOM analysis was required by the analysis method, there were no variables in the final model of the regression analysis.

Likewise, an analysis was conducted on Shoulder Discomfort Model using a POM. The score test resulted in a *p*-value of less than 0.0001. Similarly, as above, the method necessitated a PPOM, but there were no variables in the final model of the regression analysis.

Wrist and Hand Discomfort was analyzed using a POM and resulted in a violation of proportionality with a score test result *p*-value of less than 0.0001. The PPOM analysis resulted in significant equal slope variables of MouseDistance, AverageTimeBetweenBreaks, and OverallBreakCompliance. HoursK was the only unequal slope variable in this model.

Results for Frequency of Discomfort

***Partial Proportional Odds Model (Equal Slopes) – Frequency of Discomfort*.**

The Frequency of Discomfort model had two variables that resulted in proportional odds (equal slopes). Below, only significant results from the Frequency of Discomfort model are provided. Table 3 provides the partial proportional odds results for Frequency of Discomfort.

The outcome variables in this Frequency of Discomfort model have four levels, listed from highest (worst discomfort) to lowest (least discomfort):

- *CWRD*: Constant Work-Related Discomfort
- *FWRD*: Frequent Work-Related Discomfort
- *IWRD*: Infrequent Work-Related Discomfort
- *NED*: Never Experiences Discomfort

The predictor variable of Mouse Distance resulted in an odds ratio of 1.0, $p < 0.0001$. The odds ratio results explain that there was no difference or association between Frequency of Discomfort and Mouse Distance. The variable of MicroBreaksLength showed an odds ratio of 1.056. Therefore, for the variable MicroBreaksLength, participants were more likely to report *CWRD*, $p < 0.0001$.

However, this result was just above 1.0, and though the result was significant, it was not a meaningful result, and therefore no associations were found.

Table 3. Study #1 Frequency of Discomfort. Partial Proportional Odds (Equal Slopes).

Effects	Odds Ratio	95% Wald Confidence Limits		*p*-values
Mouse Distance	1.000	1.000	1.000	< 0.0001
MicroBreaksLength	1.056	1.037	1.075	< 0.0001

Partial Proportional Odds Model (Unequal slopes) – Frequency of Discomfort

The outcome variables in this Frequency of Discomfort model breaks the categories into the following groups (Table 4):

- Column 1: Constant Work-Related Discomfort (*CWRD*) vs. Frequent Work-Related Discomfort (*FWRD*) or Infrequent Work-Related Discomfort (*IWRD*) or Never Experiences Discomfort (*NED*)
- Column 2: Constant Work-Related Discomfort (*CWRD*) or Frequent Work-Related Discomfort (*FWRD*) vs. Infrequent Work-Related Discomfort (*IWRD*) or Never Experiences Discomfort (*NED*)
- Column 3: Constant Work-Related Discomfort (*CWRD*) or Frequent Work-Related Discomfort (*FWRD*) or Infrequent Work-Related Discomfort (*IWRD*) vs. Never Experiences Discomfort (*NED*)

The variables BreakTime, AverageTimeBetweenBreaks, and WordCountAMPM were the only variables produced from the PPOM. However, even though their results were significant, all of the results were either 1.0 or very close to 1.0. Therefore, these results did not produce any associations of musculoskeletal discomfort.

Table 4. Study #1 Frequency of Discomfort. Partial Proportional Odds (Unequal Slopes).

Odds Ratio Estimates (95% confidence interval) (*p*-value)			
Discomfort Categories	Constant Work-Related Discomfort vs. Frequent Work-Related Discomfort/ Infrequent Work-Related Discomfort/ Never Experiences Discomfort	Constant Work-Related Discomfort/ Frequent Work-Related Discomfort vs. Infrequent Work-Related Discomfort/ Never Experiences Discomfort	Constant Work-Related Discomfort/ Frequent Work-Related Discomfort/ Infrequent Work-Related Discomfort vs. Never Experiences Discomfort
BreakTime	1.001 (1.001, 1.002) $p < 0.0001$	1.001 (1.000, 1.001) $p < 0.0001$	1.000 (1.000, 1.001) $p < 0.0001$
AverageTimeBetweenBreaks	1.000 (1.000, 1.001) $p = 0.0031$	1.000 (1.000, 1.000) $p < 0.0001$	1.000 (1.000, 1.000) $p < 0.0001$
WordCountAMPM	0.999 (0.999, 1.000) $p = 0.0021$	1.000 (1.000, 1.000) $p = 0.6457$	1.000 (1.000, 1.000) p < 0.0001

Results of Neck and Upper Back Discomfort

Partial Proportional Odds Model (Equal slopes) – Neck and Upper Back Discomfort

The Neck and Upper Back Discomfort model's outcome variables have four levels from highest to lowest level of discomfort (Table 5):

- *ModDNUB*: Moderate discomfort in neck and upper back
- *MinDNUB*: Minimal discomfort in neck and upper back
- *SFNUB*: Slight fatigue in the neck and upper back discomfort
- *NDNUB*: No discomfort in the neck and upper back

The predictor variable of MouseScroll resulted in an odds ratio of 1.0, $p < 0.0001$. This result means there was no difference or association between Neck and Upper Back Discomfort and MouseScroll.

Table 5. Study #1 Neck and Upper Back Discomfort. Partial Proportional Odds (Equal Slopes).

Effects	Odds Ratios	95% Wald Confidence Limits		*p*-values
MouseScroll	1.000	1.000	1.000	< 0.0001

There were no results for unequal slopes for Neck and Upper Back Discomfort.

Results of Eyes or Head Discomfort Severity

Partial Proportional Odds Model (Equal slopes) - Eyes or Head Discomfort Severity

The outcome variables in the Eyes or Head Discomfort model breaks the categories into five levels. The following were the levels from highest to lowest for this model (Table 6):

- *SevDEH*: Severe discomfort in eyes or head
- *ModDEH*: Moderate discomfort in eyes or head
- *MinDEH*: Minimal discomfort in eyes or head
- *SFEH*: Slight fatigue in eyes or head
- *NDEH*: No discomfort in eyes or head

Table 6. Study #1 Eyes or Head Discomfort. Partial Proportional Odds Model (Equal Slopes).

Effects	Odds Ratios	95% Wald Confidence Limits		*p*-values
MouseDistance	1.000	1.000	1.000	0.0029
BTEnabled	0.998	0.998	0.999	0.0005
AverageTimeBetweenBreaks	1.000	1.000	1.000	< 0.0001
NumNatBreaks4min	1.028	1.018	1.037	< 0.0001

The significant variables in this regression analysis were MouseDistance, BTEnabled, AverageTimeBetweenBreaks, and NumNatBreaks4min. The predictor variable of MouseDistance resulted in an odds ratio of 1.0, $p = 0.0029$. This result means there was no difference or association between Neck and Upper Back Discomfort and Mouse Distance. The predictor variable of BTEnabled resulted in an odds ratio of 0.999, $p = 0.0005$. Since this result was close to 1.0, means there was no difference or association between Neck and Upper Back outcomes and BTEnabled. The predictor variable of AverageTimeBetweenBreaks resulted in an odds ratio of 1.0, $p < 0.0001$. This result means there was no difference or association between Neck and Upper Back and AverageTimeBetweenBreaks. As for the variable NumNatBreaks4min, the results were also close to 1 with 1.028, $p < 0.0001$. This result means there was no association between the predictor variable and the outcome variable (Eyes or Head Discomfort).

There were no PPOM results with unequal slopes for Eyes or Head Discomfort analysis.

Results of Lower Back Discomfort

Proportional Odds Model - Lower Back Discomfort Severity

The score test for the Lower Back Discomfort result was 0.0928, which was not a significant result; therefore, the analysis can be stopped at the POM, where proportionality is accepted. The results produced variables with equal slopes, but not all variables were significant; all were reported in Table 7.

The outcome variables in the Lower Back Discomfort model have four levels. The following were the levels from high to low discomfort for this model:

- *ModDLB*: Moderate discomfort in lower back
- *MinDLB*: Minimal discomfort in lower back
- *SFLB*: Slight fatigue in lower back
- *NDLB*: No discomfort in lower back

Out of the 27 variables analyzed in this regression analysis, only six out of the twenty-seven variables resulted in significant variables. Nevertheless, the only variable BreaksSkipped had a result different from 1.0. Therefore, participants who reported BreaksSkipped were 1.170 more likely to report *ModDLB.* The other significant variables resulted in 1.0 were MouseScrolls, BTEnabled, AverageTimeBetweenBreaks, OverallBreakCompliance, and WordCountAMPM.

Table 7. Study #1 Lower Back Discomfort. Proportional Odds Model (Equal Slopes).

Effects	Odds Ratios	95% Wald Confidence Limits		*p*-values
HoursM	0.937	0.840	1.046	0.2468
HoursK	1.040	0.904	1.196	0.5862
BreakTime	1.000	1.000	1.000	0.5461
BreaksSkipped	1.170	1.006	1.361	0.0410
MicroBreaksTaken	0.988	0.968	1.008	0.2197
MicroBreaksSkipped	1.013	0.980	1.048	0.4380
MouseDistance	1.000	1.000	1.000	0.1191
MouseDoubleClicks	1.000	0.999	1.000	0.5367
MouseLeftClicks	1.000	1.000	1.000	0.8891
MouseRightClicks	1.000	0.999	1.000	0.6338
MouseScrolls	1.000	1.000	1.000	0.0020
BTEnabled	0.995	0.994	0.997	< 0.0001
AverageTimeBetweenBreaks	1.000	1.000	1.000	0.0015
FMNEnabled	1.001	1.000	1.003	0.1007
FMNFrequency	1.001	0.997	1.006	0.6093
MicroBreaksEnabled	1.002	0.999	1.006	0.1344
MicroBreaksLength	1.019	0.992	1.047	0.1699
NumNatBreaks15secs	0.998	0.995	1.000	0.0573
NumNatBreaks60secs	1.004	0.993	1.015	0.4824
NumNatBreaks4min	0.995	0.969	1.021	0.7012
NumNatBreaks16min	1.009	0.966	1.053	0.7015
OverallBreakCompliance	1.004	1.001	1.008	0.0141

Table 7. (Continued).

Effects	Odds Ratios	95% Wald Confidence Limits		*p*-values
MicroBreaksCompliance	0.997	0.993	1.001	0.1500
WordCountAMPM	1.000	0.999	1.000	< 0.0001
KbdErrorsAMPM	1.000	1.000	1.001	0.1703
TodaysBuiltinKbdWork	1.000	1.000	1.000	0.3181
TodaysBuiltinPtrWork	1.000	1.000	1.000	0.7957

Results for Elbow and Forearm Discomfort

Partial Proportional Odd Model (Equal slopes) - Elbow and Forearm Discomfort

The outcome variables in Elbow and Forearm Discomfort model breaks the categories into four levels:

- *ModDEF*: Moderate discomfort in elbow and forearm
- *MinDEF*: Minimal discomfort in elbow and forearm
- *SFEF*: Slight fatigue in elbow and forearm
- *NDEF*: No discomfort in elbow and forearm

The score test of 0.0048, from the PPO model, calls for a PPOM. However, when the regression analysis was performed, there were no variables in the final model for equal or unequal slopes.

Results for Shoulder Discomfort

Partial Proportional Odds Model (Equal Slopes) – Shoulder Discomfort

The Shoulder Discomfort model breaks the categories into four levels:

- *ModDS*: Moderate discomfort in shoulder

- *MinDS*: Minimal discomfort in shoulder
- *SFS*: Slight fatigue in shoulder
- *NDS*: No discomfort in shoulder

Again, the regression analysis model (PPOM) resulted in no variables.

Results for Wrist and Hand Discomfort Severity

Partial Proportional Odds Model (Equal Slopes) – Wrist and Hand Discomfort

The outcome variables in the Wrist and Hand Discomfort model breaks the categories into four levels:

- *ModDWH*: Moderate discomfort in wrist and hand
- *MinDWH*: Minimal discomfort in wrist and hand
- *SFWH:* Slight fatigue in wrist and hand
- *NDWH*: No discomfort in wrist and hand

The results of the variables MouseDistance, AverageTimeBetweenBreaks, OverallBreakCompliance all have a result of 1.0 with $p < 0.0001$. Therefore, all the results have no associations with Wrist and Hand Discomfort. Results are in Tables 8 & 9.

Table 8. Study #1 Wrist and Hand Discomfort. Partial Proportional Odds Model (Equal Slopes).

Effects	Odds Ratios	95% Wald Confidence Limits		*p*-values
MouseDistance	1.000	1.000	1.000	< 0.0001
AverageTimeBetweenBreaks	1.000	1.000	1.000	< 0.0001
OverallBreakCompliance	1.006	1.003	1.009	< 0.0001

Partial Proportional Odds Model (Unequal Slopes) – Wrist and Hand Discomfort

The only variable reported from the regression analysis was HoursK. The HoursK variable was portioned out over the three columns; however, only the third column had significant results. The HoursK variable reported that participants were (Column 3) 1.265 times more likely to report *ModDWH* or *MinDWH* or *SFWH* versus *NDWH*, $p < 0.0001$.

Table 9. Study #1 Wrist and Hand Discomfort. Partial Proportional Odds Model (Unequal slopes).

Odds Ratio Estimates (95% confidence interval) (*p*-value)			
Discomfort Categories	Moderate discomfort in wrist and hand vs. Minimal discomfort in wrist and hand / Slight fatigue in wrist and hand / No discomfort in wrist and hand	Moderate discomfort in wrist and hand / Minimal discomfort in wrist and hand vs. Slight fatigue in wrist and hand / No discomfort in wrist and hand	Moderate discomfort in wrist and hand / Minimal discomfort in wrist and hand / Slight fatigue in wrist and hand vs. No discomfort in wrist and hand
HoursK	1.034 (0.901, 1.188) $p = 0.6324$	1.047 (0.957, 1.145) $p = 0.3170$	1.265 (1.162, 1.377) $p < 0.0001$

Discussion

This research study was conducted to determine if the objective variables regarding daily computer use statistics had any associations that may determine self-reported musculoskeletal discomfort. This data set was an uncommonly large sample (n = 13,762), making this study unusual.

Ijmker et al. (2011) and Mikkelsen et al. (2012) reported that using computer software, like this research, indicated that the objectively measured data reported no associations between the objectively measured results and musculoskeletal discomfort. The results in this current research were similar to these two previous studies.

Davis and Kotowski (2014) explored the impact of break-reminder software among 37 call center employees. The study results indicated that the program provided short-term musculoskeletal discomfort relief to participants, specifically offering relief in the upper back, lower back, and shoulders. On the contrary, a Cochran Review conducted by Hoe, Urquhart, Kelsall, & Sim (2012) reported a limited association between rest breaks and a reduction of MSDs while working at a computer. Van den Heuvel et al. (2003) conducted a study to explore the use of software to promote breaks and the impact of this software on MSDs. The researchers cited those individuals in the control group who were given extra breaks experienced greater musculoskeletal discomfort related recovery (Van den Heuvel et al., 2003). In this research study, one variable in the Lower Back Discomfort Model was significant and was greater than 1. This variable was BreaksSkipped with an odds ratio of 1.17, $p = 0.0410$. As reported above and confirmed by the findings of this study, taking breaks has been associated with a reduction of musculoskeletal discomfort.

For the purpose of this research study, analyses were performed on 27 variables; however, after the seven regression analyses were performed, using all 27 variables, there were only two significant results that were greater than 1. The variables of significance were the BreaksSkipped variable, which had an odds ratio of 1.17 for the Lower Back Discomfort model, and HoursK in the Wrist and Hand Discomfort model, which had an odds ratio1.265. Researchers have cited that breaks can reduce musculoskeletal discomfort while performing computer work (Ardahan & Simsek, 2016; Ellahi et al., 2011; Rehman et al., 2013; Sharan et al., 2011). Hours on a computer have also been associated with musculoskeletal discomfort, specifically low back, in self-reported studies (Rehman, Khan, Surti, & Khan, 2013).

