# IMPLEMENTATION AND EVALUATION OF AN OFFICE ERGONOMIC INTERVENTION AMONG WORKERS WITH NECK AND UPPER EXTREMITY PAIN

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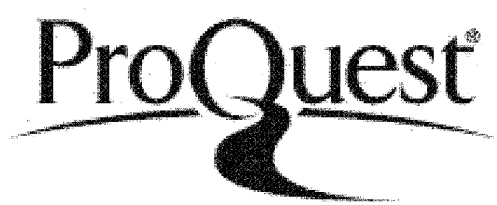


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## ABSTRACT

**Background:** Computer operators' work is associated with a high prevalence of neck and upper extremity pain. Older workers who use the computer have more severe pain and lost workdays than younger workers.

**Methods:** This 7 month, randomized controlled intervention evaluated the effects of a fully adjustable keyboard/mouse tray and a touch pad pointing device in their non-preferred limb on spine and upper extremity pain severity in 109 public sector office workers. The preferred limb continued to use a corded optical mouse. Participants were randomized into (1) an intervention group, where they received these engineering controls and training, plus training on keyboard shortcuts, and (2) a control group, where they only received training on keyboard shortcuts. Outcome measures were modified Rapid Upper Limb Assessment (RULA), Hand Activity Level (HAL), musculoskeletal pain severity, and the Medical Outcomes Study (MOS) Short Form 36. General Estimating Equations using multivariable linear and Poisson regression examined main effects models. General Estimating Equations Poisson models examined effect modification by age. Multiple regression models adjusted for individual determinants factors, physical and temporal load items, and psychosocial exposures.

**Results:** The intervention reduced postural exposures in all RULA elements; 3 findings were statistically significant. Upper extremity movement (HAL) decreased in the preferred limb and increased in the non-preferred limb. Nine of twelve anatomical regions had less likelihood of an adverse musculoskeletal outcome; six of these regions showed statistically significant findings. The non-preferred forearm region showed a statistically significant greater likelihood of an adverse musculoskeletal outcome (RR = 1.03, 95% CI 1.02-1.05). The intervention showed no effect on the MOS. RRs for the interaction terms showed that age modified the association between posture and upper extremity movement and pain severity. There were two significantly greater likelihoods of an adverse musculoskeletal outcome in the preferred proximal upper extremity quadrant, while there were two significantly protective effects in preferred and non-preferred distal upper extremity quadrants. Upper extremity movement showed that one significantly protective effect in the preferred upper extremity proximal quadrant, while there was a border significantly greater likelihood of an adverse musculoskeletal outcome in the non-preferred distal upper extremity quadrant.

**Conclusion:** The engineering controls were effective in reducing postural and movement exposures in the preferred limb. With the exception of the non-preferred forearm, the engineering controls and training are effective in reducing spine and upper extremity musculoskeletal pain severity. While there was a greater likelihood of an adverse musculoskeletal outcome in proximal upper extremity quadrants, protective effects were observed in distal upper extremity quadrants.

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Biographical sketch of author

Jonathan Dropkin, ScD, PT received a Bachelor of Science degree in Applied Physiology from Boston University in 1982. He received a second Bachelor of Science degree in Physical Therapy from the State University of New York at Stony Brook in 1984. Dr. Dropkin received his Master of Science degree and Doctor of Science degree in Occupational Ergonomics from the University of Massachusetts Lowell in 1993 and 2012, respectively.

# I. INTRODUCTION

## 1.0 Work-related musculoskeletal disorders

The World Health Organization (WHO) identifies disorders as "work-related" when work activities and conditions contribute to the development or exacerbation of these disorders, although they are not the only determinant [1]. Work-related musculoskeletal disorders (MSDs) include a range of inflammatory and degenerative diseases and disorders. These conditions may result in pain and impaired function and work performance in the spine and upper extremities [2].

MSDs accounted for 29% of all workplace illnesses and injuries requiring time away from work in 2010. Although the number of lost workdays in both public and private sectors for all age groups remained essentially unchanged from 2009, some age groups appeared more vulnerable. For example, workers aged 45-54 had a 5% increase in their incidence rate from 2009 to 2010. This age group comprised 27% of all lost workday cases in 2010. Workers aged 65 and over required the longest amount of time to recover from an illness or injury, with a median of 16 days [3].

The physical exposures related to MSDs include repetitive motions, non-neutral postures, forceful muscle-tendon contractions, sustained static loading, and insufficient recovery. Possible pathways from physical exposures to the development of neck and upper extremity MSDs have been described [4]. One model examines the cumulative nature of MSDs. Specifically, exposures associated with a work activity or task produce internal

forces, a dose, which act on the musculoskeletal system. The dose leads to a physiological and/or biomechanical response. The response may increase or decrease the ability to manage future responses. If there is insufficient time for recovery within tissues, additional responses may further reduce available physical capacity. This cumulative cycle may continue until tissue deformation occurs, such as pain or joint degeneration. Other models examine pathways between physiological capacity and work activity [2].

In general, these models also account for the work environment/work organization, and factors related to work organization, such as psychosocial exposures [5]. These determinants may modify the effect of biomechanical loads and work performance [6]. Individual work characteristics, such as age, gender, anthropometry, and past medical history may also modify the effect of these loads and work performance.

## 1.1 Widespread use of computers

I n 2003, the Bureau of Labor Statistics (BLS) of the United States (US) Department of Labor reported 77 million individuals used a computer at work. These workers accounted for approximately 56% of total employment. Approximately 2 of every 5 employees used the Internet or e-mail at work. These proportions were slightly higher than those measured in a 2001survey. Although there were large variations by job group in the proportions of workers who used computers at work, computer use was highest among managers and professionals (80%) and sales and office workers (67%) [7, 8].

Similar data have been reported for the European Union (EU). In 2000, 50% of the EU workforce used a computer for any amount of time. The growth in computer use from the

previous decade was almost completely from the increase of so-called pink- or white-collar professions [9]. Indeed, while there has been a decline among industrialized countries in heavy, physically demanding blue-collar jobs, such as manufacturing, there has been a concomitant increase in occupations requiring low but sustained levels of physical exposure. These jobs are often associated with computer-related work [10] (page 63). Mathiassen noted that future trends in the service sector will be characterized by long-lasting, repetitive operations, with limited task variability and low levels of mechanical loading, factors that already characterize computer tasks [11].

## 1.2 Burden of work-related musculoskeletal disorders from computer use

Work-related musculoskeletal disorders (MSDs) associated with computer use are a considerable public health burden in the US [12]. For more than 25 years a great deal of attention has been directed towards MSDs and their relation to occupational computer use [13].

Both incidence and prevalence of MSDs related to computer use are substantial. In a study of newly hired computer operators, over 50% had incident upper extremity symptoms after 1 year [14]. The prevalence of neck and upper extremity pain among computer operators can be as high as 50% [15]. In a cohort of administrative workers, Andersen et al. found a 43% prevalence of pain in the neck and shoulder, and a 17% prevalence of pain in the elbow, forearm, and hand [16].

The number of lost workdays associated with computer use may be increasing. For example, in 2009, computer-related occupations experienced more days away from work

than in 2008. Specifically, the median time away from work in 2009 from a computer-related MSD was 7 days, compared with 5 days in 2008.

Physical exposures associated with computer use, including repetitive motion and overexertion of the upper extremity, were the second and third highest exposures leading to lost-time illnesses. These exposures, which affected the wrist and shoulder regions, required a median of 27 and 21 days to recover in 2009, respectively [17].

Lost-time illnesses may be even greater in older workers. In general, older workers with MSDs have higher illness chronicity and severity than younger workers [10] (p. 123). In addition, the severity of MSDs associated with computer work may increase as the working population in industrialized societies is aging. Moreover, older workers seem to be over-represented in service sector jobs, which often involve computer work [18]. Since over 50% of North American workers use computers at work [7, 8], examining the relation among the physical exposures in office work, MSDs, and age seems particularly germane.

Due to the widespread use of computers, the prevalence and severity of MSDs associated with computer use, and population aging, even small risks related to computer work can have substantial public health consequences. Ergonomic interventions that reduce musculoskeletal morbidity can have an important health impact and benefit employers, employees and, more generally, the US economy.