Various study limitations should be noted. Although there were 13,762 participants in this study, not all the participants answered all the OES body part discomfort survey questions. In fact, about one-third of the participants did not answer all of the seven body part discomfort questions. Large numbers of missing data, even in a large sample, can bias the data, thus resulting in potential misclassification.

Furthermore, it was significant to note that the OES survey questions were not presented in a typical Likert scale. A Likert scale typically comprises five to seven ordinal categories (e.g., Never, Rarely, Sometimes, Often, Always; Sullivan & Artino, 2013). In the question about Neck and Upper Back Discomfort, several of the choices were similar. For example, given the choices (e.g., No Discomfort, Slight Fatigue [without any discomfort], Minimal Discomfort, Moderate Discomfort [annoying discomfort], Significant Discomfort [high-intensity discomfort]), several of these categories are very similar to each other and may have confused the participant.

As identified in the descriptive statistics article, which was written by (Bridges, 2019), study participants were given administrative rights for several software features (e.g., BTEnabled, FMNEnabled, and MicroBreakCompliance). Given the opportunity to modify software features, it was possible that the results may be cautiously evaluated.

There were various study strengths that should be noted. First and foremost, this study took place over a one-year timeframe. Secondly, this study involved a large data set. Lastly, a computer desktop software was used by each participant, whereby this software provided objectively recorded data that self-reported questionnaires cannot provide.

The weakness noted in this study were missing data, no gender information, lack of job categories for participants, software features disabled by users, and a non-Likert scale for discomfort survey categories.

CHAPTER IV

OES DATA ANALYSIS

Occupational Overview

Computers have become an essential part of the modern workplace. Employees routinely sit at computers for long durations, with static postures and without rest breaks. The growing use of computers has increased the risk of work-related musculoskeletal disorders (MSDs). These concerns in the workplace are relevant to computer use since MSDs are reported to be as high as 30 percent of overall workplace injuries, increase insurance costs, and cause significant loss in work-time.

The OES (Office Ergonomic Suite) questionnaire, which includes 40-multiple choice questions and requires participants to self-report details, was used for this project. The OES questionnaire comprises seven body part discomfort-related survey questions (e.g., Frequency of Discomfort, Neck and Upper Back Discomfort, Eyes or Head Discomfort, Lower Back Discomfort, Elbow and Forearm Discomfort, Shoulder Discomfort, and Wrist and Hand Discomfort). The seven body-part related questions were compared to 33 other questions, which pertained to the following: computer, chair, keyboard, mouse, bi/trifocals or progressive lenses use, desk set-up, body position, hours on a computer, breaks, document holder use, hand/wrist resting surface, forearm support, notebook computer use, adequate lighting, stress, monitor position and glare, equipment, and type of work. Remedy (Cority Enviance) collected information by questionnaire from each participant before starting the study. The results of the study revealed that there were subjective (self-report) methods for determining the presence of musculoskeletal disorders among employees who spend many hours per day at a computer. The statistical use of partial proportional odds models (PPOM) is the approach used to demonstrate musculoskeletal disorders in this research.

Technical Summary

Background: Computers are essential in the office work environment, and their use has increased significantly over the last two decades. The increased use of computers in the workplace has made the burden of MSDs a significant issue, as indicated by the high number of reported MSDs. ***Purpose*****:** Evaluate the OES data set using logistic regression, examining predictor variables, and comparing them to the body part discomfort outcomes to determine if any OES predictor variables demonstrate discomfort levels. ***Method*****:** This study included 13,762 participants from a secondary de-identified data set provided by Cority Enviance. A self-reported 40-question survey, which included seven body part discomfort questions, was used. Body part discomfort status (dependent variable) ranged from either four levels or five levels, comparing the highest level of discomfort at either Constant or Moderate Discomfort to the lowest level of Never experiences or No discomfort. The data's ordinal nature required a proportional odds model (cumulative logit) or a partial proportional odds model to be used. ***Results***: Two variables, Document Holder and Stress, had significant results and had associations of discomfort in each of the seven regression models (body part discomfort comparisons). This study found the variable Breaks to have discomfort associations with five models, followed by the variables Bi/trifocals and Properly Working Equipment, which had associations with four body part discomfort models. The variables Monitor

Glare, Hours on a Computer, Hand/Wrist Resting Surface, Head and Neck Posture, and Wrist Position had associations with three body part discomfort models. **Conclusion**: There were factors that influence musculoskeletal discomfort when working at a computer determined from a subjective questionnaire. Researchers may use this type of analysis and results in this study as a reference for further studies with computer software to identify variables to reduce MSDs.

Introduction

As advances in technology occur, computers have become an essential element of the workplace (Ardahan & Simsek, 2016; Estember, Panugot, & Vale, 2015; Oha et al., 2014; Yoo & Park, 2015). Furthermore, as the amount of computer use has increased, the number of musculoskeletal disorders (MSDs) reporting has escalated (Ardahan & Simsek, 2016; Estember et al., 2015; Mani, Provident, & Eckel, 2016; Nakphet, Chaikumarn, & Janwantanakul, 2014; Oha et al., 2014; Yoo & Park, 2015). Musculoskeletal discomfort among computer workers is caused by sitting for long hours, awkward posture, repetitive movements, and lack of rest breaks (Oha et al., 2014; Sharan et al., 2011), which can lead to MSDs. MSDs are the most reported occupational injury in the occupational environment, costing millions of dollars (Bureau of Labor Statistics [BLS], 2019). All the factors mentioned above reinforce the need for further research concerning musculoskeletal discomfort (Zakerian & Subramaniam, 2011).

Ardahan and Simsek (2016) conducted a cross-sectional survey and evaluated the prevalence of musculoskeletal discomfort among 395 office workers who used computers. A discomfort questionnaire was administered to the participants and based on the results; the researchers determined that working on a computer for more than seven hours per day, or three hours per day without breaks, could result in musculoskeletal discomfort (Ardahan & Simsek, 2016). Ellahi, Khalil, and Akram (2011) conducted a study on computer users and health problems associated with daily usage, which included 120 participants. Ellahi et al. (2011) found that participants who used a computer for more than four hours per day were subjected to musculoskeletal discomfort, stress, carpal tunnel, and computer vision syndrome. In a large study, which included 4,5000 participating Information Technology professionals, Sharan et al. (2011) used a questionnaire to explore the relationship between pain and hours on the computer. The researchers found that hours on a computer were a significant indicator of pain. Another study of 416 computer user participants, conducted by Rehman, Khan, Surti, and Khan (2013), identified that long hours on a computer without breaks contribute to lower back discomfort.

Sharan et al. (2011) suggested that computer workers who forgo breaks further aggravated existing musculoskeletal symptoms. Lanhers et al. (2016) used a software program to implement frequent short breaks, which resulted in a reduced number of musculoskeletal discomfort among computer users who had previously reported musculoskeletal discomfort. Active and passive rest breaks were tested on female computer workers with symptomatic neck and shoulder musculoskeletal discomfort. Those in the active rest-break group experienced decreased musculoskeletal discomfort than those in the passive group (Chaikumarn et al., 2018; Nakphet et al., 2014). Lacaze et al. (2010) conducted a study with call center workers and found that rest breaks, which included a well-designed exercise program, reduced musculoskeletal discomfort.

Researchers have reported that eye problems and headaches often occur due to working on a computer for an extended period of time each day (Ellahi et al., 2011; Gowrisankaran & Sheedy, 2015). Weidling and Jaschinski (2015) noted that computer workers who wear progressive lenses tend to tilt their heads in a way that may cause musculoskeletal discomfort, especially to the neck.

Goostrey, Treleaven, and Johnston (2014) reviewed the correlation between document location, neck movement, and muscle activity. The researchers determined that the best location for a document while working at a computer was at eye-level position. The use of a document holder was determined to facilitate the best position by the rate of neck movement and muscle activity being at their lowest. In another study by Ranasinghe et al. (2011), with 2,210 participants, reviewed the prevalence of musculoskeletal discomfort in arms, neck, and shoulders. In this study by Ranasinghe et al. (2011), the workstations were evaluated using an OSHA VDT workstation checklist, which showed that a large majority (91.9%) of participants who reported musculoskeletal discomfort had non-compliant workstations, which included either a lack of a document holder or an improperly placed document holder.

According to Estember et al. (2015), monitor position can impact musculoskeletal discomfort. Specifically, the researchers found that the monitor’s angle in relation to the user, and not the number of monitors used, influenced musculoskeletal discomfort. Farias Zuniga and Cote (2017) performed a study that evaluated the use of a laptop versus the use of dual monitors on a desktop while participants completed a 90-minute task. When using dual desk monitors, less cervical muscle activity and a more neutral neck position occurred.

The reported growing amount of time spent on a computer corresponds to an increasing amount of time sitting (Zemp, Taylor, & Lorenzetti, 2016). The length of time sitting can increase musculoskeletal discomfort in the back, legs, shoulders, arms, and neck (Zemp et al., 2016). Zemp et al. (2016) conducted studies of participants sitting on chairs that evaluated the pressure distribution while sitting on the seat pan, backrest angles, and armrest use, all of which are essential elements for comfort and reduction of work-related musculoskeletal discomfort. A study by Rodrigues, Leite, Lelis, and Chaves (2017) used Rapid Office Strain Assessment (ROSA) and Rapid Upper Limb Assessment (RULA) for ergonomic evaluations to compare computer workers who did and did not report musculoskeletal discomfort. The ROSA evaluation determined risk factors (e.g., chair, keyboard, mouse, and monitor) that impacted worker posture while at a computer and explored equipment usage. The outcome of the ROSA evaluation demonstrated a significant correlation with discomfort, especially in chair height, back, and armrests, among participants who reported having musculoskeletal discomfort compared to their counterparts with no reported musculoskeletal discomfort. In the RULA outcomes, the workstation variables (e.g., number of monitors, the height of configuration, keyboard position, chair height, armrests, and backrest) were higher among participants who reported musculoskeletal discomfort participants than participants with no musculoskeletal discomfort (Rodrigues et al., 2017).

Robertson, Huang, and Larson (2016) noted several factors that impacted musculoskeletal discomfort caused by computer use. These factors were psychosocial factors of co-worker support and relationships with their supervisor. If these relationships were favorable for workers, this could buffer stress, thereby reducing musculoskeletal discomfort (Robertson et al., 2016). Sharan et al. (2011) explored work-related stress among 4,500 computer professionals using a questionnaire and determined a correlation existed between work-related stress and musculoskeletal discomfort. Taib, Bahn, and Yun (2016) induced psychosocial stress using electromyography (EMG) while participants performed computer tasks. Taib et al. (2016) found that different levels of induced stress impact muscle activity, thereby contributing to musculoskeletal discomfort. Furthermore, Zakerian and Subramaniam (2011) noted that a significant relationship between psychosocial work factors (including stress) and the development of musculoskeletal discomfort existed.

In the 1990s, when computers gained workplace popularity, researchers explored the relationship between musculoskeletal discomfort and working on computers (Bergqvist, Wolgast, Nilsson, & Voss, 1995; Sundelin & Hagberg, 1989). Bergqvist et al. (1995) conducted a study that included 260 computer users and explored musculoskeletal discomfort using workplace ergonomic evaluations, physiotherapist's exams, and a questionnaire. The researchers noted that possible musculoskeletal discomfort occurred due to stress, lacking rest breaks, keyboard, mouse height, monitor height, and non-use of lower arm support. Sundelin et al. (1989) performed EMG testing in the upper body muscles to explore the impact of rest break pauses, specifically active and passive pauses, when engaging in computer work. Sundelin et al. (1989) concluded that active rest breaks decreased muscular discomfort and were the preferred mode of rest breaks.

Due to the increased use of computers in the workplace, which occurred in the late 1990s to early 2000s, researchers cited the development of musculoskeletal discomfort. Specifically, a correlation between the number of hours spent working on a computer and musculoskeletal discomfort was noted (Bergqvist et al., 1995; Blatter & Bongers, 2002; Gerr, Marcus, & Monteilh, 2004; Jensen, Ryholt, Burr, Villadsen, & Christensen, 2002; Van den Heuvel, De Looze, Hildebrandt, & Thé, 2003). Researchers noted that ergonomic workstations promote neutral postures and reduced musculoskeletal discomfort (Bergqvist et al., 1995; Karlqvist, Hagberg, & Selin, 1994). Further studies indicated that breaks during computer use reduced musculoskeletal discomfort (Henning, Jacques, Kissel, Sullivan, & Alteras-Webb, 1997; Van den Heuvel et al., 2003).

The primary objective of this study was to identify predictor variables for developing musculoskeletal discomfort while working at a computer through the use of a self-reported questionnaire. This procedure was accomplished by developing ordinal logistic regression models, specifically proportional and partial proportional odds models, and analyzing each of the seven body part discomfort concerns compared to the OES questionnaire.

Methods

Data Information

In 2015, Cority Enviance, Inc. provided Texas A&M University with a secondary data set. This data set reflects participation by 13,762 employees who worked for an oil and gas company from 2013 to 2015. The data set was de-identified and does not provide details regarding demographic variables (e.g., gender of participants or job classification), as agreed upon by Cority Enviance's clients when the study was initially conducted. No information about experimental design, informed consent, or specifics of the data collection is known. In March of 2016, Texas A&M University's Institutional Review Board approved the analysis of the Cority Enviance data.

Data Collection

In this Remedy Study (Cority Enviance), each participant took a 40-question survey called the Office Ergonomic Suite (OES; Appendix A). Remedy (Cority Enviance) collected the OES questionnaire from each participant before the study began.

The OES questionnaire was administered to determine body part discomfort, daily time on a computer, and computer set-ups (e.g., back and backrest position, head and neck position, chair height, seat pan, foot position, armrest position, with or without armrests, adjustable armrests, forearms support, shoulder abduction and reach, elbow position, wrist position, keyboard, and mouse space, monitor height, glare, and the number of monitors). The questionnaire also contained questions regarding document holder usage, head tilt due to bifocals, trifocals, or progressive lenses use, notebook computer uses, properly working equipment, shared workstation, secondary office, hand-held device use, type of work performed, and stress.

Statistical Analysis

The model building for the seven dependent variables (i.e., Frequency of Discomfort, Neck and Upper Back Discomfort, Eyes or Head Discomfort, Lower Back Discomfort, Elbow and Forearm Discomfort, Shoulder Discomfort, and Wrist and Hand Discomfort) were analyzed using a proportional odds model, which was due to the ordinal nature of the dependent variables. The seven dependent variables were analyzed against the 33 questions in the OES questionnaire, which had categorical choices (dependent variables; Appendix A). The four or five dependent variables (depending on the model) ranged from Constant, Frequent, Infrequent, or Never Experiences Discomfort to Severe, Moderate, Minimal, Slight, Never/No discomfort, depending on the question.

The predictor variables were based on the factors that contribute to musculoskeletal discomfort. They consisted of the following: set-up of computer, chair, keyboard, mouse, desk, body positioning, bi/trifocals use, hours on a computer, breaks, document holder use, hand/wrist resting surface, forearm support, notebook computer use, adequate lighting, stress, monitor position and glare, equipment, and type of work.

The model was built using a logistic regression analysis with SAS 9.4, which defaulted to a *p*-value of 0.05 to determine the model's variables. The proportional odds model using proc logistic in SAS gives a score test for the proportional odds assumption. The score test result tells if the proportional odds model fails to reject the null hypothesis (of the regression analysis); therefore, the results are not proportional (significant results), and a partial proportional odds model (PPOM) needs to be performed. If the null hypothesis is rejected, the proportionality is satisfied, i.e., the score test result is not significant, a POM can be utilized.

The null and alternative hypotheses for proportionality are as followed:

H_o = Score test determines there is no proportionality

H_A = Score test determines there is proportionality

Proportional and Partial Proportional Odds Model

The proportional odds model (POM) is an extremely conservative analysis method, which is often violated when there is a large data set with many variables (Allison, 2012; Fullerton & Xu, 2012; Long & Freese, 2014; Williams, 2016). The POM is based on the assumption that all the outcome categories are parallel; in other words, it assumes that the coefficient ß for all outcome categories is the same, and therefore equal or parallel (proportional; Soon, 2010). However, when the parallel assumption fails, a partial proportional odds model (PPOM) is utilized and therefore allows the ß coefficients to differ for each of the outcome categories, or if parallel, the ß coefficients can be the same (Soon, 2010). The PPOM allows the model to relax the parallel-lines assumption for the variables where the assumption is violated but not for the other variables (Das & Rahman, 2011).

A PPOM is like a POM in that the response or dependent variables are treated as ordinal variables. Still, a PPOM allows for the assumption of proportional odds for some predictor variables and relaxes the assumption of other variables, specifically when the parallel assumption has been violated (Chirikov, 2015; Sasidharan & Menéndez, 2014). Essentially, the PPOM model can have both parallel (equal slopes) and nonparallel (unequal slopes) outcomes (Soon, 2010).

Soon (2010) stated that a partial proportional analysis could further be explained as taking the 4 or 5 ordinal responses and dividing them into dichotomous responses (partial-out between the levels of discomfort), which takes the ordinal response variable and collapses it into two categories. Next, an analysis by binary logistic regression is performed (Williams, 2016). For example, responses (Table 11) are coded as:

- 1 = Constant Work-Related Discomfort (*CWRD*)
- 2 = Frequent Work-Related Discomfort (*FWRD*)
- 3 = Infrequent Work-Related Discomfort (*IWRD*)
- 4 = Never Experiences Discomfort (*NED*)

The first partitions are the following:

- (Column 1) – 1 (*CWRD*) versus 2, 3, 4 (*FWRD* or *IWRD* or *NED*)
- (Column 2) – 1 & 2 (*CWRD* or *FWRD*) versus 3 & 4 (*IWRD* or *NED*).
- (Column 3) – 1, 2, 3 (*CWRD* or *FWRD* or *IWRD)* versus 4 (*NED*)

The other 6 PPOM follow the same process.

Results

Overview of the Hypothesis

Initially, the researcher hypothesized that there would be no difference between the OES predictor variables and reported musculoskeletal discomfort among the participants. If the predictor variables were associated with musculoskeletal discomfort and were significant, then there was an association of the predictor variables to body discomfort (musculoskeletal discomfort) in the analysis.

The null and alternative hypotheses for the study are the following:

H_o =There is no association between the OES predictor variables and musculoskeletal discomfort in computer work

H_A=There is an association between the OES predictor variables and musculoskeletal discomfort in computer work

In the following paragraphs, only significant results were discussed. However, significant results and non-significant results are provided in the tables below from the regression analysis results.

Results of the Proportional Odds Assumption

A proportional odds model (POM) was analyzed for Frequency of Discomfort, which produced a score test *p*-value of less than 0.0001. Since that was a proportionality assumption failure, a PPOM model was analyzed. This result gave equal slopes with significant variables to Hours on a Computer, Breaks, Bi/trifocals, Monitor Glare, Back position, Backrest position, Hand/Wrist Resting Surface, Head and Neck Posture, Monitor Position Rotation, Properly Working Equipment, Secondary Home Office, and Type of Work. The unequal slopes result that were significant results included the variables Use of Notebook Computer without Equipment, Document Holder, and Stress.

The Neck and Upper Back Discomfort model was analyzed using a POM. SAS provided a score test for the proportional odds assumption as a significant result of 0.0052, which was a failure of the proportionality assumption. Since the model's score test was significant, a PPOM was utilized. The results from the PPOM showed a model of equal slope variables, with significant results of Breaks, Bi/trifocals, Monitor Glare, Hand/Wrist Resting Surface, Head and Neck Posture, and Keyboard and Mouse Height. The PPOM resulted in three significant unequal slope variables: Document Holder, Properly Working Equipment, and Stress.

The Eyes or Head Discomfort model was initially analyzed using a POM; however, the score test result was 0.0001. This result was a failure of proportionality, and therefore a PPOM was used. The results for the PPOM showed equal slope variables with significant results for Hours on a Computer, Document Holder, Bi/trifocals, Head and Neck Posture, and Stress. The PPOM only resulted in one unequal slope variable of Monitor Glare.

The Lower Back Discomfort model was only analyzed with a POM because the score test result was 0.2280, which was not significant and, therefore, the assumption of proportionality was accepted. Since the score test was not significant, all 33 variables were analyzed in the POM. However, many of the variables were eliminated through the stepwise process in the regression analysis. The Lower Back Discomfort model's significant variables were Breaks, Document Holder, Bi/trifocals, Monitor Height, Forearm Support, Notebook Travel, Properly Working Equipment, and Stress.

For the Elbow and Forearm model, a POM was initially utilized in the analysis; however, the score test result was 0.0114. This score test was a failure of proportionality, and therefore a PPOM was used. The variables Breaks and Wrist Position were found to be equal slope variables and significant. The unequal slope variables with significance in this model were Document Holder and Stress.

In the Shoulder Discomfort model, a POM was analyzed, which resulted in a score test of 0.0002, which was a failure of proportionality. The only equal slope variables with significance were Properly Working Equipment and Wrist Position. The unequal slope variables with significance were Document Holder and Stress.

The Wrist and Hand Discomfort was analyzed with a POM and resulted in a failure of proportionality with a score test result *p*-value of less than 0.0001. The PPOM analysis resulted in significant equal slope variables of Hours on a Computer, Breaks, Document Holder, Hand/Wrist Resting Surface, Stress, and Wrist Position. There were no unequal slope variables in this model.

Results for Frequency of Discomfort

Partial Proportional Odds Model (Equal Slopes) – Frequency of Discomfort

The Frequency of Discomfort model had 12 variables that resulted in proportional odds (equal slopes). See Table 10, Frequency of Discomfort – Partial Proportional Odds Results (Equal Slopes).

The outcome variables in this Frequency of Discomfort model consist of four levels, listed from highest (worst discomfort) to lowest (least discomfort):

- Constant Work-Related Discomfort (*CWRD*)
- Frequent Work-Related Discomfort (*FWRD*)
- Infrequent Work-Related Discomfort (*IWRD*)
- Never Experiences Discomfort (*NED*)

Lastly, if the predictor variables were not significant, they are not discussed here.

Table 10. Study #2 Frequency of Discomfort. Partial Proportional Odds (Equal Slopes).

Effect	Odds Ratio	95% Wald Confidence Limits		*p*-values
Hours on a Computer				
– 0-2 hrs on a computer vs. 6+ hours on a computer	0.431	0.352	0.529	< 0.0001
– 2-6 hrs on a computer vs. 6+ hours on a computer	0.771	0.694	0.857	< 0.0001
Breaks				
– Takes break once every hour vs. Takes breaks once every 3 hours	0.658	0.554	0.782	< 0.0001
– Takes breaks once every 2 hours vs. Takes breaks once every 3 hours	0.883	0.736	1.059	0.1791
Bi/trifocals				
– Does not lean head backward due to bi/trifocal use vs. Leans head backward due to bi/trifocal use	0.490	0.387	0.621	< 0.0001

Table 10. (Continued).

Effect	Odds Ratio	95% Wald Confidence Limits		*p*-values
Monitor Glare				
– No monitor glare vs. Severe monitor glare	3.284	1.024	10.531	0.0454
– Moderate monitor glare vs. Severe monitor glare	7.615	2.353	24.643	0.0007
Back Position				
– Neutral back position vs. Severe low back slump	1.116	0.477	2.615	0.7998
– Back position neutral (no use of backrest, sitting upright) vs. Severe low back slump	0.974	0.137	6.920	0.9788
– Back leaning forward vs. Severe low back slump	0.898	0.053	15.208	0.9403
– Back moderately leaning forward vs. Severe low back slump	1.815	0.767	4.296	0.1752

Table 10. (Continued).

Effect	Odds Ratio	95% Wald Confidence Limits		*p*-values
– Moderate low back slump vs. Severe low back slump	1.752	0.716	4.289	0.2194
– Reclined backrest vs. Severe low back slump	2.384	0.842	6.750	0.1018
– Back severely leaning forward vs. Severe low back slump	5.217	1.590	17.112	0.0064
Backrest position				
– Neutral backrest position vs. Backrest too high	0.687	0.569	0.830	< 0.0001
– Backrest too low vs. Backrest too high	0.838	0.678	1.036	0.1030
Hand/Wrist Resting Surface				
– Hands and wrists do not rest on a hard surface vs. Hands and wrists rest on hard surface	0.608	0.507	0.729	< 0.0001
Head and Neck Posture				
– Neutral head and neck posture vs. Severe forward head posture	0.482	0.331	0.703	0.0001

Table 10. (Continued).

Effect	Odds Ratio	95% Wald Confidence Limits		*p*-values
– Moderate forward head posture vs. Severe forward head posture	1.149	0.794	1.661	0.4614
Monitor Position Rotation				
– Neutral monitor position (rotation) vs. Monitor severely off center	2.528	1.339	4.771	0.0042
– Monitor moderately off-center vs. Monitor severely off center	3.823	2.102	7.262	< 0.0001
Properly Working Equipment				
– Equipment and accessories are working properly vs. Equipment and/or accessories not working properly	0.485	0.380	0.617	< 0.0001
Secondary Home Office				
– Does not have a secondary home office vs. Has a secondary home office	0.827	0.747	0.914	0.0002

Table 10. (Continued).

Effect	Odds Ratio	95% Wald Confidence Limits		*p*-values
Type of Work				
– Moderate levels of both keyboard and mouse work vs. Precision mouse work (e.g., graphic design, CAD, etc.)	0.733	0.650	0.827	< 0.0001
– Keyboard intensive work (e.g., data entry, spreadsheet, etc.) vs. Precision mouse work (e.g., graphic design, CAD, etc.)	0.797	0.666	0.955	0.0138

For the question regarding Hours on a Computer, participants reporting *0-2 hours on a computer* were 0.431 times more likely to report *NED* than participants who reported *6+ hours on a computer*, $p < 0.0001$. For participants reporting *2-6 hours on a computer*, the results were 0.771 times more likely to report *NED* than participants who reported *6+ hours on a computer*, $p < 0.0001$.

For the variable Breaks, participants who reported *Takes break once every hour* were approximately 0.658 times more likely to report *NED* than participants who reported *Takes breaks once every 3 hours*, $p < 0.0001$.

When asked about Bi/trifocals or Progressive lenses when viewing a monitor, those who reported *Does not lean head backward due to bi/trifocal* use were approximately 0.490 times more likely to report *NED* than participants who reported *Leans head backward due to bi/trifocal use*, $p < 0.0001$.

When asked about Monitor Glare, participants who reported *No monitor glare* were 3.284 times more likely to report *CWRD* than the participants who reported *Severe monitor glare*, $p = 0.0454$. For Monitor Glare's other level, participants that reported *Moderate monitor glare* were 7.615 times more likely to report *CWRD* versus participants who reported *Severe monitor glare*, $p = 0.0007$.

For the question about Back Position, participants who reported *Back severely leaning forward* were 5.217 times more likely to report *CWRD* than participants who reported *Severe low back slump*, $p = 0.0064$.

For the question regarding Backrest Support, the participants who reported *Neutral backrest position* resulted in an odds ratio of 0.687 times more likely to report *NED* than the participants who experienced *Backrest too high*, $p < 0.0001$.

In the question concerning Hand/Wrist Resting Surface type (hard or sharp), participants who reported *Hands and wrists do not rest on a hard surface* were 0.608 times more likely to report *NED* than participants who reported *Hands and wrists rest on a hard surface*, $p < 0.0001$.

In the question about Head and Neck posture when viewing the monitor, participants that showed *Neutral head and neck posture* were 0.482 times more likely to report *NED* than the participants who reported *Severe forward head posture*, $p = 0.0001$.

When asked about head rotation when viewing the monitor (Monitor Position Rotation), participants who reported *Neutral monitor position* were 2.528 times more likely to report *CWRD* than participants who reported *Monitor severely off-center*, $p = 0.0042$. When participants reported *Monitor moderately off-center*, these participants were 3.823 times more likely to report *CWRD* than participants who reported *Monitor severely off-center*, $p < 0.0001$.

When asked, "Does all of your workstation equipment work properly?" participants who reported that their *Equipment and accessories were working properly* were 0.485 times more likely to report *NED* than participants who reported that their *Equipment and/or accessories were not working properly*, $p < 0.0001$.

When asked, "Do you have a secondary home office at home where you do computer work on a weekly basis (at least once per week)?" Participants who reported *Does not have a secondary home office* were 0.827 times more likely to report *NED* than the participants who *Has a secondary home office*, $p = 0.0002$.

When asked, "What type of work do you spend the most time doing on the computer?" participants who reported *Moderate levels of both keyboard and mouse work* were 0.733 times more likely to report *NED* than participants who claimed *Precision mouse work* (e.g., graphic design, CAD, etc.), $p < 0.0001$. Participants who reported *Keyboard-intensive work* (e.g., data entry, spreadsheets, etc.) were 0.797 times more likely to report *NED* than participants who claimed *Precision mouse work* (e.g., graphic design, CAD, etc.), $p < 0.0138$.

Partial Proportional Odds Model (Unequal Slopes) – Frequency of Discomfort

The outcome variable in this Frequency of Discomfort model breaks the categories into the following groups:

- Column 1: Constant Work-Related Discomfort (*CWRD*) vs. Frequent Work-Related Discomfort (*FWRD*) or Infrequent Work-Related Discomfort (*IWRD*) or Never Experiences Discomfort (*NED*)
- Column 2: Constant Work-Related Discomfort or Frequent Work-Related Discomfort vs. Infrequent Work-Related Discomfort or Never Experiences Discomfort
- Column 3: Constant Work-Related Discomfort or Frequent Work-Related Discomfort or Infrequent Work-Related Discomfort vs. Never Experiences Discomfort

Table 11 lists results for Frequency of Discomfort PPOM unequal slopes.

For the variable Use of Notebook Computer without External Equipment, participants were asked, "During a typical work week, how many hours do you work with your notebook computer without any equipment attached to it (No external keyboard, mouse, stand or monitor)?" The results showed that participants who reported that they *Never use a notebook computer without external equipment* were (Column 3) 1.872 times more likely to report *CWRD, FWRD*, or *IFRD* versus *NED*, compared to participants who reported *Uses a notebook computer without external equipment greater than 20 hours/week, p* = 0.0011.

Table 11. Study #2 Frequency of Discomfort. Partial Proportional Odds (Unequal slopes).

	Odds Ratio Estimates (95% confidence interval) (*p*-value)		
Discomfort Categories	Constant Work-Related Discomfort vs. Frequent Work-Related Discomfort/ Infrequent Work-Related Discomfort/ Never Experiences Discomfort	Constant Work-Related Discomfort/ Frequent Work-Related Discomfort vs. Infrequent Work-Related Discomfort/ Never Experiences Discomfort	Constant Work-Related Discomfort/ Frequent Work-Related Discomfort/ Infrequent Work-Related Discomfort vs. Never Experiences Discomfort
Use of Notebook Computer w/o Equipment			
– Never uses a notebook computer w/o external equipment vs. Uses notebook computer w/o external equipment > 20 hrs/wk	2.178 (0.620, 7.653) $p = 0.2246$	1.172 (0.712, 1.930) $p = 0.5316$	1.872 (1.284, 2.729) $p = 0.0011$

Table 11. (Continued).