## 2.0 Interrelation among the following sections

The following sections explain the rationale and justification for the dissertation: 1) the implementation and evaluation of an office ergonomic intervention involving secondary

prevention; this section also highlights practical and economic issues regarding the choice of macro versus micro intervention to reduce physical exposure in the office environment; 2) whether the magnitude of the effect of physical exposures on musculoskeletal pain varies by age; and 3) whether magnitude and frequency of postural movements vary over the workday in workers with pain.

These 3 sections are interrelated as follows: there are limited studies on interventions for symptomatic workers [19]. Workers in pain appear to have more altered motor control and movement patterns than asymptomatic workers [20, 21]; greater pain chronicity and severity seem to affect motor control and movement patterns greater than less chronic and severe individuals. Pain chronicity and severity in older workers may be greater than in younger workers [22-24]. Since motor patterns may become deranged over the workday among symptomatic individuals, and older workers appear to have greater pain chronicity and severity than younger workers, workers in pain and, specifically, older workers, may require different exposure assessment strategies over the workday. They may also need additional ergonomic controls to maintain their work performance.

## 3.0 Office ergonomic intervention involving secondary prevention

The goal of primary prevention is to protect healthy people from developing a disease or experiencing an injury in the first place. Secondary prevention occurs soon after an illness has already been identified. The goal is to stop or slow the progress of the illness in its earliest stages. Tertiary prevention helps individuals manage complicated, long-term health

problems, such as chronic musculoskeletal pain, and seeks to prevent further physical deterioration [25].

There are limited investigations on prognosis, which is the prediction of the course of disease and chance of recovery [26] for work and health outcomes in individuals who remain working after the onset of their illness [27-29]. Burdorf et al. noted that prognostic studies should identify which factors influence the workers' ability to cope with their MSD while remaining in their exposed jobs [30].

Numerous studies have been published on primary prevention, while fewer studies have examined recovery or persistence of MSDs following an intervention [19, 31]. Although substantial epidemiologic evidence suggests that physical, psychosocial and bio-behavioral factors can affect prevalent neck and upper extremity MSDs, effective long term approaches for secondary prevention are scarce [32].

In a recent review that examined intervention studies among computer workers with MSDs, authors noted although office ergonomic interventions were widely available and marketed, there was little evidence to support their use among workers with MSDs [19]. Other authors have stated a major difficulty of secondary prevention is to filter theoretical concepts in order to implement controls that were realistic and cost-effective for symptomatic workers [33].

## 3.1 Macro versus micro level interventions

Authors have described nodes in a pathway in which ergonomic interventions can be implemented at various points along the nodes [34]. Upstream nodes can be considered

macro-ergonomics, while changes that affect the task or worker can be considered micro-ergonomics. Examples of such nodes range from managements' attitudes of changing working conditions, which involve resources, commitment, and organizational, system level changes, to changing exposures at the worker level and prompt medical treatment once an illness occurs.

The literature on the effectiveness of ergonomic interventions has noted that multiple components addressing both macro- and micro-ergonomic factors were the most effective interventions [35]. Other researchers concurred with these conclusions: develop integrated controls that address work organizational factors and both psychosocial and physical exposures [34, 36-38].

Although we agree the best approach is to address all levels of the organization [39, 40], factors such as an agency's production demands, whether the workforce is unionized, changes in or downsizing of the workforce, available financial resources, stakeholders' commitment, and political climate make these types of interventions challenging. The current political climate in the US might make a micro-ergonomic approach more attractive to employers and more realistic to implement.

At the micro-ergonomic level, a recent review [19] noted that only one paper examined the effect of a negatively tilted keyboard, in which the keyboard was pitched away from the worker, on secondary prevention [41]. Three papers examined the effects of pointing devices on secondary prevention [42-44].

## 3.2 Research gaps

Research gaps were identified in four recent reviews on ergonomic interventions. One review noted that most of the secondary prevention outcomes studied were symptoms, with little attention paid to exposure reduction [19]. These authors recommended that secondary prevention studies should involve intervention strategies designed to reduce exposure and pain, allow workers to remain at work, and prevent worsening of the illness from advancing to a loss time illness or chronic MSD.

Their review examined corrective lenses, biofeedback training, ergonomic training, ergonomic counseling, lighting, alternative mice, forearm supports, lumbar supports, a negatively tilted keyboard trays, rest breaks, workstation adjustments, workstation redesign, and an adjustable chairs. They concluded that no studies provided "strong evidence" to support the effectiveness of secondary prevention in the office environment. They did find a "moderate level of evidence" to support the use of group ergonomic training and counseling.

In this same review on secondary prevention, three of the studies examined pointing devices [42-44] and one investigated the effects of downward tilting keyboards [41]. The authors found that there was "fair" evidence that alternative pointing devices improved comfort, although they concluded additional research was needed to add to the credibility of these studies. There was "insufficient evidence" to support improvements in comfort and reductions in physical exposure for a downward tilting keyboard.

Other authors examined both primary and secondary interventions among office workers [31]. Secondary interventions involved exercise, job stress management, ergonomics training, an "ergonomic" chair, workstation rearrangement, pointing devices, alternative

keyboards, rest breaks, a new office, corrective lenses, screen filters, and eye drops. These reviewers found "moderate evidence" that workstation rearrangement without adjustable equipment had no effect on musculoskeletal outcomes. "Moderate evidence" was also found that rest breaks combined with exercise had no effect on musculoskeletal outcomes. There was "mixed evidence" (i.e., inconsistent findings among medium and high quality studies) that ergonomics training, arm supports, alternative keyboards, and rest breaks had a positive effect on musculoskeletal outcomes. There was also "mixed evidence" that screen filters had a positive effect on musculoskeletal outcomes. There was "insufficient evidence" to conclude that a combination of stress management and ergonomic training had a positive effect on musculoskeletal outcomes. There was also "insufficient evidence" to conclude that a new chair, lighting, computer glasses, exercise training, a new office, and corrective lenses had positive effects on musculoskeletal outcomes.

In this same review that pertained to secondary prevention, there was "moderate evidence" that alternative pointing devices had a positive effect on musculoskeletal outcomes among secondary prevention studies. One study involved a track ball and the other a vertical mouse. For these studies, a trackball reduced prevalent neck and upper extremity MSDs and a 3M Anir mouse reduced prevalent upper extremity pain [31, 44-46]. However, reviewers noted the pointing devices used in these studies were too dissimilar to issue practice recommendations. Nonetheless, they noted that more studies were needed to examine what features of pointing devices were beneficial.

Kennedy and co-workers reviewed occupational intervention studies involving primary and secondary prevention among numerous industries and occupations, although over 67% of the exposures involved office work [47]. Among studies involving secondary

prevention in computer-intensive work, the interventions comprised ergonomic training, exercise, biofeedback training, job stress management, workstation adjustment, workstation rearrangement, alternative keyboards and pointing devices, a new chair, rest breaks, physical therapy, and workstation redesign [47]. Reviewers found a "strong level of evidence" there was no effect of only workstation rearrangement without equipment for upper extremity MSDs. A "moderate level of evidence" was found for no effect of biofeedback and job stress management training on upper extremity MSDs. The reviewers concluded there was limited utility to conduct further studies focused solely on workstation rearrangement, biofeedback training, or job stress management.

In the same review, a "moderate level of evidence" was found for a positive effect of arm supports on upper extremity MSD outcomes. They found "limited evidence" for a positive effect of ergonomics training plus workstation adjustment, a new chair, and rest breaks on upper extremity MSDs. Workstation adjustment combined with training appeared to be more effective than using either intervention independently. A "mixed level of evidence" was found for exercise programs, ergonomic training plus exercise, alternative pointing devices, and alternative keyboards. These authors provided a similar recommendation for pointing devices as in the last review [31]: while "mixed evidence" exists for alternative pointing devices, differences between pointing devices (a trackball and a vertical mouse) made practice recommendations problematic and were cautious to provide recommendations about specific alternative pointing devices.