Discomfort Categories	CWRD vs. FWRD/IWRD/NED	CWRD/FWRD vs. IWRD/NED	CWRD/FWRD/ IWRD vs. NED
– Uses a notebook computer w/o external equipment 1-10 hrs/wk vs. Uses notebook computer w/o external equipment > 20 hrs/wk	1.761 (0.512, 6.059) $p = 0.3691$	1.246 (0.766, 2.028) $p = 0.3753$	2.575 (1.772, 3.740) $p < 0.0001$
– Uses a notebook computer w/o external equipment 10-20 hrs/wk vs. Uses notebook computer w/o external equipment > 20 hrs/wk	0.791 (0.156, 4.008) $p = 0.7770$	0.914 (0.512, 1.629) $p = 0.7595$	2.567 (1.664, 3.958) $p < 0.0001$
Document Holder			
– Does not commonly view documents lying flat on desk vs. Commonly views documents lying flat on desk	0.736 (0.427, 1.272) $p = 0.2723$	0.341 (0.266, 0.436) $p < 0.0001$	0.326 (0.225, 0.471) $p < 0.0001$

Table 11. (Continued).

Discomfort Categories	CWRD vs. FWRD/IWRD/NED	CWRD/FWRD vs. IWRD/NED	CWRD/FWRD/ IWRD vs. NED
Stress			
– Low stress vs. High stress	0.205 (0.108, 0.391) $p < 0.0001$	0.361 (0.284, 0.460) $p < 0.0001$	0.382 (0.318, 0.458) $p < 0.0001$
– Medium stress vs. High stress	0.348 (0.218, 0.555) $p < 0.0001$	0.609 (0.496, 0.747) $p < 0.0001$	0.735 (0.614, 0.881) $p = 0.0008$

In the next level of the notebook computer question, participants who reported *Uses a notebook computer without external equipment 1-10 hrs/wk* were (Column 3) 2.575 times more likely to report *CWRD, FWRD,* or *IWRD* versus *NED* than the participants who reported *Uses notebook computer without external equipment greater than 20 hours/week, p* < 0.0001.

In the third level of the notebook computer question, participants who reported *Uses a notebook computer without external equipment 10-20 hrs/wk* were (Column 3) 2.567 times more likely to report *CWRD, FWRD,* or *IWRD* versus *NED* than participants who reported *Uses notebook computer without external equipment greater than 20 hours/week, p* < 0.0001.

For the question concerning Document Holder in the PPOM, the results were partitioned into two columns with significant results. Participants who reported *Does not commonly view documents lying flat on desk* were (Column 2) 0.341 times more likely to report *IWRD* or *NED* versus *CWRD* or *FWRD;* (Column 3) 0.326 times more likely to report *NED* versus *CWRD*, *FWRD,* or *IWRD* than participants who reported *Commonly views documents lying flat on a desk, p* < 0.0001, for both columns.

The question concerning Stress, partitioned out over the three columns, showed that participants that reported *Low stress* were 0.205 times more likely to report (Column 1) *FWRD*, *IWRD*, or *NED* versus *CWRD*; (Column 2) 0.361 times more likely to report *IWRD* or *NED* versus *CWRD* or *FWRD;* (Column 3) 0.382 more likely to report *NED* versus *CWRD* or *FWRD* or *IWRD* than participants who reported *High stress, p* < 0.0001 for all columns. Participants that reported *Medium stress* were 0.348 times more likely to report (Column 1) *FWRD* or *IWRD* or *NED* versus *CWRD;* (Column 2) 0.609 times more likely to report *IWRD* or *NED* versus *CWRD* or *FWRD*; (Column 3) 0.735 times more likely to report (Column 3) *NED* versus *CWRD, FWRD,* or *IWRD* than participants who reported *High stress, p* < 0.0001 (Column 1 & 2), *p* = 0.0008 (Column 3).

Results of Neck and Upper Back Discomfort

Partial Proportional Odds Model (Equal Slopes) – Neck and Upper Back Discomfort

The outcome variables in the Neck and Upper Back Discomfort model have four levels from highest to lowest level of discomfort. Moderate discomfort in neck and upper back (*ModDNUB*), Minimal discomfort in neck and upper back (*MinDNUB*), Slight fatigue in neck and upper back discomfort (*SFNUB*), and No discomfort in neck and upper back (*NDNUB*). If the predictor variables are not significant, they are therefore not discussed. Table 12 lists the results for Neck and Upper Back Discomfort equal slopes results.

Table 12. Study #2 Neck and Upper Back Discomfort. Partial Proportional Odds (Equal Slopes).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Breaks				
– Takes breaks once every hour vs. Takes break once every 3 hours	0.602	0.502	0.722	< 0.0001
– Takes breaks once every 2 hours vs. Takes breaks every 3 hours	0.659	0.544	0.798	< 0.0001
Bi/trifocals				
– Does not lean head backward due to bi/trifocal use vs. Leans head backward due to bi/trifocal uses	0.645	0.510	0.817	0.0003
Monitor Glare				
– No monitor glare vs. Severe monitor glare	3.082	1.170	8.115	0.0227
– Moderate monitor glare vs. Severe monitor glare	4.596	1.726	12.237	0.0023
Hand/Wrist Resting Surface				
– Hands and wrists do not rest on a hard surface vs. Hands and wrists rest on hard surface	0.794	0.658	0.958	0.0162

Table 12. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Head and Neck Posture				
– Neutral head and neck posture vs. Severe forward head posture	0.474	0.338	0.665	< 0.0001
– Moderate forward head posture vs. Severe forward head posture	0.892	0.628	1.265	0.5203
Keyboard Mouse Height				
– Neutral keyboard and mouse height vs. Keyboard too high	0.600	0.463	0.777	0.0001
– Keyboard too low vs. Keyboard too high	0.656	0.479	0.899	0.0087
Shared Workstation				
– Uses non-shared ("Dedicated") workstation vs. Never works at corporate site	5.318	0.672	42.108	0.1134
– Uses shared ("Free Address") workstation vs. Never works at corporate site	7.421	0.927	59.384	0.0589

For the variable Breaks, participants reporting *Takes breaks once every hour* are approximately 0.602 times more likely to report *NDNUB* than participants who reported

Takes breaks once every 3 hours, $p < 0.0001$. In the next level, participants that report *Takes breaks once every 2 hours* were approximately 0.659 times more likely to report *NDNUB* than participants who reported *Takes breaks once every 3 hours*, $p < 0.0001$.

For the question concerning wearing Bi/trifocals or Progressive lenses when viewing a monitor, those reporting *Does not lean head backward due to bi/trifocal use* are 0.645 more likely to report *NDNUB* than participants who reported *Leans head backward due to bi/trifocal use*, $p < 0.0003$.

When asked about Monitor Glare, participants that reported *No monitor glare* were 3.082 times more likely to report *ModDNUB* versus participants reporting severe monitor glare, $p = 0.0227$. For the next level of Monitor Glare, participants that reported *Moderate monitor glare* were 4.596 times more likely to report *ModDNUB* versus participants reporting *Severe monitor glare*, $p = 0.0023$.

When asked about Hand/Wrist Resting Surface, participants who answered *Hands and wrists do not rest on a hard surface* were 0.794 more likely to answer *NDNUB* than participants who answered *Hands and wrists rest on a hard surface*, $p = 0.0162$.

The question of Head and Neck Posture as you view your monitor, the results showed that participants who chose *Neutral head and neck posture* were 0.474 times more likely to report *NDNUB* than the participants who reported *Severe forward head posture*, $p < 0.0001$.

The question about Keyboard and Mouse Height (concerning elbow position) showed participants reporting *Neutral keyboard and mouse height* were 0.600 times more likely to report *NDNUB* than the participants who reported *Keyboard too high*, *p* = 0.0001. The other level (elbow position) showed that participants reporting *Keyboard too low* were 0.656 times more likely to report *NDNUB* than the participants who reported *Keyboard too high*, *p* = 0.0087.

Partial Proportional Odds Model (Unequal Slopes) – Neck and Upper Back Discomfort

The outcome variables in this Neck and Upper Back Discomfort model breaks the categories into the following groups (Table 13):

- Column 1: Moderate discomfort in neck and upper back (*ModDNUB*) versus Minimal discomfort in neck and upper back (*MinDNUB*) or Slight fatigue in neck and upper back discomfort (*SFNUB*) or No discomfort in neck and upper back (*NDNUB*)
- Column 2: Moderate discomfort in neck and upper back (*ModDNUB*) or Minimal discomfort in neck and upper back (*MinDNUB*) versus Slight fatigue in neck and upper back discomfort (*SFNUB*) or No discomfort in neck and upper back (*NDNUB*)
- Column 3: Moderate discomfort in neck and upper back (*ModDNUB*) or Minimal discomfort in neck and upper back (*MinDNUB*) or Slight fatigue in neck and upper back discomfort (*SFNUB*) versus No discomfort in neck and upper back (*NDNUB*)

For the question regarding using a Document Holder and do you frequently experience upper back and/or neck fatigue, the participants that reported *Does not* *commonly view documents lying flat on desk* were (Column 1) 0.320 times more likely to report *MinDNUB* or *SFNUB* or *NDNUB* versus *ModDNUB*; (Column 2) 0.299 times more likely to report *SFNUB* or *NDNUB* versus *ModDNUB* or *MinDNUB*; (Column 3) 0.280 times more likely to report *NDNUB* versus *ModDNUB* or *MinDNUB* or *SFNUB*, compared to the participants who reported *Commonly views documents lying flat on a desk*, $p < 0.0001$ (all results).

Table 13. Study #2 Neck and Upper Back Discomfort. Partial Proportional Odds (Unequal Slopes).

Odds Ratio Estimates (95% confidence interval) (*p*-value)			
Discomfort categories	Moderate discomfort in neck and upper back vs. Minimal discomfort in neck and upper back/ Slight fatigue in neck and upper back/ No discomfort in neck and upper back	Moderate discomfort in neck and upper back/ Minimal discomfort in neck and upper back vs. Slight fatigue in neck and upper back/ No discomfort in neck and upper back	Moderate discomfort in neck and upper back/ Minimal discomfort in neck and upper back/ Slight fatigue in neck and upper back vs. No discomfort in neck and upper back
Document Holder			
– Does not commonly view documents lying flat on desk vs. Commonly views documents lying flat on desk	0.320 (0.237, 0.430) $p < 0.0001$	0.299 (0.236, 0.378) $p < 0.0001$	0.280 (0.193, 0.406) $p < 0.0001$

Table 13. (Continued).

Discomfort categories	ModDNUB vs. MinDNUB/SFNUB/ NDNUB	ModDNUB/ MinDNUB vs. SFNUB/NDNUB	ModDNUB/ MinDNUB/ SFNUB vs. NDNUB
Properly Working Equipment			
– Equipment and accessories are working properly vs. Equipment and/or accessories not working properly	0.610 (0.422, 0.884) $p = 0.0089$	0.487 (0.368, 0.643) $p < 0.0001$	0.787 (0.564, 1.098) $p = 0.1580$
Stress			
– Low stress vs. High stress	0.289 (0.202, 0.414) $p < 0.0001$	0.403 (0.325, 0.500) $p < 0.0001$	0.582 (0.474, 0.713) $p < 0.0001$
– Medium stress vs. High stress	0.453 (0.344, 0.597) $p < 0.0001$	0.602 (0.501, 0.724) $p < 0.0001$	0.772 (0.637, 0.936) $p = 0.0085$

When asked about Properly working equipment, participants that reported *Equipment and accessories are working properly* were (Column 1) 0.610 more likely to report *MinDNUB* or *SFNUB* or *NDNUB* versus *ModDNUB*; (Column 2) 0.487 more likely to report *SFNUB* or *NDNUB* versus *ModDNUB* or *MinDNUB* when compared to participants who reported *Equipment and/or accessories not working properly*, $p = 0.0089$, $p < 0.0001$, respectively.

When asked about Stress, participants that reported *Low stress* were (Column 1) 0.289 times more likely to report *MinDNUB* or *SFNUB* or *NDNUB* versus *ModDNUB*; (Column 2) 0.403 times more likely to report *SFNUB* or *NDNUB* versus *ModDNUB* or *MinDNUB*; (Column 3) 0.582 times more likely to report *NDNUB* versus *ModDNUB* or *MinDNUB* or *SFNUB* in comparison to participants who reported *High stress*, $p < 0.0001$, for all columns. For the next level of Stress, participants that reported *Medium stress* were (Column 1) 0.453 times more likely to report *MinDNUB* or *SFNUB* or *NDNUB* versus *ModDNUB*; (Column 2) 0.602 times more likely to report *SFNUB* or *NDNUB* versus *ModDNUB* or *MinDNUB*; (Column 3) 0.772 times more likely to report *NDNUB* versus *ModDNUB* or *MinDNUB* or *SFNUB* in comparison to participants who reported *High stress*, $p < 0.0001$ (Column 1 & 2), $p = 0.0085$ (Column 3).

Results of Eyes or Head Discomfort Severity

Partial Proportional Odds Model (Equal slopes) – Eyes or Head Discomfort Severity

The outcome variables in the Eyes or Head Discomfort model breaks the categories into five levels. The following are the levels for this model:

- *SevDEH*: Severe discomfort in eyes or head
- *ModDEH*: Moderate discomfort in eyes or head
- *MinDEH*: Minimal discomfort in eyes or head
- *SFEH*: Slight fatigue in eyes or head
- *NDEH*: No discomfort in eyes or head

If the predictor variables were not significant, they were therefore not explained. Results are reported in Table 14.

Table 14. Study #2 Eyes or Head Discomfort. Proportional Odds Model (Equal Slopes).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Hours on a Computer				
– 0-2 hours on a computer vs. 6+ hours on a computer	0.466	0.342	0.636	< 0.0001
– 2-6 hours on a computer vs. 6+ hours on a computer	0.780	0.690	0.883	< 0.0001
Document Holder				
– Does not commonly view documents lying flat on desk vs. Commonly views documents lying flat on desk	0.485	0.391	0.601	< 0.0001
Bi/trifocals				
– Does not lean head backward due to bi/trifocal use vs. Leans head backward due to bi/trifocal use	0.653	0.511	0.836	0.0007

Table 14. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Head and Neck Posture				
– Neutral head and neck posture vs. Severe forward head posture	0.399	0.282	0.565	< 0.0001
– Moderate forward head posture vs. Severe forward head posture	0.610	0.425	0.876	0.0074
Stress				
– Low stress vs. High stress	0.528	0.442	0.631	< 0.0001
– Medium stress vs. High stress	0.622	0.529	0.732	< 0.0001

In the question of Hours on a Computer, participants reporting *0-2 hours on a computer* were 0.466 more likely to report *NDEH* than participants who reported *6+ hours on a computer*, $p < 0.0001$. In the next level, participants who chose *2-6 hours on a computer* were 0.780 times more likely to report *NDEH* than participants who reported *6+ hours on a computer*, $p < 0.0001$.

For the question with regards to using a Document Holder and do you frequently experience upper back and/or neck fatigue, the participants that reported *Does not commonly view documents lying flat on desk* were 0.485 times more likely to report *NDEH* than the participants who reported *Commonly views documents lying flat on a desk*, $p < 0.0001$.

For the variable Bi/trifocals or Progressive Lenses use and head tilt, the participants reporting *Does not lean head backward due to bi/trifocal use* were approximately 0.653 times more likely to report *NDEH* than participants who reported *Leans head backward due to bi/trifocal use*, $p = 0.0007$.

In the question of Head and Neck Posture, while viewing a monitor, participants who chose *Neutral head and neck posture* were 0.399 more likely to report *NDEH* than the participants who reported *Severe forward head posture*, $p < 0.0001$. Participants in the next level reporting *Moderate forward head posture* were 0.610 more likely to report *NDEH* than the participants who reported *Severe forward head posture*, $p = 0.0074$.

Regarding stress, participants who reported *Low stress* were 0.528 times more likely to report *NDEH* than the participants who reported *High stress*, $p < 0.0001$. In the higher stress level, participants that reported *Medium stress* were 0.622 more likely to report *NDEH* than the participants who reported *High stress*, $p < 0.0001$.

Partial Proportional Odds Model (Unequal slopes) – Eyes or head discomfort

The outcome variables in the Eyes or Head Discomfort model breaks the categories into four of the following groups: Column 1: Severe discomfort in eyes or head (*SevDEH*) versus Moderate discomfort in eyes or head (*ModDEH*) or Minimal discomfort in eyes or head (*MinDEH*) or Slight fatigue in eyes or head (*SFEH*) or No discomfort in eyes or head (*NDEH*); Column 2: Severe discomfort in eyes or head (*SevDEH*) or Moderate discomfort in eyes or head (*ModDEH*) versus Minimal discomfort in eyes or head (*MinDEH*) or Slight fatigue in eyes or head (*SFEH*) or No discomfort in eyes or head (*NDEH*), and Column 3: Severe discomfort in eyes or head

(*SevDEH*) or Moderate discomfort in eyes or head (*ModDEH*) or Minimal discomfort in eyes or head (*MinDEH*) versus Slight fatigue in eyes or head (*SFEH*) or No discomfort in eyes or head (*NDEH*). Column 4: Severe discomfort in eyes or head (*SevDEH*) or Moderate discomfort in eyes or head (*ModDEH*) or Minimal discomfort in eyes or head (*MinDEH*) or Slight fatigue in eyes or head (*SFEH*) versus No discomfort in eyes or head (*NDEH*). Results for the Eyes or Head PPOM are reported in Table 15.

For the question of Monitor Glare, participants that reported *Moderate monitor glare* resulted in an odds ratio of (Column 3) 4.263 times more likely to report *SevDEH* or *ModDEH* or *MinDEH* versus *SFEH* or *NDEH* than the participants who experienced *Severe monitor glare*, $p = 0.0314$.

Table 15. Study #2 Eyes or Head Discomfort. Partial Proportional Odds (Unequal slopes).

Discomfort categories	Odds Ratio Estimates (95% confidence interval) (*p*-values)			
	Severe discomfort in eyes or head vs. Moderate discomfort in eyes or head/ Minimal discomfort in eyes or head/ Slight fatigue in eyes or head / No discomfort in eyes or head	Severe discomfort in eyes or head/ Moderate discomfort in eyes or head vs. Minimal discomfort in eyes or head/ Slight fatigue in eyes or head / No discomfort in eyes or head	Severe discomfort in eyes or head/ Moderate discomfort in eyes or head/ Minimal discomfort in eyes or head vs. Slight fatigue in eyes or head / No discomfort in eyes or head	Severe discomfort in eyes or head/ Moderate discomfort in eyes or head/ Minimal discomfort in eyes or head/ Slight fatigue in eyes or head vs. No discomfort in eyes or head
Monitor Glare				
– No monitor glare vs. Severe monitor glare	1.448 (0.055, 38.056) $p = 0.8243$	0.733 (0.177, 3.025) $p = 0.6674$	1.846 (0.498, 6.845) $p = 0.3594$	1.211 (0.296, 4.945) $p = 0.7900$
– Moderate monitor glare vs. Severe monitor glare	3.213 (0.115, 89.611) $p = 0.4918$	1.918 (0.457, 8.049) $p = 0.3735$	4.263 (1.138, 15.974) $p = 0.0314$	2.516 (0.608, 10.415) $p = 0.2031$

Results of Lower Back Discomfort

Proportional Odds Model – Lower Back Discomfort Severity

The score test for the Lower Back Discomfort result was 0.2280, which was not a significant result; therefore, the analysis can be stopped at the proportional odds model where proportionality was accepted. The results produce variables with equal slopes, but not all variables were significant; all are reported in Table 16.

The outcome variables in the Lower Back Discomfort model have four levels. The following are the levels for this model:

- *ModDLB*: Moderate discomfort in lower back
- *MinDLB*: Minimal discomfort in lower back
- *SFLB*: Slight fatigue in lower back
- *NDLB*: No discomfort in lower back

For the variable Breaks, participants reporting *Takes break once every hour* were approximately 0.675 times more likely to report *NDLB* than participants who reported *Takes breaks once every 3 hours*, $p < 0.0001$. At the next level, participants reporting *Takes breaks once every 2 hours* were approximately 0.729 times more likely to report *NDLB* than participants who reported *Takes breaks once every 3 hours*, $p = 0.0014$.

For the question with regards to using a Document Holder and do you frequently experience upper back and/or neck fatigue, the participants that reported *Does not commonly view documents lying flat on desk* were 0.427 times more likely to report *NDLB* than the participants who reported *Commonly views documents lying flat on a desk*, $p < 0.0001$.

Table 16. Study #2 Lower Back Discomfort. Proportional Odds (Equal Slopes).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Hours on a Computer				
– 0-2 hours on a computer vs. 6+ hours a computer	1.241	0.943	1.633	0.1233
– 2-6 hours on a computer vs. 6+ hours on a computer	0.996	0.879	1.128	0.9500
Breaks				
– Takes breaks once every hour vs. Takes breaks once every 3 hours	0.675	0.561	0.814	< 0.0001
– Takes breaks once every 2 hours vs. Takes breaks once every 3 hours	0.729	0.600	0.885	0.0014
Use of Notebook Computer Use Hours/Week				
– Never uses a notebook computer vs. Uses a notebook computer more than 20 hours/week	0.399	0.032	4.910	0.4729
– Uses a notebook computer 1-10 hours/week vs. Uses a notebook computer more than 20 hours/week	0.958	0.830	1.107	0.5644

Table 16. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
– Uses a notebook computer 10-20 hours/week vs. Uses a notebook computer more than 20 hours/week	1.090	0.897	1.326	0.3860
Use of Notebook Computer w/o External Equipment				
– Never uses notebook computer w/o external equipment vs. Uses notebook computer w/o external equipment >20 hrs/week	0.740	0.499	1.099	0.1354
– Uses notebook computer w/o external equipment 1-10 hrs/wk vs. Uses notebook computer w/o external equipment >20 hrs/week	0.766	0.519	1.131	0.1801
– Uses notebook computer w/o external equipment 10-20 hrs/wk vs. Uses notebook computer w/o external equipment >20 hrs/week	0.747	0.483	1.155	0.1892

Table 16. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Document Holder				
– Does not commonly view documents lying flat on desk vs. Commonly views documents lying flat on desk	0.427	0.347	0.526	< 0.0001
Cradles Phone				
– Does not commonly cradle phone vs. Commonly cradles phone	0.895	0.729	1.100	0.2933
Bi/trifocals				
– Does not lean head backward due to bi/trifocal use vs. Leans head backward due to bi/trifocal use	0.741	0.586	0.937	0.0125
Monitor Height				
– Neutral monitor height vs. Monitor too high	0.796	0.662	0.958	0.0156
– Monitor too low vs. Monitor too high	0.794	0.582	1.083	0.1453
Monitor Glare				
– No monitor glare vs. Severe monitor glare	0.917	0.361	2.332	0.8553

Table 16. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
– Moderate monitor glare vs. Severe monitor glare	1.459	0.568	3.747	0.4329
Back Position				
– Neutral back position vs. Severe low back slump	0.745	0.343	1.621	0.4582
– Back position neutral (no use of backrest, sitting upright) vs. Severe low back slump	0.473	0.043	5.155	0.5392
– Back leaning forward vs. Severe low back slump	< 0.001	< 0.0001	>999.999	0.9593
– Back moderately leaning forward vs. Severe low back slump	1.108	0.505	2.433	0.7981
– Moderate low back slump vs. Severe low back slump	0.867	0.382	1.968	0.7331
– Reclined backrest vs. Severe low back slump	0.766	0.287	2.042	0.5940
– Back severely leaning forward vs. Severe low back slump	0.875	0.286	2.675	0.8147
Backrest Position				
– Neutral backrest position vs. Backrest too high	0.826	0.676	1.010	0.0629

Table 16. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
– Backrest too low vs. Backrest too high	0.990	0.789	1.242	0.9326
Chair Height				
– Neutral chair height vs. Chair too high	0.926	0.499	1.720	0.8082
– Chair too low vs. Chair too high	0.752	0.083	6.807	0.7995
– Knees below hips vs. Chair too high	0.899	0.482	1.677	0.7383
– Knees above hips, lumber pressure vs. Chair too high	1.327	0.627	2.810	0.4590
– Knees above hips, reclined vs. Chair too high	1.190	0.451	3.141	0.7255
Seat Pan				
– Neutral seat pan vs. Seat pan too small	0.835	0.649	1.075	0.1613
– Seat pan too big vs. Seat pan too small	0.912	0.690	1.206	0.5195

Table 16. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Foot Position				
– Feet rest comfortably on the floor or footrest vs. Feet do not rest comfortably on floor or footrest	0.936	0.697	1.258	0.6619
Adequate Lighting				
– Adequate lighting vs. Inadequate lighting	0.915	0.737	1.135	0.4181
Adjustable Armrests				
– Has adjustable armrests vs. Doesn't have armrests	0.886	0.201	3.907	0.8734
– Has non-adjustable armrests vs. Doesn't have armrests	0.944	0.211	4.227	0.9395
Forearm Support				
– Neutral armrest position vs. No armrests	1.061	0.854	1.318	0.5920
– Arms are supported by armrests vs. No armrests	2.424	0.473	12.419	0.2882
– Arms are supported by a desk or other surface vs. No armrests	15.027	0.417	541.782	0.1385
– Other type of forearm support vs. No armrests	1.084	0.657	1.790	0.7523

Table 16. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
– Rests elbows on armrests vs. No armrests	1.073	0.809	1.423	0.6249
– Low armrests vs. No armrests	0.955	0.732	1.245	0.7330
– Forearm support board vs. No armrests	1.295	0.711	2.360	0.3980
– Desk surface vs. No armrests	1.074	0.825	1.397	0.5954
– Arms don't rest on armrests vs. No armrests	3.019	0.239	38.090	0.3929
– Armrests too high vs. No armrests	1.794	1.049	3.068	0.0326
Forward Shoulder Reaching				
– No forward shoulder reaching vs. Severe forward shoulder reaching	0.901	0.617	1.317	0.5910
– Moderate forward shoulder reaching vs. Severe forward shoulder reaching	0.998	0.687	1.450	0.9912

Table 16. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Hand-Held Device				
– Does not frequently use a hand-held device vs. Frequently uses a hand-held device	1.131	0.956	1.337	0.1503
Hand/Wrist Resting Surface				
– Hands and wrists do not rest on a hard surface vs. Hand and wrists rest on hard surface	0.896	0.742	1.083	0.2579
Head Neck Posture				
– Neutral head and neck posture vs. Severe forward head posture	0.742	0.513	1.074	0.1142
– Moderate forward head posture vs. Severe forward head posture	0.798	0.558	1.142	0.2177
Keyboard Mouse Height				
– Neutral keyboard and mouse height vs. Keyboard too high	0.946	0.726	1.232	0.6790
– Keyboard too low vs. Keyboard too high	1.026	0.746	1.412	0.8734

Table 16. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Monitor Position Rotation				
– Neutral monitor position (rotation) vs. Monitor severely off center	0.841	0.461	1.532	0.5710
– Monitor moderately off-center vs. Monitor severely off center	0.917	0.501	1.681	0.7804
Multiple Monitor Usage				
– Doesn't use multiple monitors vs. Uses multiple monitors	1.017	0.885	1.168	0.8140
Notebook Travel				
– Does not travel with notebook computer vs. Travels with notebook computer	0.857	0.757	0.970	0.0148
Properly Working Equipment				
– Equipment and accessories are working properly vs. Equipment and/or accessories not working properly	0.638	0.500	0.814	0.0003

Table 16. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Second Home Office				
– Does not have a secondary home office vs. Has secondary home office	0.973	0.864	1.096	0.6531
Shared Workstation				
– Uses non-shared ("Dedicated") workstation vs. Never works at corporate site	1.004	0.123	8.219	0.9974
– Uses shared ("Free Address") workstation vs. Never works at corporate site	1.252	0.151	10.362	0.8351
Shoulder Abduction				
– Neutral shoulder abduction vs. Severe shoulder abduction	0.969	0.637	1.472	0.8817
– Moderate shoulder abduction vs. Severe shoulder abduction	0.989	0.656	1.493	0.9596

Table 16. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Space Keyboard Mouse				
– Keyboard and mouse proximity is good vs. Keyboard and mouse cannot be placed in proximity of each other	0.787	0.588	1.054	0.1077
Stress				
– Low stress vs. High stress	0.693	0.585	0.822	< 0.0001
– Medium stress vs. High stress	0.780	0.668	0.910	0.0016
Type of Work				
– Moderate levels of both keyboard and mouse work vs. Precision mouse work (e.g., graphic design, CAD, etc.)	1.025	0.895	1.174	0.7186
– Keyboard intensive work (e.g., data entry, spreadsheet, etc.) vs. Precision mouse work (graphic design, CAD, etc.)	0.886	0.722	1.089	0.2506
Wrist Position				
– Neutral wrist position vs. Wrists bent to the side	0.810	0.607	1.081	0.1528

Table 16. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
– Wrists bent forward vs. Wrists bent to the side	1.536	0.869	2.714	0.1398
– Wrists bent backward vs. Wrists bent to the side	1.064	0.769	1.473	0.7082

The question concerning Bi/trifocals or Progressive Lenses use shows that those reporting *Does not lean head backward due to bi/trifocal use* were approximately 0.741 more likely to report *NDLB* than the participants who reported *Leans head backward due to bi/trifocal use, p* = 0.0125.

For the question about Monitor Height, participants that reported *Neutral monitor height* were 0.796 times more likely to report *NDLB* than the participants who experienced *Monitor too high*, *p* = 0.0156.

Regarding the question about Forearm Support, participants who reported *Armrests too high* reported 1.794 times more likely to report *ModDLB* than participants who reported *No armrests, p* = 0.0326.

When asked about using a Notebook Computer, the participants who reported *Does not travel with the notebook computer* were 0.857 more likely to report *NDLB* than participants who reported *Travels with notebook computer, p* = 0.0148.

When asked about Properly Working Equipment, the participants who reported *Equipment and accessories working properly* were 0.638 more likely to report *NDLB* than those who reported *Equipment and/or accessories not working properly*, p = 0.0003.

The question concerning Stress, participants who reported *Low stress* were 0.693 more likely to report *NDLB* than the participants who reported *High stress*, $p < 0.0001$. If participants reported *Medium stress*, they were 0.780 times more likely to report *NDLB* than the participants who reported *High stress*, $p = 0.0016$.

Results for Elbow and Forearm Discomfort

Partial Proportional Odd Model (Equal slopes) – Elbow and Forearm Discomfort

The outcome variables in the Elbow and Forearm Discomfort model breaks the categories into four levels:

- *ModDEF*: Moderate discomfort in elbow and forearm
- *MinDEF*: Minimal discomfort in elbow and forearm
- *SFEF*: Slight fatigue in elbow and forearm
- *NDEF*: No discomfort in elbow and forearm

As before, if the predictor variables were not significant, they were not explained in the results. Table 17 lists the results for this model.

For the Breaks variable, participants reporting *Takes break once every hour* were approximately 0.678 times more likely to report *NDEF* than participants who reported *Takes breaks once every 3 hours*, $p < 0.0001$.

For the predictor variable Wrist Position, the participants who answered *Neutral wrist position* were 0.660 more likely to answer *NDEF* than the participants who answered *Wrist bent to the side*, $p = 0.0047$.