In a review examining upper extremity MSDs in a wide range of industrial sectors and occupations, Boocock et al. found seven office ergonomic studies involving secondary prevention. The authors classified all of these studies as "mechanical interventions"

(indicating a micro-ergonomic approach) and categorized the interventions into two groups: 1) work environment/workstation adjustments and 2) workstation equipment. Interestingly, they were unable to identify "organizational culture interventions" with respect to the office work environment. The interventions consisted of modified lighting, a new workplace, office layout, "take-a-break" software, alternative keyboard and mouse design, and adjustable chairs. These reviewers concluded there was "some evidence" for work environment/workstation adjustment for improved health outcomes in computer workers with neck/upper extremity conditions. They also noted there was "moderate evidence" that alternative mice and keyboard designs can lead to positive health benefits in computer workers with neck/upper extremity musculoskeletal conditions. They concluded that no single- or multi-dimensional intervention strategy provided strong evidence; and there was limited data to support the establishment of "evidence-based guidelines" that can be applied to several industrial sectors, including the office environment [48].

## 3.3 Definition of neutral posture

The term "neutral posture" in this study was operationalized with respect to the length of a muscle crossing a joint, its relation to the contractile tension it can generate, and the physical load about the joint. The length-tension relation states the tension generated in skeletal muscle is partially a function of the magnitude of cross-bridge formation between protein filaments. The greater the magnitude of cross-bridge formation, the greater the generation of force [49-51]. The greatest force generated is defined when the muscle is at resting length. However, the load about the joint should also be considered. For example,

while the biceps brachii are at resting length when the elbow is flexed at 90 degrees, the ulnar nerve within the cubital tunnel becomes compressed; continued 90 degree posture at the elbow may lead to ulnar neuropathy in this joint [52]. Ulnar nerve compression decreases when the elbow moves into extension.

Angular definitions of neutral joints we are examining include approximately 0-10 degrees of extension at the wrist [53] when the interphalangeal joints are slightly flexed, 35-45 degrees from full pronation at the forearm [54], <60 degrees of flexion at the elbow [55], < 30 of shoulder flexion and abduction [4], < 15 degrees of shoulder internal or external rotation [56], 0-5 degrees of scapula elevation, and between 95-110 degrees of hip flexion [57].

Neutral postures at the wrist are important for several reasons. Carpal tunnel pressure is a function of the forces exerted by wrist tendons, which increase as a function of wrist extension, wrist flexion, and ulnar and radial deviation for a given hand position; muscle co-activation forces and moments amplify these effects when the hand is positioned in extension, flexion or deviation [58]. Schoenmarklin and Marras found that when the hand is accelerated and decelerated, such as in wrist extension and flexion when typing, compression forces on the tendons and median nerve increase [59]. Extension and flexion movements may lead to more of an increased risk of median nerve neuropathy than ulnar and radial deviations [60]; a low, negatively tilted keyboard would positively affect extension wrist postures greater than deviated wrist postures. Armstrong and Chaffin found that finger movements during wrist extension resulted in greater forces on wrist structures than during a neutral wrist posture [61]. These same authors found that for subjects with and without carpal tunnel

syndrome, symptomatic subjects assumed wrist extension more frequently than asymptomatic controls [62].

Maintaining neutral postures at the elbow may help reduce the risk of persistent or incident MSDs in the elbow, upper back, and neck. Research indicates that ulnar nerve dysfunction at the elbow may increase as the elbow flexes and decrease as the elbow extends. During elbow extension and flexion movements, the ulnar nerve's anatomical location changes; beginning at 90 degrees of elbow flexion and continuing into full elbow flexion, ulnar nerve tracking problems may develop [63]. The ulnar nerve also begins to tighten at 90 degrees of elbow flexion [64]. In addition, the humeroulnar arcade is slack in elbow extension and the nerve lies loosely in the ulnar groove of the medial epicondyle. As the elbow moves from extension to flexion, the humeroulnar arcade tightens, increasing pressure on the ulnar nerve from 19 mmHg in full extension to greater than 200 mmHg in full flexion [65].

Sauter and colleagues found that a lower keyboard height was the most important factor associated with decreased discomfort throughout the upper extremity, while a keyboard above elbow height was associated with increased upper extremity discomfort [66]. This implied that acute elbow angles – angles less than 90 degrees – were associated with increased upper extremity symptoms. In a prospective study that characterized the effect of computer operators' postures on musculoskeletal health, researchers found that an elbow angle of 121 degrees or greater was protective against incident distal MSDs [55]. In a laboratory study that examined electromyography among computer workers with and without shoulder symptoms, researchers found that at elbow angles of 105 degrees or greater, electromyography amplitude in the upper trapezius decreased in both groups of workers [67].

Maintaining neutral posture in proximal quadrants (i.e., the neck, upper back, and shoulders) is important because several studies suggested that MSDs might be more prevalent in proximal than distal quadrants (elbows, forearms, wrists, fingers) in computer operators [55, 68-71].

Moreover, the BLS reported the severity and number of lost workdays due to illness in proximal regions, such as the shoulder, is only slightly less than distal regions, such as the wrist. For example, shoulder MSDs resulted in a median of 21 lost work days before recovery in 2010, which was only 6 days less than the median number of lost work days before recovery from carpal tunnel syndrome [72].

## 3.4 Rationale for keyboard/mouse tray

The beneficial effects of an appropriately adjusted keyboard/mouse tray, with adjustments for both height and angle, include neutral postures in the digits, wrists, elbows, shoulders, and scapulas. In a laboratory study, Hedge and Powers found a 12 degree negatively tilted keyboard reduced wrist extension to nearly zero degrees, and neither impaired typing performance nor elicited negative participant responses [58]. In a small randomized study, Hedge et al. found a reduction of wrist extension angles of approximately six degrees in the intervention group that used a negatively tilted keyboard tray. The control group worked on the desktop. The intervention group also spent more than 60% of their time in <15 degrees of wrist extension (which they defined as "neutral") in which estimated wrist extension angles produced less than 40 mmHg of carpal tunnel pressure. This is a threshold at which adverse neurological changes in the median nerve can exist [73]. Curiously, this

study did not examine the effects of a negatively tilted tray and pointing device on distal upper extremity posture [41].

Gilad and Harel found forearm extensor muscle activity to be approximately 25% to 66% less when participants used a negatively sloped keyboard compared with traditional and alternatively designed keyboards [74].

A study by Hedge et al. found reductions in shoulder pain and "poor shoulder posture" from the use of a negatively tilted keyboard tray [41]. To provide dynamic ball and socket movement in the glenohumeral joint, shoulder movements are accompanied by scapula movements. Thus, glenohumeral and scapula movements will work jointly as synergists, agonists, or antagonists [75].

## 3.5 Hypotheses relating to keyboard and mouse tray

1) A keyboard and mouse tray that is adjusted to promote neutral postures, and training in its adjustment and use, will reduce non-neutral postures in the neck, upper back, and preferred and non-preferred limbs[1];
2) A keyboard and mouse tray that is adjusted to promote neutral postures, with training in its adjustment and use, will reduce pain severity in the neck, upper back and upper extremities, and improve quality of life of an intervention group compared with a control group.

[1] The preferred limb refers to the limb using the traditional corded optical mouse, while the non-preferred limb refers to the other limb.

## 3.6 Rationale for use of pointing devices, one in each hand

In a laboratory study initiated due to musculoskeletal complaints in the upper extremity using a mouse, researchers found that upper extremity postures and movements during mousing were characterized by prolonged periods with body joints in non-neutral postures [76]. In a study that examined musculoskeletal symptoms and mouse and keyboard work, attributable fractions among the exposed - the proportion by which the rate ratio of the outcome among the exposed would be reduced if the exposure was eliminated [37] - were greater than 20% for symptoms in both shoulders, both elbows, and right wrist [77]. These investigators also found that symptoms were more prevalent in computer operators working at least 5.6 hours per week with a mouse. Jensen found using a mouse for more than 50% of the work time increased the risk of developing hand-wrist symptoms compared with using a mouse for 25% of the work time [78].

Researchers also reported that computer operators, whose symptoms are associated with mouse usage, often change mousing hands to improve their comfort and reduce extreme, non-neutral postures [77]. Lassen et al. found that 17% of symptomatic participants in their study made changes in their preferred limb: they changed hands during mouse use or alternated between hands when using the mouse [79].

In a laboratory study that examined bilateral mouse use, although not simultaneously, investigators found that when using a standard keyboard, left sided mousing reduced postural exposures in the left upper extremity; conversely, similar results were not observed between right sided mousing and reductions of postural exposures in the right upper extremity [80]. These authors concluded that left sided mousing would be an interesting alternative to right

sided mousing provided enough time was allowed for the worker to practice with the left hand.