Table 17. Study #2 Elbow and Forearm Discomfort. Partial Proportional Odds Model (Equal Slopes).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Breaks				
– Takes breaks once every hour vs. Takes breaks once every 3 hours	0.678	0.562	0.817	< 0.0001
– Takes breaks once every 2 hours vs. Takes breaks once every 3 hours	0.825	0.678	1.004	0.0555
Wrist Position				
– Neutral wrist position vs. Wrist bent to the side	0.660	0.495	0.880	0.0047
– Wrist bent forward vs. Wrist bent to the side	1.728	0.975	3.061	0.0609
– Wrist bent backward vs. Wrist bent to the side	1.181	0.849	1.644	0.3236

Partial Proportional Odds Model (Unequal slopes) - Elbow and Forearm Discomfort

The outcome variables in the Elbow and Forearm Discomfort model breaks the categories into the three of the following groups (Table 18):

- Column 1: Moderate discomfort in elbow and forearm (*ModDEF*) versus Minimal discomfort in elbow and forearm (*MinDEF*) or Slight fatigue in elbow and forearm (*SFEF*) or No discomfort in elbow and forearm (*NDEF*)

- Column 2: Moderate discomfort in elbow and forearm (*ModDEF*) or Minimal discomfort in elbow and forearm (*MinDEF*) versus Slight fatigue in elbow and forearm (*SFEF*) or No discomfort in elbow and forearm (*NDEF*)
- Column 3: Moderate discomfort in elbow and forearm (*ModDEF*) or Minimal discomfort in elbow and forearm (*MinDEF*) or Slight fatigue in elbow and forearm (*SFEF*) versus No discomfort in elbow and forearm (*NDEF*)

For the question regarding using a Document Holder, that asked, "Do you frequently experience upper back and/or neck fatigue as a result of viewing documents that are lying flat on your desk?" The participants that reported *Does not commonly view documents lying flat on a desk* were (Column 1) 0.414 times more likely to report *MinDEF*, *SFEF*, or *NDEF* versus *ModDEF*; (Column 2) 0.417 times more likely to report *SFEF* or *NDEF* versus *ModDEF* or *MinDEF*; (Column 3) 0.551 times more likely to report *NDEF* versus *ModDEF*, *MinDEF*, *SFEF* than the participants who reported *Commonly views documents lying flat on a desk*, $p < 0.0001$ *(for all columns)*.

Table 18. Study #2 Elbow and Forearm Discomfort. Partial Proportional Odds (Unequal Slopes).

Odds Ratio Estimates (95% confidence interval) (*p*-values)			
Discomfort categories	Moderate discomfort in elbow and forearm vs. Minimal discomfort in elbow and forearm / Slight fatigue in elbow and forearm / No discomfort in elbow and forearm	Moderate discomfort in elbow and forearm / Minimal discomfort in elbow and forearm vs. Slight fatigue in elbow and forearm / No discomfort in elbow and forearm	Moderate discomfort in elbow and forearm /Minimal discomfort in elbow and forearm / Slight fatigue in elbow and forearm vs. No discomfort in elbow and forearm
Document Holder			
– Does not commonly view documents lying flat on desk vs. Commonly views documents lying flat on desk	0.414 (0.289, 0.593) $p < 0.0001$	0.417 (0.327, 0.530) $p < 0.0001$	0.551 (0.440, 0.689) $p < 0.0001$
Monitor Glare			
– No monitor glare vs. Severe monitor glare	1.134 (0.152, 8.484) $p = 0.9026$	1.664 (0.389, 7.113) $p = 0.4921$	1.257 (0.409, 3.863) $p = 0.6897$
– Moderate monitor glare vs. Severe monitor glare	1.983 (0.261, 15.087) $p = 0.5083$	2.264 (0.523, 9.796) $p = 0.2743$	1.945 (0.625, 6.049) $p = 0.2507$

Table 18. (Continued).

Discomfort categories	ModDEF vs. MinDEF/SFEF/ NDEF	ModDEF/MinDEF vs. SFEF/ NDEF	ModDEF/ MinDEF/SFEF vs NDEF
Stress			
– Low stress vs. High stress	0.412 (0.276, 0.616) $p < 0.0001$	0.532 (0.417, 0.680) $p < 0.0001$	0.713 (0.594, 0.856) $p = 0.0003$
– Medium stress vs. High stress	0.511 (0.367, 0.711) $p < 0.0001$	0.732 (0.595, 0.901) $p = 0.0033$	0.834 (0.707, 0.985) $p = 0.0326$

The question concerning Stress, participants that reported *Low stress* were (Column 1) 0.412 more likely to report *MinDEF*, *SFEF*, or *NDEF* versus *ModDEF*; (Column 2) 0.532 more likely to report *SFEF* or *NDEF* versus *ModDEF* or *MinDEF*; (Column 3) 0.713 more likely to report NDEF versus *ModDEF*, *MinDEF*, or *SFEF* than the participants who reported *High stress*, $p < 0.0001$, $p < 0.0001$, $p = 0.0003$, respectively. Those participants that reported *Medium stress* were (Column 1) 0.511 more likely to report *MinDEF*, *SFEF*, or *NDEF* versus *ModDEF*; (Column 2) 0.732 more likely to report *SFEF* or *NDEF* versus *ModDEF* or *MinDEF*; (Column 3) 0.834 more likely to report *NDEF* versus *ModDEF*, *MinDEF*, or *SFEF* than the participants who reported *High stress*, $p < 0.0001$, $p = 0.0033$, $p = 0.0326$, respectively.

Results for Shoulder Discomfort

Partial Proportional Odds Model (Equal Slopes) – Shoulder Discomfort

The outcome variables for the Shoulder Discomfort model breaks the categories into four levels: Moderate discomfort in shoulder (ModDS), Minimal discomfort in shoulder (MinDS), Slight fatigue in shoulder (SFS), and No discomfort in shoulder (NDS). Results are listed in Table 19.

When asked about Properly Working Equipment, participants that reported *Equipment and accessories are working properly* were 0.591 times more likely to report NDS than the participants who reported *Equipment and/or accessories not working properly*, $p < 0.0001$.

For the predictor variable concerning Wrist Position, the participants who answered *Neutral wrist position* were 0.691 times more likely to answer NDS than the participants who answered *Wrist bent to the side*, $p = 0.0138$.

Table 19. Study #2 Shoulder Discomfort. Proportional Odds Models (Equal Slopes).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Properly Working Equipment				
– Equipment and accessories are working properly vs. Equipment and/or accessories not working properly	0.591	0.465	0.752	< 0.0001
Wrist Position				
– Neutral wrist position vs. Wrist bent to the side	0.691	0.516	0.927	0.0138
– Wrist bent forward vs. Wrist bent to the side	1.386	0.771	2.492	0.2751

Table 19. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
– Wrist bent backward vs. Wrist bent to the side	1.373	0.980	1.921	0.0650

Partial Proportional Odds Model (Unequal Slopes) – Shoulder Discomfort

The outcome variables in the Shoulder Discomfort model breaks the categories into three of the following groups (Table 20):

- Column 1: Moderate discomfort in shoulder (*ModDS*) versus Minimal discomfort in shoulder (*MinDS*) or Slight fatigue in shoulder (*SFS*) or No discomfort in shoulder (*NDS*)
- Column 2: Moderate discomfort in shoulder (*ModDS*) or Minimal discomfort in shoulder (*MinDS*) versus Slight fatigue in shoulder (*SFS*) or No discomfort in shoulder (*NDS*)
- Column 3: Moderate discomfort in shoulder (*ModDS*) or Minimal discomfort in shoulder (*MinDS*) or Slight fatigue in shoulder (*SFS*) versus No discomfort in shoulder (*NDS*)

For the question regarding using a Document Holder and do you frequently experience upper back and/or neck fatigue, the participants that reported *Does not commonly view documents lying flat on a desk* were (Column 1) 0.313 times more likely to report *MinDS*, *SFS*, or *NDS* versus *ModDS*; (Column 2) 0.292 times more likely to report *SFS* or *NDS* versus *ModDS* or *MinDS*; (Column 3) 0.389 times more likely to report *NDS* versus *ModDS* or *MinDS* or *SFS* than the participants who reported *Commonly views documents lying flat on a desk*, $p < 0.0001$, results for all columns.

Table 20. Study #2 Shoulder Discomfort. Partial Proportional Odds Model (Unequal slopes).

Odds Ratio Estimates (95% confidence interval) (*p*-value)			
Discomfort categories	Moderate discomfort in shoulder vs. Minimal discomfort in shoulder/ Slight fatigue in shoulder/ No discomfort in shoulder	Moderate discomfort in shoulder/ Minimal discomfort in shoulder vs. Slight fatigue in shoulder/ No discomfort in shoulder	Moderate discomfort in shoulder/ Minimal discomfort in shoulder/ Slight fatigue in shoulder vs. No discomfort in shoulder
Document Holder			
– Does not commonly view documents lying flat on desk vs. Commonly views documents lying flat on desk	0.313 (0.216, 0.454) $p < 0.0001$	0.292 (0.228, 0.373) $p < 0.0001$	0.389 (0.310, 0.488) $p < 0.0001$
Stress			
– Low stress vs. High stress	0.311 (0.194, 0.500) $p < 0.0001$	0.371 (0.283, 0.485) $p < 0.0001$	0.616 (0.512, 0.742) $p < 0.0001$
– Medium stress vs. High stress	0.526 (0.368, 0.752) $p = 0.0004$	0.562 (0.451, 0.699) $p < 0.0001$	0.799 (0.676, 0.945) $p = 0.0088$

The question concerning Stress the participants that reported *Low stress* were (Column 1) 0.311 more likely to report *MinDS*, *SFS*, or *NDS* versus *ModDS*; (Column 2) 0.371 more likely to report *SFS* or *NDS* versus *ModDS* or *MinDS*; (Column 3) 0.616 more likely to report *NDS* versus *ModDS*, *MinDS*, or *SFS* than the participants who reported *High stress*, $p < 0.0001$ for all columns. Participants that reported *Medium stress* were (Column 1) 0.526 times more likely to report *MinDS*, *SFS*, or *NDS* versus *ModDS*; (Column 2) 0.562 times more likely to report *SFS* or *NDS* versus *ModDS* or *MinDS*; (Column 3) 0.799 times more likely to report *NDS* versus *ModDS*, *MinDS*, or *SFS* than the participants who reported *High stress*, $p = 0.0004$, $p < 0.0001$, $p = 0.0088$, respectively.

Results for Wrist and Hand Discomfort Severity

Partial Proportional Odds Model (Equal Slopes) – Wrist and Hand Discomfort

The outcome variables in the Wrist and Hand Discomfort model breaks the categories into four levels (Table 21):

- *ModDWH*: Moderate discomfort in wrist and hand
- *MinDWH*: Minimal discomfort in wrist and hand
- *SFWH*: Slight fatigue in wrist and hand
- *NDWH*: No discomfort in wrist and hand

In the question of Hours on a Computer, participants reporting *0-2 hours on a computer* are approximately 0.546 more likely to report *NDWH* than participants who reported *6+ hours on a computer*, $p < 0.0001$. At the next level, participants reporting *2-*

6 hours on a computer are approximately 0.746 more likely to report *NDWH* than participants who reported *6+ hours on a computer*, $p < 0.0001$.

For the question of Breaks, participants reporting *Takes breaks once every hour* are approximately 0.695 times more likely to report *NDWH* than participants who reported *Takes breaks once every 3 hours*, $p < 0.0001$.

For the question regarding using a Document Holder and do you frequently experience upper back and/or neck fatigue, the participants who reported *Does not commonly view documents lying flat on a desk* were 0.645 times more likely to *NDWH* than the participants who reported *Commonly views documents lying flat on a desk*, $p < 0.0001$.

When asked about Hand/Wrist Resting Surface, participants who answered *Hands and wrists do not rest on a hard surface* were 0.645 more likely to answer *NDWH* than participants who answered *Hands and wrists rest on a hard surface*, $p < 0.0001$.

The question concerning Stress, the participants that reported *Low stress* were 0.601 times more likely to report *NDWH* than the participants who reported *High stress*, $p < 0.0001$. When participants reported *Medium stress*, they were 0.715 times more likely to report *NDWH* than the participants who reported *High stress*, $p < 0.0001$.

For the predictor variable Wrist Position, the participants who answered *Neutral wrist position* were 0.552 more likely to answer *NDWH* than the participants who answered *Wrist bent to the side*, $p < 0.0001$.

Table 21. Study #2 Wrist and Hand Discomfort. Partial Proportional Odds Model (Equal Slopes).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Hours on a Computer				
– 0-2 hours on a computer vs. 6+ hours on a computer	0.546	0.417	0.715	< 0.0001
– 2-6 hours on a computer vs. 6+ hours on a computer	0.746	0.663	0.840	< 0.0001
Breaks				
– Takes breaks once every hour vs. Takes breaks once every 3 hours	0.695	0.580	0.834	< 0.0001
– Takes breaks once every 2 hours vs. Takes breaks once every 3 hours	0.837	0.692	1.012	0.0664
Document Holder				
– Does not commonly view documents lying flat on desk vs. Commonly views documents lying flat on desk	0.645	0.528	0.787	< 0.0001

Table 21. (Continued).

Effect	Odds Ratios	95% Wald Confidence Limits		*p*-values
Hand/Wrist Resting Surface				
– Hands and wrists do not rest on a hard surface vs. Hands and wrists rest on hard surface	0.645	0.537	0.775	< 0.0001
Keyboard Mouse Height				
– Neutral keyboard and mouse height vs. Keyboard too high	0.800	0.619	1.034	0.0879
– Keyboard too low vs. Keyboard too high	1.204	0.885	1.639	0.2379
Stress				
– Low stress vs. High stress	0.601	0.509	0.709	< 0.0001
– Medium stress vs. High stress	0.715	0.615	0.832	< 0.0001
Wrist Position				
– Neutral wrist position vs. Wrists bent to the side	0.552	0.417	0.729	< 0.0001
– Wrist bent forward vs. Wrist bent to the side	0.887	0.508	1.551	0.6744
– Wrist bent backward vs. Wrist bent to the side	0.982	0.713	1.353	0.9109

Discussion

This study examined the variables that could predict self-reported musculoskeletal discomfort from working at a computer, drawn from a large sample (n = 13,762). This study was unique in that it implemented an unprecedentedly large participant size.

It is common to find research that postulates that the more hours per day one spends working on a computer, the more likely one is to report musculoskeletal discomfort. This outcome was not unexpected, considering that the number of hours worked, repetitive movements, awkward positions, and lack of rest breaks were consistent among various studies (Oha et al., 2014; Sharan et al., 2011). However, in this study, the Hours on a computer predictor variable was significant only in the models of Frequency of Discomfort, Eyes or Head Discomfort, and Wrist and Hand Discomfort; the results were all in the lower category of Never Experiences Discomfort or No discomfort.

It was also commonplace in related research to see that the lack of rest breaks, especially among those working more than three hours per day, can lead to musculoskeletal discomfort (Ardahan & Simsek, 2016; Ellahi et al., 2011; Rehman et al., 2013; Sharan et al., 2011). The models with significant results for the variable Breaks were Frequency of Discomfort, Neck and Upper Back, Lower Back, Elbow and Forearm, and Wrist and Hand Discomfort. These outcomes suggested that taking breaks either once or twice an hour resulted in favoring the lower category of Never Experiences Discomfort or No discomfort.

Several researchers have shown that Notebook Computer Use, especially when not using external equipment such as a keyboard or other ergonomic equipment, can lead to more head and neck flexion and shoulder rotation (Dennerlein, 2015; Malinska & Bugajska 2010). In this study, *Never uses a notebook computer without external equipment* resulted in partitioned results with the highest category of *CWRD* or *FWRD* or *IWRD* versus *NED*. However, this result was only answered by 20 % (2819 out of 5631 answered from 13762 total) of the participants, and therefore, many may not be an actual reflection of the participants. When reported in the other levels that say *Uses a notebook computer without external equipment 1-10 or 10-20 hours per week*, the results both gave significant results that were reported as *CWRD* or *FWRD* or *IWRD* versus *NED*, which is supported by other studies. In this study, only the Frequency of Discomfort model gave a significant result.

Participants who wore Bi/trifocals or Progressive Lenses reported that the resulting head tilt could lead to musculoskeletal discomfort. This result has been verified by Weidling and Jaschinski (2015) for computer workers. In this study, the models Frequency of Discomfort, Neck and Upper Back Discomfort, Eyes or Head Discomfort, and Lower Back all reported *Does not lean head backward* due to various eyewear. All of these models reported at the lower end of the discomfort level with either No discomfort or Never Experiences Discomfort.