In a large study of computer operators, researchers found a marked laterality with respect to right upper extremity discomfort among data entry workers who used their right-sided numeric keypads and mice extensively; the right upper extremity experienced approximately double the rates of discomfort than the left upper extremity [66]. When these researchers examined a subsample of keyboard operators with more diverse tasks, in which participants used their keyboards with both upper extremities and their mice considerably less, this right versus left sided laterality differential disappeared.

In another laboratory study, Ackland and colleagues examined pointing device use in the preferred and non-preferred limbs [81]. Researchers found that pointing device control by the non-preferred limb improved significantly following training. The non-preferred limb also reached a level of proficiency equal to the preferred limb for computer tasks. Moreover, participants felt more comfortable using their non-preferred limb for pointing device work following the study. The researchers reported that with only minimal training, alternating between the preferred and non-preferred limbs may not substantially reduce productivity.

Building on this evidence, our study used bilateral pointing devices among workers: a mouse in the preferred limb and a touch pad in the non-preferred limb. It is conceivable that using pointing devices in both preferred and non-preferred limbs will reduce physical exposure of mouse use in the preferred limb.

We hypothesized we would not be transferring higher duration, repetition, or magnitude of physical exposures to the non-preferred limb; we would not be exchanging short-term reductions in physical exposure and improvements in health in the preferred limb

for potential adverse health effects in the non-preferred limb; and the use of bilateral pointing devices would allow one upper extremity to recover while the other upper extremity is being used for pointing tasks. For example, right-handed individuals usually use a mouse on the right and, because of the right-sided numeric keypad, often have to rotate their right shoulder and position their upper back in flexion, external rotation and abduction when using a mouse. This increases loading forces in this quadrant. Moreover, these individuals usually have to elevate their right scapula because the keyboard tray is too short, which further increases loading forces and strain in this quadrant.

An additional device in the non-preferred limb, to *supplement* preferred limb use, will allow the preferred limb to recover while the non-preferred limb is active. Specifically, increased hand activity and upper extremity and upper back movement in the non-preferred limb will reduce the repetition and duration of movement in the preferred limb, reduce the duration of static loads in the upper back and neck of the preferred limb, and reduce the magnitude and duration of non-neutral postures in these same regions [80, 82].

Because hand activity in the non-preferred limb will only augment hand activity in the preferred limb, it should not lead to an exacerbation of musculoskeletal pain in any upper extremity or upper back region at follow-up [83, 84]. Therefore, although we hypothesized a likely increase in non-neutral posture and repetitive motion from use of the additional device in the non-preferred limb, the low magnitude, repetition, and duration of pointing device use in this limb should not increase existing musculoskeletal pain or adversely affect quality of life health status [80]. That is, use of an alternative pointing device in the non-preferred limb should not breach an exposure-dose-response threshold.

## 3.7 Hypotheses relating to dual pointing devices

1) The introduction of a touch-pad pointing device in the non-preferred limb, plus training, will reduce repetitive motions and non-neutral postures in the preferred limb of an intervention group compared with a control group; it will also increase repetitive motions and non-neutral postures in the non- preferred limb of an intervention group compared with a control group;
2) The introduction of a touch pad in the non-preferred limb will reduce musculoskeletal pain severity in the neck, upper back, and preferred limb, and improve quality of life compared with a control group;
3) The introduction of a touch pad in the non-preferred limb will not be associated with an exacerbation of pain in the neck or non-preferred limb.

## 4.0 An aging workforce and research needs

The BLS data show that although the entire labor force is projected to increase by 9% from 2006 to 2016, trends appear when examined by age categories. The number of workers in the youngest age group (16-24) is predicted to decline by 7%; the number of workers aged 25-54 will increase by 3%; workers aged 55-64 is predicted to increase by 37%; and the number of workers at or over 65 years of age is predicted to increase by more than 83% [85]. Workers aged 65 and over are also expected to account for 6% of the total labor force by 2016; this is up substantially from their 2006 proportion of 4% [85].

Workers may also have to work more years before reaching retirement. In 2000, the US Congress began to gradually increase the retirement age - from 65 to 67 - at which an individual can receive full social security benefits [86], and further increases are expected.

The definition of "older worker" varies among studies, which may correspond to biological or legal considerations. Some data presented effects of health or exposure with respect to age by deciles (e.g. 20-30, >30-40, etc.) (page 32) [10]. Other studies and reports have used dichotomous age categories, such as <40 years versus ≥40 years [23, 87] or <50 years versus ≥50 years [88]. The Age Discrimination Act of 1967 defined "older worker" as ≥ 40 years [89]. The US Government Accounting Office uses ≥55 to define older worker [90].

In 2001, the National Institute for Occupational Safety and Health National Occupational Research Agenda (NIOSH NORA) on MSDs listed older workers as a "special population" requiring further research. A NIOSH NORA MSD team conference in 2005, titled "The Changing Nature of MSD Risk: The Effects of Obesity and Aging in the American Workplace," focused on how population changes in age distribution are going to affect the work environment, and which factors should be addressed to protect the health of older workers.

Much of the literature on aging workers is cross-sectional. These data are problematic, as they are difficult to gain greater insight into the processes of aging [24]; in particular, these studies make it difficult to examine the cumulative effects between work-related physical exposures and aging on health. Longitudinal research is needed to determine whether older workers are at greater risk for musculoskeletal morbidity than younger workers.

## 4.1 Age, physical exposures, and musculoskeletal pain severity

Workers over 45 years of age in the US appeared to be only somewhat less exposed to non-neutral postures and repetitive motions than workers less than 45 years of age. For example, Occupational Health Supplement data of the 1988 National Health Interview Survey showed the prevalence of non-neutral distal upper extremity postures and repetitive upper extremity motions after more than 4 hours per workday was only slightly less among workers between 45 and 64 years old than those under 45 (36.7% versus 35.3%, respectively). Workers >65 reported somewhat lower physical exposures than those between 45 and 64 year old; about 23% of adults employed over the age of 65 reported non-neutral distal upper extremity postures and approximately 16% reported repetitive upper extremity motions after more than 4 hours per workday [18].

In Canada, work-related computer use was only 6% higher for the youngest than oldest age group. Specifically, computer use was estimated at 53% for the youngest group of workers (aged 15-24); it was 59% among the 25-34 age group and 62% for those aged 35 to 44; it was 53% for the 45-54 age group and 47% for the oldest age group [91].

While older workers appear only slightly less exposed to physical stressors, they have accrued longer work and exposure histories than younger workers, and may have to work at increased risk of illness severity. This may increase their duration of work absence. For example, in 1993, the median duration of work absence for all illnesses and injuries increased with age; workers under 24 years had a median duration of work absence of 4 days, while workers over 55 years had a median duration of 10 days [18].

Likewise, while the absolute percentage of lost workday cases in workers under 45 years of age declined between 1992 and 2000, it rose among older workers, albeit slowly [10] (page 131) . In 1990, older workers represented 30% of the US working population and accounted for approximately 21% of lost workdays; in 2000, they were 36% of the working population (a 5.5% increase) and had 30% of lost workdays (a 9% increase) [92]. Conversely, the absolute percentage of younger workers declined about 3.5% between 1990 and 2000, while their absolute percentage of lost workdays declined 9%. A review on older workers noted that pain severity may be explained by reduced resilience in the musculoskeletal and neuromuscular systems among older workers [93].

More recently, the BLS continued to report that severity and lost workdays for all MSDs seem to increase with age. In 2009, the median duration of illness and injury work absence among workers under 24 years was 5 days, while workers over 55 years had a median duration of 12 days [3].

## 4.2 Age-related impairment and disability

In England, workers ≥45 are twice as likely to report a chronic illness than those under 45 years of age [94]. Approximately 17% of older workers also report their health status as fair or poor compared with younger workers. The prevalence of functional impairment among workers increases with age: 3.4% of workers between 18 and 28 years old have a work-limiting impairment, while this percentage increases to 8.4 in workers between 50 and 59, and to 13.6% in workers between the ages 60 and 69 [18]. Zwerling and

colleagues reported a strong association between preexisting functional impairment and subsequent workplace MSD illness [95].

The extent of impairment from physical demands is difficult to predict among age groups, as health status variability increases markedly with advancing age. However, there may be several reasons why the joint effects of physical demands and age are associated with increased prevalence of impairment in older workers.