Several studies have investigated eye strain, concerning screen glare, from viewing a computer screen for many hours; they determined that this can cause computer vision syndrome (Glimne & Österman, 2019; Gowrisankaran & Sheedy, 2015; Mork, Falkenberg, Fostervold, & Thorud, 2018). The models of Frequency of Discomfort, Neck and Upper Back, and Eyes or Head reported the highest levels of discomfort (monitor glare) at Constant, Moderate, and Severe discomfort, respectively. The monitor glare results in the Frequency of Discomfort model gave results of *No monitor glare* versus *Severe monitor glare* at *CWRD*. Likewise, the result in the Neck and Upper Back Model for both levels of *No monitor glare* and *Moderate monitor glare* versus *Severe monitor glare* produced a similar result in the highest level of discomfort, rather than lowest. These results are in opposition to other ergonomic results in the referenced articles. Furthermore, most of the participants (12,563) reported *No monitor glare* in the OES questionnaire.

Relevant to eye strain is adequate lighting while using a computer (Gowrisankaran & Sheedy, 2015; Parihar et al., 2016). Several researchers have investigated Computer Vision Syndrome (CVS) related to tedious viewing of the computer screen, with one of the contributing factors being the lack of adequate lighting. However, there were no models with significant results for the variable Adequate Lighting in this study.

Forearm support was acknowledged by Zhu and Shin (2012), where muscle loading was lowest when forearm supports were resting at elbow height, and by Onyebeke, Young, Trudeau, and Dennerlein (2014), especially when compared to no forearm supports. For this study in the Lower Back Discomfort model, the results for forearm support with *Armrests too high* were 1.794, which favors the Moderate

Discomfort level; therefore, this study showed similar results as previous studies for forearm support and reported discomfort.

When discussing *Hands and wrists do not rest on a hard surface* while working on a computer, participants were more likely to report less discomfort in the Frequency of Discomfort, Neck and Upper Back, and the Wrist and Hand Discomfort models. This information is corroborated in two studies by Callegari, de Resende, & da Silva Filho (2016) and Kim, Aulck, Trippany, & Johnson (2015), both of which found that hand and wrist resting supports can reduce muscle fatigue and potentially MSDs.

When evaluating head and neck postures, it was not uncommon to find forward neck postures among participants who worked on computers for prolonged hours per day (Nejati, Lotfain, Moezy, Nejati, 2015; Kang et al., 2012). The Frequency of Discomfort, Neck and Upper Back discomfort, and Eyes or Head Discomfort models report the low end of discomfort as Never or No discomfort.

As expected, keyboard and mouse height had significant results in the Neck and Upper Back Discomfort model. It was found that when participants reported their keyboard position as *Neutral* or *too low*, they also reported *No Discomfort in Neck and Upper Back*, compared to when the keyboard is too high. This proper ergonomic set-up was confirmed in studies by Lima and Coelho (2011) and Van Eerd, Hogg-Johnson, Cole, Wells, and Mazumder (2011), which explored the proper ergonomic set-up of keyboard and mouse for the mitigation of MSDs.

For the variable Monitor Position Rotation in the Frequency of Discomfort model, participants reported *Neutral monitor position (rotation)* or *Monitor moderately* *off-center*, the result for both reported Constant Work-Related Discomfort *(CWRD)*. The frequency tables of this data reported that most participants chose *Neutral monitor position (rotation)* (10762 participants). This particular question in the OES questionnaire was from an image depicting three potential head rotation selections, which may not have been apparent to the participants. There were some contradictions in the literature reporting head and neck rotation, especially using dual monitors. The research by Estember et al. (2015) and Nimbarte, Alabdulmohsen, Guffey, and Etherton (2013) both report that using dual monitors causes head and neck rotation and may therefore increase the risk of musculoskeletal discomfort. Whereas the study by Farias-Zuniga and Cote (2017) determined that dual monitor use resulted in a more neutral head position and a more protective neck posture to reduce muscle activity in the neck and, therefore, musculoskeletal discomfort.

For the variable of Type of Work (mouse or keyboard intensive work), the Frequency of Discomfort model showed participants who chose *Moderate levels of both keyboard and mouse work*, and the other choice of *Keyboard intensive work* both report Never Experiences Discomfort. In the research by Mattioli et al. (2015), where they reviewed previous research on musculoskeletal discomfort from keyboard and mouse use, they conclude that the evidence is inconclusive that mouse or keyboard work is associated with musculoskeletal discomfort.

When reviewing the wrist position variable for how participants work at their computer, in the Elbow and Forearm Discomfort, Shoulder Discomfort, and Wrist and Hand Discomfort models all report that *Neutral wrist position* versus *Wrist bent to the* *side* favors No discomfort. In 2016, Kaliniene, Ustinaviciene, Skemiene, Vaiciulis, and Vasilavicius concluded from a questionnaire that participants report wrist problems about 50% of the time from computer work. Yet, research from Waersted, Hanvold, Veiersted (2010), performed by a systematic review, compared diagnosed MSDs to mouse and keyboard time to wrist tendonitis, found limited evidence of MSDs.

For the variable Back Position, the Frequency of Discomfort Model reported that *Back severely learning forward* versus *Severe low back slump* was more likely to report Constant Work-Related Discomfort. In the related variable Backrest position, the Frequency of Discomfort model shows the result of *Neutral backrest position* was more likely to report Never Experiences Discomfort. A study by Baumgartner et al. (2012) realized that sitting in an office chair has an effect on the musculoskeletal system; they researched the best backrest and back posture position using an MRI that determine disc loading, which revealed an upright or inclined (slightly forward) position resulted in more favorable spinal wedge angle.

The variable Stress had low-level stress and medium-level stress compared to high-level stress. There were significant results in all seven logistic regression analyses, which all favored the lowest level of discomfort of either No Discomfort or Never Experiences Discomfort. Ellahi et al. (2011) and Taib et al. (2016) agreed that stress could contribute to musculoskeletal discomfort while working on a computer.

Document holder usage for reduction of MSD risk was verified in studies by Goostrey, Treleaven, and Johnston, 2014 and Lima and Coelho, 2011, where they discuss using a document holder on the side of the computer at eye level to maintain the head and neck in a neutral posture. It was interesting that in this research, Document Holder was one of the two predictor variables that were significant in each of the seven body part discomfort models; however, there was little research found on this potential for MSDs in the last decade. Document holder was significant in the PPOM (unequal slopes) and partitioned out in the Frequency of Discomfort, Neck and Upper Back Discomfort, Elbow and Forearm Discomfort, and Shoulder Discomfort Models. For equal slopes, the variable Document Holder had significant results in Eyes or Head Discomfort, Lower Back Discomfort, and Wrist and Hand Discomfort models. All of these proportional (equal slope) models favor the lower end of the discomfort levels of either, Never Experiences Discomfort or No Discomfort.

Even though there were thirty-three questions in the survey, many of the variables did not appear significant in the regression model. There were twenty out of thirty-three variables that resulted in significant results throughout the seven models. It was also surprising that the Hours on Computer variable was not significant in more models since that has been reported in many research articles (Ardahan & Simsek, 2016; Rehman, Khan, Surti, & Khan, 2013; Sharan et al., 2011).

The study's limitations were that many of the questions were not answered by all 13,762 participants. As many as one-third of the participants did not give answers to the body part discomfort survey. A large number of unanswered survey questions can skew the data and may present biased, inaccurate results for the study. Likewise, the categories (discomfort levels) that participants had to choose from in the seven-question body part discomfort survey may have been confused as to which to choose. Two of the categories, “Slight fatigue” (described as without any discomfort) versus the category of “No discomfort,” appear to be similar. These categories are similar in description and may lead to miscategorization of answers (levels of discomfort) which, in turn, may have biased the results.

It is relevant to note that this data was analyzed using a proportional odds assumption. *SAS/STAT User’s Guide* gives a cautionary note that if both the sample size is large and there are a lot of independent variables, the score test tends to reject the null hypothesis (Allison, 2012). Consequently, this data analysis may have rejected more proportionality models than necessary. Allison (2012) stated that when the number of categories increases on the dependent variable, it is more difficult for the predictor variables to predict the dependent variable well. All these issues listed above could have affected the analysis results and may have produced some of the answers not common in the literature on this topic.

The study’s strength was that no other studies found analyzed a musculoskeletal study with a partial proportional odds model (PPOM), which was dictated by the categorical data. Another strength was that this study had a large 13,762 participant database. Lastly, it was a large study with thirty-three comparison variables. Several of the findings can be used for more research and developing programs to reduce musculoskeletal discomfort, which in turn, will reduce overall MSDs.

In summary, although this study has some unusual associations, these results show correlations, but that does not necessarily equal causation. The fact that this study showed mostly null associations between the Remedy data and the body part discomfort survey leads to the question as to why the OES data study (self-reported) resulted in several associations to musculoskeletal discomfort. In that regard, what is missing between the two different types of studies can only lead to more research on this topic.

CHAPTER V

CONCLUSION

Study comparisons

These two studies were related in that they were the same study population. The OES Data study was a 40-question questionnaire performed on the study population before the research began on the Remedy Data. The Remedy Data was collected at 28, 91, and 364 days continuously, using computer desktop software. However, only the data collected at the 364-day interval was used in the analysis. Therefore, the data was not analyzed longitudinally. The data was collected at an Oil and Gas Company; however, no specific information was given, such as gender, job description, health data, location information, or any previous interventions. The study's intention was to determine if any variables indicated musculoskeletal discomfort from subjective and objective data.

The study comparisons are shown in Table 22. The strength of the Remedy Data study was that it was performed using Remedy RSIGuard® desktop software (Version 3) on each participant's desktop in an office environment. In contrast, many studies in the past have been performed subjectively with questionnaires only. Another strength of this study was the large population of 13,762 participants, with a study length of 364-days. When comparing similar predictor variables between studies, it is interesting to see the variable Total Hours [on a computer] objectively measured gives a result of 3.14 hours on average versus 55 percent (7546 participants) who chose the category of 6+ hours on a computer from the OES questionnaire. This overestimation was determined by the

Table 22. Study Comparisons.

Study	N	Type of study Population	Intervention Length	Data Collection	Prior Intervention Exposure	Health behavior change construct
Study #1 (Remedy Data)	13762	Non-volunteer	365	Objective	Unknown	Computer Based Prompts
Study #2 (OES Data)	13762	Non-volunteer	1-day*	Subjective	Unknown	Self-monitoring

*****Beginning of the study period**.**

research studies by Douwes, de Kraker, and Blatter (2007), Gerr and Fethke (2011), and Heinrich et al. (2004). According to Douwes et al. (2007), computer use statistics are much better predictors of computer use than self-reports. This issue was mainly seen in the observation method, whereas the observers discovered that overestimation tended to be reduced in managers and other higher-level positions.

Research limitations were that this was a secondary data set, and therefore the researcher did have any input in the set-up of the data or questions in the OES questionnaire. The outcome categories were not a typical Likert scale in the dependent variable. For example, the wording of minimal discomfort and slight fatigue appeared to be similar, even though the description explained the difference. Other limitations on the Remedy Data were that several features could be disabled or turned off by the user. The BreakTimer feature was one of the features that could be disabled by the user, which the variable BTEnabled tracked. In fact, approximately 50 percent of the participants had this feature disabled, which is an essential variable for tracking the variable BreakTime that tracks the amount of time in breaks. The fact that all the participants did not enable this variable may have played a role in the lack or weak associations in the Remedy data between musculoskeletal discomfort and predictor variables. Another weakness was the lack of a 1-year follow-up questionnaire performed in other studies with objectively recorded data. Therefore, a comparison of the difference of the outcome variables between the beginning and the termination of the study could not be performed (Ijmker et al., 2010; Mikkelsen et al., 2012). Lastly, the body part discomfort survey, which was 7 of the 40 OES questions, was performed subjectively (categorical) and therefore may lead to selection biases or exposure misclassification (Mikkelsen et al., 2012). However, the OES data analysis, which was subjectively obtained, showed several predictor variables associated with musculoskeletal discomfort.

Research process

The de-identified data was provided by Remedy, now called Cority Enviance. Texas A&M School of Public Health, through the Department of Environmental and Occupational Health, was given permission from Ron Goodman, Office Products Manager, Cority Enviance, to perform statistical analysis to determine outcomes on data.

Public health relevance and contributions to public health

Since computers have come into the workplace, and with the advancement of technology, the problem of sedentary work has been an issue (Sharma, 2018). The problems from working at a computer for hours have been attributed to sedentary work, awkward postures, repetitive movements, and without sufficient rest breaks, which has been reported to attribute to musculoskeletal discomfort (Oha et al., 2014; Sharan et al., 2011). In fact, the more advances in technology, the more workers have been tied down to a computer workstation and contribute to problems to employee health (Garrett, 2019).

Previous studies have researched computer use and the relationship to work-related musculoskeletal discomfort. Specifically, study research has evaluated ergonomic interventions such as workstation design, ergonomic training, and scheduled breaks (Lanhers et al., 2016). A more recent trend in studying sedentary issues while working at a computer is research on stand-capable desks. However, research is still in progress, but it may reduce sedentary work and the associated work-related issues (Garrett, 2019; Sharma, 2018).

This study is relevant to public health because, yearly, 30 % of occupational illnesses and injuries are from MSDs, which has been relatively consistent for several years without a significant downtrend. This percentage is considerable, although not all work-related MSDs are due to working on a computer. Even though there have been many studies related to work-related MSDs and advancements in ergonomic workspace design, there are still solutions needed for reducing MSDs.

Contributions to public health indicate that Companies can model their ergonomic program or offer user-specific computer recommendations utilizing aspects of this study's findings. For this study, a dataset comprised of 13,762 participants was reviewed. The dataset contained risk factor variables that often result in musculoskeletal issues (e.g., HoursM, HoursK, TotalHours, and BreakTime). The RSIGuard® program collected user computer statistics, which ranged from HoursM mean (SD) 2.79 (1.20) Range 0 - 9.99, HoursK mean (SD) 1.04 (0.57) Range 0 – 5.37, TotalHours mean 3.14 (1.28) Range 0 - 10.70. However, the previously noted variables (e.g., HoursM, HoursK, TotalHours, and BreakTime) were of most importance to this study. The study findings showed numerous variables of concern that should be addressed to minimize computer user risks.

The findings of the logistic regression analysis from Study #1 demonstrated two statistically significant results (BreaksSkipped in the Lower Back Model, HoursK in the Wrist & Hand Model). While these findings are important because they are typical variables studied in other research, the findings in this study are not a suitable predictor of musculoskeletal discomfort.

The descriptive statistics revealed some noteworthy findings. When analyzing the variable of hours on a mouse (HoursM), the highest amount of time reported was 9.9 hours for 364 days. The mean average score of all participants for hours on a mouse (HoursM) was 2.79 hours per day. The DataLogger feature of RSIGuard® reported this running average (both measured and averaged daily). Assuming the reported values were correct, it was interesting that the participant who recorded 9.9 hours of mouse use per day answered *Never Experiences Discomfort* when responding to a question associated with the Frequency of Discomfort Model. It is important to note that this individual did not answer any other body part discomfort questions. Aside from the highest hours of mouse use per day, the other highest recorded use values were 9.44, 9.41, and 9.19 hours. The three individuals who had these high scores only reported *Infrequent Work-related Discomfort*, which is defined as less than one discomfort experience per week. The four results denote extremely high average daily hours using a mouse. In fact, these four individuals might be called mouse “superusers.” These high daily mouse use averages are concerning, because they can cause musculoskeletal problems. Therefore, further investigations are needed to explore why these individuals are using their mouse for so many hours per day. Specifically, the following information should be obtained: (1) What jobs do these individuals have? (2) Why are these individuals working more than eight hours per day, and (3) Why do these individuals have such high average daily mouse use? Ideally, qualitative data would assist the researcher in further understanding work habits and other work-related details. By conducting interviews or carrying out observations, considering this would not violate any company-related policies nor individual rights, additional data of importance could be obtained. Utilizing a qualitative methodology, it would be beneficial to understand what high-usage mouse individuals are doing to avoid injuries and how these practices can be applied to other individuals who experience mouse-related injuries.

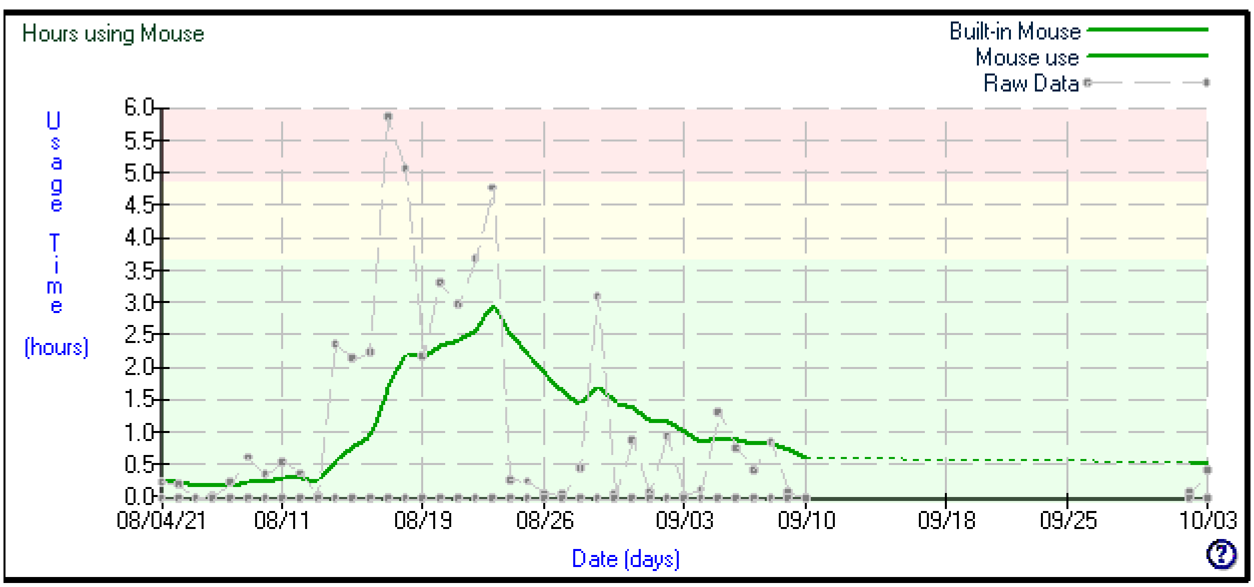
The variable of hours on a keyboard (HoursK) was evaluated. The highest daily average use of the keyboard was 5.36 hours per day over a period of 364 days. Among all participants, the average mean score for daily keyboard use was 1.04 hours per day. The participant who averaged 5.36 hours per day reported *Infrequent work-related discomfort* in the Frequency of Discomfort Model. It is important to note that this individual did report *Slight fatigue in neck and upper back*, *No discomfort in lower back*, *No discomfort in shoulder,* and *Slight Fatigue in wrist and hand*. Although the result of 5.36 hours is very high, and well above the mean score average of 1.04 hours per day, the answers in the body part discomfort questions did not indicate musculoskeletal problems. It would be beneficial for an ergonomist or health and safety professional to further understand the hours recorded, specifically to determine why and how these high results occur.

Total hours on a computer (TotalHours) found that the highest recorded computer use was 10.7 hours. Specifically, the individual with this score recorded HoursM at 9.41 and HoursK at 4.89. Although these variables were not additive (i.e., HoursM plus HoursK do not directly equal TotalHours), this participant's total hours on a computer were reflective of high daily hourly usage time.

After identifying high users, other statistics should be reviewed to further understand what is occurring to these individuals. For instance, mouse usage statistics (i.e., mouse clicks [DoubleClicks, LeftClicks, RightClicks], MouseDistance, and MouseScrolls) should be reviewed to understand patterns and job types among high usage participants. Breaks-related statistics were crucial to review, especially after determining the "superusers." Researchers have studied the importance of breaks when performing numerous ergonomic studies, specifically how breaks can result in a reduction of musculoskeletal discomfort when working at a computer. Various break statistics (i.e., BreakTime, AverageBreakLength, Stretch Feature Usage [not evaluated during this study], and BreakTimer) among high users should be analyzed. Specifically, it would be beneficial to understand how often or for how long higher users were utilizing various Break features. BreakTimer, a feature used in this study, was controlled by users (i.e., users could enable or disabled it).

The RSIGuard® software provides a graphical representation of many variables (e.g., hours on a mouse, time spent using a computer, hours using a keyboard, etc.), which can be reviewed by the individual user or an administrator. The RSIGuard® DataLogger Analysis document states that the UserInsight Application, which is reflective of years of data collected by RSIGuard®, can provide a tool to evaluate an individual's potential for musculoskeletal problems due to computer use. The UserInsight graph, as noted in Figure 4, provides color-coded graphs that show users/administrators computer usage over a specific period of time, as dependent on a particular variable. In Figure 4, the UserInsight graph displays hours using a mouse in the green zone (ranging from 0-3.75 hours per day), which is considered to be an acceptable usage range. Those who fall into the acceptable usage range have lower exposure to musculoskeletal problems. However, since this data set had much higher usage times for HoursM, it would be important to start with the highest levels of hours on a mouse or keyboard, then continue the evaluation until at risk individuals have been reduced to low levels of risk for musculoskeletal problems.

Figure 4. Individual UserInsight Graph (Usage Time and Date)



Based upon the data presented in Figure 4, a potential Ergonomic Action Plan has been developed, which includes:

- Review and evaluate users who have recorded more than six daily hours of average mouse use

- Review and evaluate users who have more than three daily hours of average keyboard usage
- Identify users who report *Constant* or *Moderate Work-Related Discomfort*
- Determine job categories and uniqueness of jobs for users who report high daily mouse and keyboard usage
- After identifying individuals as high users, review the individual's workstation to correct any non-neutral postures
- Consider a user-specific action plan to reduce an individual's likelihood of musculoskeletal discomfort and/or potential diagnosis of a musculoskeletal disorder
- Collaborate with medical professionals to determine if work restrictions are necessary
- Administratively control BreakTimer and ForgetMeNots features in order to have features enabled
- Provide user-specific ergonomic training for users to identify musculoskeletal problems and understand neutral-posture desktop arrangement for their individual use
- Review GroupInsight statistics (RSI Administrative Statistics) data at sufficient intervals, e.g., quarterly, bi-annual, to identify participants who may be "superusers" to identify employees who change jobs or job responsibilities. Provide a user-specific action plans as necessary

By reviewing and analyzing available data, anticipated musculoskeletal problems may be identified. Unfortunately, the previous statistical analyses (Study1 & Study2) are not reflective of the necessary data needed to establish musculoskeletal issue-related conclusions. Monitoring key variables, such as HoursM, HoursK, TotalHours, and Break statistics, can assist ergonomists or health and safety professionals to identify high usage times for mouse, keyboard, and computer use. Proactive ergonomic programs must identify "superusers" to determine if an ergonomic intervention plan is necessary, therefore resulting in a potential reduction in musculoskeletal problems. While high user participants did not report any musculoskeletal discomfort, it is likely that continuous mouse and/or keyboard usage, which does not involve sufficient rest breaks, can result in musculoskeletal problems.

Other RSIGuard® features (e.g., AutoClick [reduces clicks by hovering], HotKeys [shortcut for high-usage function, reducing clicking, i.e., CTRL+C)], or ErgoCoach [coach user on multiple monitors, sit-stand desk, virtual terminal]) could contribute to creating a user-specific ergonomic plan. Job modifications (medical professional approval) and work restrictions can result in potential reduction of musculoskeletal problems. Organizations may consider performing an individual workplace evaluations and implementing simple fixes (e.g., changing the mouse type, changing the location of the mouse, moving the desk closer to the worker, adjusting the chair, or adding a stand-capable desk). Users should also have access to their UserInsight statistics, specifically color-coded graphs, so they can understand their likelihood of experiencing potential musculoskeletal issues. Furthermore, it is important to monitor individuals who report high levels of discomfort (OES Data) and to determine what might be causing this discomfort.

While there were various study-related strengths, weaknesses also existed. Although self-reports can be a valuable tool for research, the OES self-reported questionnaire had some weaknesses. When reviewing the SAS output, examining the 40 OES questions, participants often answered the non-body part discomfort questions, yet many participants did not answer the seven body-part discomfort survey questions. This was problematic because these questions were important for determining the association between the predictor variables and musculoskeletal discomfort. In order to maximize response rates, design the survey with short, clear, and concise questions, without bias, that have been developed and tested before administering the survey. It is possible that certain questions were not answered due to survey-related issues. To address problematic survey questions, pilot testing should occur. One of the main issues with the survey, which was immediately noticed by the researcher, was that no Likert-type scale was used. For example, the term *Slight-fatigue* was used as a choice in for six of the seven body-part discomfort survey questions. It is important to note that the survey definition for slight discomfort was “without any discomfort,” which could be interpreted as the same as the other survey choice of *No Discomfort*. Clarity in terms of definitions and scale ratings is essential. In addition to survey definition issues, an end-of-study OES questionnaire should have been conducted to compare pre- and post-study results. This information would have been beneficial to have because it would have allowed additional comparisons between the beginning and 1-year results.

RSIGuard® is a robust software program that collects various user data. However, in a RSIGuard® document, which is entitled “A Detailed Analysis of RSIGuard®’s DataLogger,” it is reported that strain is more of a risk predictor as compared to keystroke or mouse click numerical counts. Therefore, dataset variables related to strain (e.g., measurement muscle strain in wrists and other body parts) can analyze measured strain (e.g., Mouse/Keyboard strain exposure, Keypress intensity, Number of manual mouse drag & drops, etc.). The aforementioned variables, which were not evaluated in this study, may predict musculoskeletal symptoms, thus resulting in the prevention of musculoskeletal disorders using statistical data.

In addition to survey-related issues and risk predictor factors, this dataset lacked demographic data. In fact, the data was a secondary data with no identification, gender or occupational data. By further understanding demographic factors, other data-related conclusions could have been drawn.

Using the proposed ergonomics action plan could help companies to develop a proactive ergonomics program, therefore resulting in continuous process improvements. By proactively identifying potential ergonomic problems, a reduction of injuries and illnesses is likely to occur. Evaluating work patterns and understanding the impact of an individual’s job on mouse, keyboard, and computer usage can assist ergonomists or safety and health professionals in identifying potential musculoskeletal problems. Ergonomic data should be frequently evaluated to assist organizations in improving the health and wellness of employees.

Only a few predictor variables associated with musculoskeletal discomfort were obtained from this study's data findings; however, it is important to note that intensive computer usage can contribute to musculoskeletal discomfort. Although high user study participants reported very few musculoskeletal issues, these findings are not reflective of findings noted by various researchers. In fact, annually, 30% of reported occupational illnesses and injuries are due to musculoskeletal disorders. Therefore, occupational environmental factors can cause musculoskeletal discomfort while working on a computer. However, it is important to remember that not all OSHA-reported musculoskeletal disorders are computer-related.

Future research

Questions remain as to how to reduce MSDs when working at a computer. This research determined that only variables found subjectively (OES data analysis) were associated with musculoskeletal discomfort. There are many factors (e.g., repetitive movements, awkward positions, static posture, insufficient rest breaks, psychosocial) that can cause computer-induced MSDs. Several studies indicate that rest breaks, depending on the MSD, can be essential in reducing MSD symptoms (Lanhers et al., 2016). Madeleine et al. (2013) reported that MSDs were a multifaceted problem, and therefore needed a multi-disciplinary approach in order to determine work-related MSDs. Furthermore, this study found women had a much higher pain severity, more locations of pain, and experienced a longer extent of pain.

A research proposal would be to have all participants have the features enabled (turned-on), especially the BreakTimer feature with the variable BTEnabled, to track the essential variable BreakTime. Evaluating breaks is based on previous studies, whereas taking sufficient rest breaks can be an effective method, if followed, in reducing MSD symptoms.

Another research proposal for studying using the RSIGuard® data would be to compare a company's OSHA 300 Injury & Illness Log to reported musculoskeletal discomfort from a discomfort questionnaire. The questionnaire could be compared to the RSIGuard® data to possibly see trends in occupational injuries (MSDs) and develop a specific protocol (e.g., work restrictions, auto-click feature, key control, or ergo coach feature) for individuals with potential MSDs. A study in this manner should also include the input of the individual of interest (or a person with the same occupation), occupational medical personal, available new technologies, and possible stand-capable desks. Baseline medical information and a follow-up questionnaire should be performed to determine improvements in reducing MSDs.

One more research proposal would be to evaluate specific occupations within an organization to identify trends or outliers that may lead to MSDs and develop a specific protocol discussed previously.

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APPENDIX A.

QUESTIONS FROM OES QUESTIONNAIRE

Question	Variable Name
How many hours do you spend working on a computer in a typical workday?	Hours on a Computer
How often do you typically perform NON-computer activities? Which can include phone calls, rest breaks, in-person meetings, or fax/copy machine use.	Breaks
How many hours do you use a notebook computer per week?	Use of Notebook Computer use hours/week
During a typical workweek, how many hours do you work with your notebook computer without ANY equipment attached to it (NO external keyboard, mouse, stand, or monitor)?	Use of Notebook Computer w/o external equipment
Do you frequently experience upper back and/or neck fatigue as a result of viewing documents that are lying flat on your desk?	Document Holder
Do you commonly cradle your phone between your ear and shoulder?	Cradles Phone

Appendix A. (Continued).

Question	Variable Name
Do you need to tilt your head backward when viewing your monitor due to the use of bifocals, trifocals, or progressive lenses?	Bi/trifocals
Which picture best demonstrates your monitor height?	Monitor Height
Which of the following pictures best demonstrates the glare you usually experience on your monitor?	Monitor Glare
Which picture best demonstrates your typical back position when sitting at your computer?	Back Position
Which picture below best indicates where your backrest supports your back?	Backrest Position
Select the picture that best represents your typical chair height and body position?	Chair Height
When sitting all the way back in your chair, which of the pictures below best shows the distance between your knees and your seat edge?	Seat Pan

Appendix A. (Continued).

Question	Variable Name
Do your feet rest comfortably on a flat surface? (e.g., floor, footrest)	Foot Position
Do you have adequate lighting to perform your desk work effectively?	Adequate Lighting
Can your armrests be adjusted up and down?	Adjustable Armrests
When you are typing, do your arms rest on armrests, a desk, or other surface/Which picture best describes your armrest situation?	Forearm Support
Which picture below best demonstrates the position of your arms as you use your keyboard or mouse?	Forward Shoulder Reaching
Do you frequently use a hand-held device (e.g., smartphone or hand-held computer) during the workday and/or outside of work?	Hand-Held Device

Appendix A. (Continued).

Question	Variable Name
Do your hands or wrist rest on an uncomfortable surface or sharp desk edge while in the resting position or while typing/mousing?	Hand/Wrist Resting Surface
Which picture best demonstrates your typical head and neck posture as you view your monitor?	Head and Neck Posture
Are they [elbows] above, below, or at about the same height as your keyboard and mouse?	Keyboard and Mouse Height
Which picture best demonstrates the rotation of your head when viewing your monitor(s)?	Monitor Position Rotation
Do you use multiple monitors to perform the majority of your work?	Multiple Monitor Usage
Do you regularly travel with a notebook computer?	Notebook Travel
Does all of your workstation equipment work properly?	Properly Working Equipment

Appendix A. (Continued).

Question	Variable Name
Do you have a secondary office at home where you do computer work on a weekly basis (at least once per week)?	Second Home Office
Is your primary workstation shared with other people?	Shared Workstation
Which picture best represents the position of your arms/elbows when working with your mouse (or other pointing device)?	Shoulder Abduction
Do your keyboard and mouse rest on a surface that has enough room for both devices to be positioned next to each other?	Space Keyboard and Mouse
In the last six months, would you describe your stress level as…?	Stress
What type of work do you spend the most time doing on the computer?	Type of Work
Which picture below best demonstrates your typical <u>wrist posture</u> when working at your computer?	Wrist Position