An overall construct of age-related change is the "life course" model, in which biological, social, occupational, and environmental factors interact throughout life. Health and function among older workers depend on past and present determinants, such as socioeconomic factors and occupational exposures [10] (page 17). This construct, coupled with an expected aging of the workforce, may indicate an increase in the number of workers who will be working with functional impairments associated with MSDs.

In a random sample of workers' compensation claims from Washington State that sought to predict duration of disability, the average length of disability increased with age [96]. The effect of being more than 44 years old increased the estimated proportion of claims involving 6 months or more of disability from about 5% for males less than 30 years (reference group) to 16%. In addition, older workers (greater than 44 years old) were substantially less likely than younger workers (under 30 years of age) to return to work over their working life after an illness or injury. Likewise, a review of safety research found a positive relation among age, severity, and permanent disability [97].

## 4.3 Are older workers at increased vulnerability to impaired functional status and health?

Shephard noted that decrements in work capacity associated with the musculoskeletal system impair functional ability in older workers more than younger workers [98]. Although older workers are generally healthier than their non-working peers, they report, on average, having at least one chronic disorder or illness. About 17% of workers greater than 45 year old also reported their health status as fair or poor compared with younger workers less than 45 years old [10].

Griffiths suggested that while physical and psychosocial demands, and adverse environmental conditions are risk factors affecting all workers, older workers may be more vulnerable to these exposures than their younger counterparts, particularly in terms of musculoskeletal-related disability [99]. In other words, there may be a differential in health outcomes between older and younger workers exposed to physical and psychosocial exposures. Specifically, older workers exposed to a combination of physical and psychosocial exposures may be at increased risk of illness compared to their younger colleagues with similar exposures [10].

Pedersen et al. defined biological stress as a disturbance in physiological homeostasis; this stress can be associated with environmental factors, occupational factors (e.g. physical and psychosocial exposures, organizational determinants), or individual factors [100]. Employing this concept, the National Research Council (NRC) explained that in stressful situations, such as the onset of an MSD, an older adult's ability to return to his or her prior

health and normal functional status following exposure to a determinant may be less than a younger individual's ability if the older adult experiences a greater disturbance in physiological homeostasis [10]. Similarly, Laflamme and Menckel [97] noted that in the work environment, physical exposures may lead to MSD symptoms in older workers in which severity is similar to younger workers, but recovery takes longer.

## 4.4 Work ability and age

The concept of "work ability," developed by Ilmarinen and coworkers [101], is based on a model in which work, aging, disease, and lifestyle interact. Work ability, a worker's capacity to handle occupational demands, examines work and individual factors, and their effects on strain among workers. These investigators stated that work, which includes work content, job tasks, work organization, and work environment, has a "central role" for healthy aging.

According to these authors, 3 groups of risk factors explain the deterioration of work ability in older workers. The first group of risk factors involves physical exposures; the second group involves poor work organizational factors; the third group involves "stressful and dangerous" environmental conditions. Researchers found the more risk factors an older worker experiences on a daily basis, the greater the risk of lowering work ability; conversely, a reduction of 1 risk factor would have a beneficial effect on work ability [102].

Sjogren-Ronka et al. [103] examined office workers in relation to physical and psychological functioning, the social work environment, individual factors, and work ability. The work ability assessment consisted of physical and mental work demands, diagnosed

diseases and their effects on work ability, sick leave, work ability prognosis, and psychological resources. Intensity of musculoskeletal symptoms and age had a negative impact on work ability, although the authors concluded a high intensity of symptoms had the greatest negative impact on work ability. They also noted the physical requirements involved in functioning are among the most important factors for maintaining work ability.

A prospective study examined 4 birth cohorts, and physical and psychosocial work demands on neck and shoulder pain with respect to incidence and recovery of pain [104]. For women, recovery rate was lowest in the 2 oldest age groups, independent of other determinants. Only 1 interaction between age and other determinants was observed: age and "repetitive work under time constraints" for men born in the youngest birth cohort. Specifically, men born in this cohort and who worked repetitively under time constraints reported a lower recovery rate than men of the same birth cohort who had never worked under these conditions. Recovery among all birth cohorts was thought to be due to changing of jobs, worksite prevention, and medical management. As workers aged, however, complete recovery was reduced. The investigators noted the majority of workers with chronic pain were at work "coping" with their impairment at the end of the study.

In a cross-sectional survey that examined white collar occupational categories, work capacity, and health complaints, Broersen et al. sought to determine which demands pose the greatest risk on aging workers [105]. The authors hypothesized that work complaints would increase with age, although mitigating factors, such as the transfer of older employees to less stressful jobs and self-selection of symptomatic or injured older employees out of work (i.e., healthy worker effect, or HWE), might play a role in reducing complaints. Findings indicated that, overall, health and work capacity of employees decreased with increasing age.

However, health complaints in the oldest age categories leveled off compared with younger workers. Moreover, prevalence of complaints about work conditions did not increase with increasing age categories. According to the authors, possible explanations included the HWE and the hypothesis that older workers had more job experience and control, and had implemented more job modifications.

de Zwart et al. [22] examined changes in musculoskeletal complaints in the neck, trunk, and upper and lower extremities over a 4 year period in workers exposed to mentally demanding work in 4 age groups, ranging from 20-29 to 50-59. At baseline, prevalence for most musculoskeletal complaints was higher in older age groups. Chronicity increased with age between baseline and follow-up. Moreover, the proportion of cases that recovered from baseline to follow-up in the youngest group was higher than the proportion of cases that recovered from baseline to follow-up in the oldest age group.

## 4.5 Possible explanations for why older workers may have different physical exposures and health outcomes than younger workers

Few studies have examined physical exposure, age effects, and health. In a randomized controlled study that examined these determinants and musculoskeletal health outcome in office workers following training on posture and appropriate workstation layout, workers <40 years of age had improvements in postural exposures and upper extremity MSDs more frequently than workers ≥40 years of age [87]. Hand activity and upper extremity movement were not examined. Possible explanations for their findings were younger workers were more inclined to make workstation changes; and since younger

workers had worked for shorter periods of time, their work habits may have been more modifiable. Interestingly, they further noted the difference in effects of MSDs between age groups were much greater than the difference in frequency of improvements in postural exposures [87].

In the work physiology literature, possible explanations of why older workers may have greater non-neutral postures, reduced hand activity/upper extremity movement, and more adverse health outcomes than younger workers include: older workers experience a greater overall reduction in motor function compared with younger workers [106]; muscle strength declines with increasing age, largely due to loss of muscle mass [107]; the decline in strength is accompanied by a reduction in speed of upper and lower extremity movement, beginning at 40 years of age and substantially increasing after 50 years of age [108]; steadiness may be impaired [18], as is the decline in the ability to perform precision tasks [109]; older adults use a greater amount of muscle co-activation to complete an activity; motor contractions in older individuals involve more than the requisite number of muscle groups needed to accomplish a task [107]; muscle contractions become disorganized; the time it takes to repair damaged tissue is longer in older individuals [18]; older populations have greater bone density loss than younger populations, which may increase the risk of degenerative joint disease in both spinal and peripheral regions [110]; older workers have accumulated more daily overload and local muscle-tendon damage, experienced more age-related deterioration [111] and chronic overload due to an imbalance between physical work capacity and physical workload [112]; have more medical conditions (co-morbidity) that affect health and work adaptability and capacity than younger workers [10]; and require longer periods of recovery following a task [97].

## 4.6 Cognitive loads

Cognitive function can be dichotomized between fluid and crystallized cognition: fluid knowledge refers to basic or inherent cognitive abilities, while crystallized knowledge refers to experience and accumulated knowledge [113]. Cognitive abilities are related to declines in some aspects of cognitive functioning, although data are limited regarding adverse associations between age and cognitive work performance [10]. Likewise, Avolio and coworkers reported little association between aging and cognitive work performance, as research on plasticity of cognitive abilities has provided evidence against a pure deleterious model of aging [113].

This notwithstanding, possible reasons for cognitive differences between older and younger workers are declines in memory and spatial abilities, which begin in an individual's third decade of life [10]. While crystallized cognition, as measured by acquired knowledge, may show increases until approximately 50 years of age, fluid knowledge shows continuous declines beginning in early adulthood, as indicated by difficulties in the extrapolation of associations, novel problem solving, memory of unrelated information, efficiency of transforming or manipulating unfamiliar information, and real-time processing in dynamic environments. However, the true relation between age, knowledge, and cognition appears unknown, as much of the data have been collected in standardized tests rather than information specific to a particular job [10].

## 4.7 Psychosocial exposures and older workers

In addition to physical exposures, MSDs in the neck and shoulder have been associated with psychosocial factors, such as job control and psychological job demand [114], although these are not always clearly distinguished from physical exposures. There are limited data examining the relations among age, psychosocial factors, and MSDs [6, 115]. In a study that examined proximal musculoskeletal pain and age, age was not associated with any MSD outcome in the study. However, it did change certain effect estimates (of unspecified determinants) for shoulder symptoms [114].

In a systematic review of shoulder pain and occupational exposures, there was a relation with psychosocial exposures; however, consistent patterns were not seen in any of the four psychosocial exposure categories that were examined (job demands, control, social support, job satisfaction) [116]. The relation between age and MSDs was not reported. In another systematic review, Kuijpers et al. found "consistent evidence" that high shoulder pain intensity in a wide range of occupational groups in middle age (45–54) workers was a strong predictor of poor prognosis; effect modification of psychosocial determinants by age and MSDs was not found [117].

In a large prospective cohort study, Cassou et al. found that psychosocial factors and age explained both the development and recovery of neck and shoulder pain [104]. One interaction between age and working conditions was found: older workers had less pain recovery than younger workers for repetitive work under time constraints. In another prospective study of automobile assembly workers that examined factors affecting persistent

elbow tendonitis, higher hand repetition level, non-neutral wrist postures, and low perceived decision authority were predictive of persistent symptoms [118].

Since older workers have greater severity, impairment, disturbance in physiological homeostasis, and disability than younger workers, we chose to examine whether older office workers with musculoskeletal pain were at increased risk for more non-neutral postures, increased or decreased hand activity/upper extremity movement, and greater pain than younger workers in which both groups received the identical intervention. This appeared to be an understudied topic.

Further, the effects of the types and choices of controls required over the day in the office environment remains uncertain, yet are important if all workers are to remain healthy and maintain their work performance.

## 4.8 Hypotheses

1) Non-neutral postures would be greater in older than younger workers at baseline and follow-up in the spine, and in preferred and non-preferred limbs;
2) Hand activity/upper extremity movement in preferred and non-preferred limbs would be less in older than younger workers at baseline and follow-up;
3) The association between non-neutral postures in the spine, and preferred and non-preferred limbs and adverse musculoskeletal pain would be greater in older than younger workers; and

4) The association between increased hand activity/upper extremity movement in preferred and non-preferred limbs and adverse musculoskeletal pain would be greater in older than younger workers.

## 5.0 Magnitude & frequency (repetition) of postural movements in workers with pain

There is a lack of information on whether magnitude and frequency of postural movements vary over the workday in office workers with musculoskeletal pain. Without adequate recovery and with poor equipment, attendant degeneration of motor control may increase over the workday for all workers. However, literature indicates that symptomatic workers may experience degeneration of motor control sooner than asymptomatic workers [119-121]. Likewise, studies have suggested that pain may be associated with changes in kinematic and muscular coordination and joint proprioception [119]. The consequences may be greater pain, increased deranged motor control, and greater magnitudes and reduced frequencies of postural movements over the workday. Moreover, prolonged occupational exposure and pain may compel workers to adapt more extreme magnitudes and frequencies of postural movements [121], resulting in a positive feedback loop. The association between magnitude and frequency of postural movements and pain may also vary by pain chronicity, severity and age.

Madeleine concluded that the non-trivial changes in regions with and without pain, and changes between acute, sub-chronic, and chronic conditions highlight the difficulty in defining motor variability and motor patterns (changes in range and frequency of postural movements) as having potential beneficial or adverse health effects [122].

Interestingly, Kilbom and Persson stated that workers employing greater dynamic postural movement patterns have a reduced risk of incident MSDs, such as pain [123]; nonetheless, changes in magnitude and frequency of postural movements – either increased or decreased changes – among symptomatic workers may indicate a problem with motor control or a sensory-motor mismatch [124]. On an applied ergonomics level, these workers may require different exposure assessment strategies and additional work practice or engineering controls over the day.

## 5.1 Postural movements

Authors have noted that although postures and movements are considered separate physical exposures, separating physical exposures at the workplace may be problematic [125]. They suggest that in tasks involving dynamic movements, posture and movement should be considered as a single exposure, that is, postural movements. They further noted that this exposure should be divided into 3 dimensions: range/magnitude, duration, and frequency/repetition. We address 2 of these dimensions in this section: range and frequency.

## 5.2 How is chronicity defined?

Definitions vary regarding what is meant by chronic, subacute, and acute levels of pain. The most common method to define these terms is usually by duration [126]. The International Association for the Study of Chronic Pain defines chronic pain as "pain that

persists beyond the normal time of healing." However, what exactly is meant by the normal time [127]? Likewise, authors have noted the definition of subacute "still needs interpreting" [128]. A common definition of acute pain is "the normal, predicted physiological response to an adverse ... mechanical stimuli ... associated with acute illness." However, individuals' attitudes, beliefs, and personalities strongly affect their immediate and prolonged experience of pain. Acute pain may be associated with new tissue illness that may last for less than 1 month or longer than 6 months [129].

Moreover, many studies in our literature review do not define these terms [21, 122, 130-133]. Clinicians' suggest a more appropriate method may be to consider not only duration, but also severity [126, 134], although we were unable to find any literature that describes chronicity in terms of both duration and severity. In this section, we operationalize acute/subacute pain as $\leq$ 1 year [134, 135], and chronic pain as >1 year.

## 5.3 Magnitude of postural movements in workers with pain over the day

Djupsjobacka and colleagues reported that during sustained, monotonous, repetitive work (as in computer work), low-threshold motor units in the proximal musculature are active over a wide range of upper extremity positions; these are the first to be recruited, remain active throughout the contraction, and are the last to be de-recruited upon relaxation [120]. Hagg hypothesized that these motor units were most prone to work overload and degenerative processes [136]. This concept is still controversial. Others have suggested that to prevent overload from occurring during normal, healthy patterns of motor unit recruitment, it is hypothesized that different motor units rotate in their activity to lessen discomfort. This

so-called *substitution phenomenon* is thought to protect motor units in proximal, stabilizing muscles from excessive discomfort [120, 137].

However, van Dieen et al. and Djupsjobacka found that constrained, sustained activity inhibits normal proprioception in proximal musculature [119, 137]. These authors hypothesized this may affect task movements involving precision, such as computer work, which could then lead to a greater magnitude of postural movements throughout the upper extremity, which in turn may lead to increased co-activation of proximal, stabilizing musculature. Pain may increase the effect of this feedback loop. In a study that of precision work in the garment industry, subjects with carpal tunnel syndrome assumed wrist extension more frequently than asymptomatic controls [62]. One possible explanation is that symptomatic workers had a greater magnitude of postural movements at the wrist.

While several experimental and field studies have examined the effects of asymptomatic controls and participants with sub-chronic and chronic clinical neck and shoulder pain, and the magnitude of postural movements in heavy, physical demanding work, few studies have examined low physical demanding work [21, 122, 130, 131].

In field studies that have examined substantially lighter physical demands, Szeto et al. found trends of increased neck, upper back, and upper extremity range of postural movements in participants with mild to moderate pain versus controls with respect to computer work [138, 139]. In a laboratory study, these same authors observed that computer workers with mild and moderate symptoms had a greater magnitude in forward head and shoulder protraction postural movements than asymptomatic workers [20]. A positive feedback loop may accompany these postures; increased pain severity may lead to further increased magnitudes in postural movements, as researchers found higher compressive

loading forces in joint structures as flexion increases in the cervical spine [140]. Straker et al. reported that even small increases in cervical spine extension, usually seen in forward head posture, can create inefficient length-tension relations on deep upper cervical extensor muscles, resulting in attendant strain on these muscles, and may leave symptomatic workers even more susceptible to pain [138, 141]. This may lead to a greater magnitude in postural movements in the head and neck [131].

However, these researchers found no differences in the magnitude of neck and shoulder postural movements between morning and afternoon work shifts. They acknowledged this was contrary to anecdotal beliefs [138]; prior hypotheses of an increasing trend toward both greater forward head posture and shoulder protraction with prolonged computer work. Since Szeto et al. reported that forward head posture and shoulder protraction among symptomatic office workers were constant over the workday, they hypothesized that head and shoulder postures may be habitual and remain consistent across task and time.

In a laboratory experiment that examined posture and pain when performing a computer task, Liao and Drury hypothesized that shifts in the magnitude of postural movements observed among participants may be an indication the computer worker was trying to reduce chronic and severe musculoskeletal pain [142]. These shifts involved hypothesized non-work-related body movements (e.g., moving the trunk forward and backward), rather than work-related movements, such as typing. They also reported that pain and shifts substantially increased after 2 hours of work, and the magnitude of upper body and trunk shifts increased with time. These shifts in the magnitude of postural movements in the trunk and upper extremities were associated with higher regional pain in the neck, shoulders,

and right upper extremity [142]. To relieve pain, participants increased the magnitude of postural movements. In addition, the magnitude of postural movements of upper body shifts was correlated with the Borg scale, which might suggest that the magnitude of postural movements increased with the development of exertion and pain. The authors concluded the magnitude of postural movements may be an indicator of musculoskeletal pain in a computer task [142].

Other researchers who have examined the magnitude of postural movements within and between asymptomatic workers performing computer work found different results [143]. The researchers hypothesized that for postural measures to be stable over time, within subject-variability had to be smaller than between-subject variability; moreover, they hypothesized that a single postural measurement at any time of the workday or work week would adequately represent an individual's posture while working on the computer. Results indicated that between-subject variability was significantly larger than within-subject variability; the authors concluded a single postural measurement was "sufficient" in ergonomic field studies that examined posture and computer work. Moreover, they concluded that "concerns about the reliability of one postural joint measurement as a meaningful estimator of posture in epidemiologic studies appears to be unfounded." This implies workers do not substantially change their magnitude of postural movements over the workday or work week, despite cumulative exposure over the week. However, participants in the Ortiz et al. study were asymptomatic; thus, the study might not be generalized to a symptomatic cohort.

Fjellman-Wiklund and Sundelin observed that when teachers spent approximately 25% of their working day with their scapulas positioned in elevation, and their shoulders in

abduction and flexion between 30-90 degrees range of motion, there was a positive association between pain intensity and a greater magnitude of postural movements in the upper extremities, possibly indicating impaired proprioception [144].

Additional research on magnitude of postural movements found temporal effects (duration) and work quality to be associated with pain and shifts in the magnitude of postural movements. Karwowski et al. observed that with moderate or severe musculoskeletal pain, the number and magnitude of head and neck shifts in postural movements increased as a function of duration of work [145]. Pan et al. indicated that performance variability, as an indicator of shifts in postural movement during computer work, was associated with increased pain in a computer task and error rates [146].

## 5.4 Frequency of postural movements

Similar to the studies on magnitude of postural movements, little research has been conducted on tasks involving the relation between frequency of postural movements and low physical loads. Madeleine and co-workers found that during a repetitive, high loading forceful task, subjects with chronic, severe, clinical pain demonstrated a decreased working rhythm and upper extremity frequency of postural movements.

Conversely, in field and experimental studies that examined computer work, Szeto et al. found trends of increased upper extremity frequency in symptomatic participants versus controls [139]. Although these findings were opposite tasks that required high loading forces, they hypothesized that both forms of motor variation may be maladaptive responses to MSDs.

Likewise, Fjellman-Wiklund and Sundelin observed that when teachers spent approximately 25% of their working day in non-neutral postures in the proximal upper body regions, there was a positive association between discomfort intensity and increased frequency of postural movements [144].

These findings have implications for both posture and upper extremity movement measurement strategies during exposure assessment for computer work among symptomatic employees. Specifically, an ergonomist should ask the question: Is one measurement for a particular joint sufficient to describe the magnitude and frequency of computer workers' postural movements throughout the day, or would another sampling strategy, in general, such as work-sampling, improve validity?

Ortiz et al. [143] found that among a cohort of asymptomatic computer workers, one goniometric measurement for posture per joint was adequate over a working day. Szeto et al. found no differences in the magnitude in forward head posture and shoulder protraction between morning and afternoon work shifts, although the authors' acknowledged this was contrary to anecdotal beliefs [139]. To date, these two studies remain the only examinations of this question. We found no studies that examined this question for frequency of postural movements, and none at all that addressed whether symptomatic operators have more or less postural movement variability than asymptomatic individuals.

## 5.5 Relation between chronicity, severity, age, musculoskeletal pain, and magnitude and frequency of postural movements

In general, severe and chronic musculoskeletal pain are more prevalent in older than younger workers [23, 24]. Researchers found that subjects with pain demonstrated altered motor unit recruitment and motor control, impaired proprioception, and dysfunctional upper extremity movement during precision tasks. These restrictions may lead to changes in the magnitude and frequency of postural movements in the spine and upper extremities [119, 120]; the effects for tasks involving precision may be substantial. In the work physiology literature, possible explanations of why older workers who experience more chronic and severe pain may have different changes in the magnitude and frequency of postural movements than younger workers include: older workers experience a greater overall reduction in motor function compared with younger workers [106]; muscle strength declines with increasing age, largely due to loss of muscle mass [107]; the decline in strength is accompanied by a reduction in speed of upper and lower extremity movement, beginning at 40 years of age and substantially increasing after 50 years of age [108]; steadiness may be impaired [18], as is the decline in the ability to perform precision tasks [109]; older adults use a greater amount of muscle co-activation to complete an activity; motor contractions in older individuals involve more than the requisite number of muscle groups needed to accomplish a task [107]; muscle contractions become disorganized [18]; older populations have greater bone density loss than younger populations, which may increase the risk of degenerative joint disease in both spinal and peripheral regions [110]; older workers have

accumulated more daily overload and local muscle-tendon damage, experienced more age-related deterioration [111] and chronic overload due to an imbalance between physical work capacity and physical workload [112]; and have more medical conditions (co-morbidity) that affect health and work adaptability and capacity than younger workers [10].

## 5.6 Hypotheses

We hypothesized that for the same task performed over the day:

a. symptomatic workers would have increased magnitude and decreased frequency of postural movements in the spine and upper extremities in the afternoon than morning;
b. workers with longer pain chronicity (greater than 1 year) would have increased magnitude and decreased frequency of postural movements in the spine and upper extremities in the afternoon than morning than workers with shorter pain chronicity;
c. workers with higher pain severity would have increased magnitude and decreased frequency of postural movements in the spine and upper extremities in the afternoon than morning than workers with less pain severity;
d. workers $\geq$44 years old would have increased magnitude and decreased frequency of postural movements in the spine and upper extremities in the afternoon than morning than workers <44 years old.

## 6.0 Objectives and Specific Aims

The overall objective of this dissertation was to examine the effect of a physical intervention involving two engineering controls on physical exposure, musculoskeletal pain severity, and quality of life health status among workers with substantial occupational computer use and neck and upper extremity musculoskeletal symptoms.

Two secondary objectives were: 1) to examine whether age modifies the effect of physical exposure measures on pain severity; and 2) to examine whether magnitude and frequency of postural movements in the spine and upper extremities vary in workers with pain over the day. The objectives will be met by the three specific aims listed below, each one addressed in a separate results section.

Aim 1: Examine the effects of two engineering controls, a) an adjustable keyboard and mouse tray and b) touch pad pointing device, along with training in their use on physical exposure, pain severity and quality of life among employees with neck and/or upper extremity musculoskeletal pain.

Aim 2:

1) Examine the relation between posture and age, and hand activity/upper extremity movement and age before and after the implementation of two engineering controls and training on their use;
2) Examine whether age modifies the association between posture and musculoskeletal pain severity following the implementation of these controls;
3) Examine whether age modifies the association between hand activity/upper

extremity movement and musculoskeletal pain severity following the implementation of these same controls.

Aim 3: Examine whether the magnitude and frequency of workers in pain adopt different postural movements over the day while performing the same computer task.

# II. METHODOLOGY

This section describes methods common to all 3 specific aims.

## 1.1 Study design

This was a randomized office ergonomic intervention study, conducted over a seven month period, using a pre- and post-intervention design (baseline and follow-up). A cohort of office workers with episodic or continuous non-specific musculoskeletal pain in at least 1 upper body anatomical region was constructed. Individuals were randomly assigned to an intervention group and a control group. The intervention group received a fully adjustable keyboard and bilateral mouse tray (Figure 1a), a touch pad pointing device in the non-preferred limb (Figure 1b), and training on these devices. The intervention group continued to use their mouse in their preferred limb without any changes introduced by the investigators. Thus, the intervention group could employ the adjustable keyboard tray and bilateral pointing devices over the study. The control group did not receive any engineering controls; they continued to use only the mouse that was provided by management before baseline, usually a traditional corded optical mouse, in their preferred limb. Both intervention and control groups received training on keyboard shortcuts immediately after the intervention group received the engineering controls and training. Training on keyboard shortcuts was the only intervention the control group received.

## 1.2 Recruitment

Table 1 shows the recruitment process. In order to be eligible participants had to be permanent, "non-sessional" employees but not necessarily full time. Non-sessional employees work year round, during both the legislative session and during "the interim between sessions." Sessional employees are only hired during the legislative session, for either 4 or 6 months per year. The other inclusion criteria were: must work at least 4 hours per day on the computer; must have musculoskeletal pain at the time of the screening in at least one upper body anatomical region; have not had an acute traumatic injury in the upper extremity or neck in the past year; and be willing to attempt to use a keyboard and mouse tray, and touch pad pointing device with their non-preferred hand.

Participants were recruited with the assistance of the Office of Legislative Management. The Office of Legislative Management ensures the daily functioning of the Legislature for the benefit of the legislators, their staff, and the general public. This office provides administrative and operational support for the legislators and their support staff. The office, while implementing the policies of the legislators, also provides administrative and financial services, administered compensation and human resources services, and oversees the management and maintenance of all buildings and grounds under the supervision and control of the Legislature.

Initially, the Office of Legislative Management sent two emails over an approximately three month recruitment period to the workplace of all permanent, non-sessional employees, briefly stating the purpose of the project, and informing them that a University of Massachusetts research ergonomist would be contacting them by email with a

recruitment letter. See Appendix A for a copy of the recruitment letter. In addition, the Office of Legislative Management sent one announcement with similar information via a monthly newsletter over this three month period. The invitation was open to all eligible employees, both asymptomatic and symptomatic, as the emails and announcement did not discuss inclusion criteria.

The Office of Legislative Management also provided the principal investigator (PI) with a list of all eligible employees and their work emails. The PI emailed all employees to explain the general purpose and design of the study, reviewed the timeline and flowchart, and asked them to email their work phone numbers to the PI *if* they were interested in participating in the study. These emails also did not discuss inclusion criteria. Employees interested in the study or those who refused to participate but were willing to answer the screening items emailed their work phone numbers to the PI. The PI then called these individuals. If an employee was contacted and agreed to participate, telephone consent was obtained, followed by a 15 minute telephone-screening interview (Figure 2) to determine eligibility. For those willing to participate, experimental procedures were again explained at this screening. If the employee was contacted and refused to participate or was ineligible, but was willing to answer screening items, telephone consent was obtained and demographic data and information on present or absent neck, upper back, and upper extremity musculoskeletal pain was collected. The PI also made 8 worksite recruitment visits to the support staff of the legislative and non-partisan departments over the recruitment period.

The participants' computer tasks were also determined during the screening. A task was defined as the largest group of activities normally performed by a worker to achieve a common goal [147]. Computer tasks were defined based primarily on the National Research

Council's (NRC) Video Displays, Work, and Vision: Panel on Impact of Video Viewing on Vision of Workers [148], but we added tasks excluded in that report: creating powerpoint slides, email, data analysis, internet/intranet use, and graphics-processing [149]. A total of 5 task categories were defined: 1) data entry; 2) data acquisition; 3) word processing and powerpoint; 4) interactive communication, consisting of email, internet and intranet use, and data analysis; and 5) programming and graphics-design tasks.

## 1.3 Study Timeline

Figure 3 presents the study timeline and flowchart following recruitment. Baseline evaluations for both groups comprised: 1) observational exposure assessments on posture and upper extremity movement, classification of task, and equipment used at the workspace; 2) interviewer-administered surveys on self-assessed physical exposures, individual determinants, and musculoskeletal pain; and 3) self-administered surveys on psychosocial determinants, additional individual determinants, ergonomic knowledge, and quality of life health status.

Randomization of individuals into either the intervention or control group was conducted soon afterwards. The intervention was implemented soon after random allocation. Follow-up training sessions on engineering controls were conducted soon after implementation of the intervention for each individual in the intervention group; both groups also received training on keyboard shortcuts at this time. An intervention compliance visit was conducted soon after the follow-up training sessions for the intervention group.

Follow-up measures for both groups were conducted soon after the compliance visits were completed. These were similar to baseline measures and comprised: 1) observational exposure assessments on posture and upper extremity movement, classification of task, and equipment used at the workspace; 2) interviewer-administered surveys on self-assessed physical exposures, individual determinants, and musculoskeletal pain; and 3) self-administered surveys on psychosocial determinants, additional individual determinants, ergonomic knowledge, and quality of life health status. The follow-up self-administered surveys also asked participants in the intervention group to rate the effects of the engineering controls with respect to symptom reduction, ease of use, and productivity.

Exit telephone interviews were conducted to determine whether work demands changed during the follow-up period. The interviews also inquired about work before the intervention compared with work after the intervention. These interviews were conducted on both intervention and control groups approximately one month after the study ended, during the legislative session. Table 2 presents the list of data collection tools used during the study.

To mitigate loss to follow-up and demonstrate commitment to the study, the PI was on-site throughout the seven month study for approximately 83% of the time. For participants inclined to leave the study, the PI clarified any concerns they had and encouraged them to remain in the study. Those who decided to discontinue participation were asked the reason.

## 1.4 Study sites and participants

The study sites were located in two state legislative office buildings in the Northeastern US. State legislators of the legislative branch of this state government enact laws dealing with the collection and allocation of funds, public welfare, the environment, education, public works, and civil and criminal law. Study participants were recruited from support staff of state legislators and all "non-partisan" departments; no state legislators were involved in the study. Study participants (n=113) were drawn from the 20 departments (n=418) within the two state legislative office buildings.

The 20 departments were: African American Affairs Committee, Commission on Aging, Commission on Children, Committee Administrators, House Clerks' Office, House Democrats and Republicans, Information Technology, Latino and Puerto Rican Affairs Commission, Legislative Commissioners' Office, Office of Fiscal Analysis, Office of Legislative Research, Permanent Commission on the Status of Women, Program Review and Investigation, Senate Clerks' Office, Senate Democrats and Republicans, State Capitol Police, and Office of Legislative Management.

## 1.5 Randomization to study groups

Since there were only two study worksites, individual randomization was used. An epidemiologist, blind to study objectives and hypotheses, conducted the random allocation of participants into either the intervention group or control group after baseline measures were

collected. This process was concealed from the PI, who conducted all baseline and follow-up measurements and implemented all the interventions. A simple randomization scheme was employed, in which each participant was allocated to either group with a 50-50 probability. To prevent unbalanced randomization, the randomization syntax was reiterated until the predetermined number of participants per group was achieved.

## 1.6 Institutional Review Board

A Certificate of Confidentiality was first obtained from the Centers for Disease Control and Prevention, Atlanta, Georgia, USA. The study protocol and consent forms were then approved by the Office of Human Protection and Research at the Mount Sinai School of Medicine and the Office of Institutional Compliance at the University of Massachusetts Lowell. Informed written consent was obtained prior to study onset for all participants. Participants were told that they could withdraw from the study at any time without adverse consequences, and to inform the PI if any aspect of the study increased pain in any anatomical region.

## 2.0 Baseline workspace configuration and equipment

All participants used a flat panel monitor with a detached, corded QWERTY keyboard, and most used a standard, corded optical mouse. There were five exceptions regarding the mouse: these participants used a wired Logitech right handed four button "Trackman" wheel trackball (three participants from the control group). Three participants

also used a Microsoft Natural keyboard (one participant from the control group) rather than a detached, corded QWERTY keyboard. Participants had been given these devices by the Office of Legislative Management prior to baseline, due to musculoskeletal pain that was thought to be associated with mouse or keyboard use. Neither document holders nor telephone headsets were observed at most participants' workstations. Although keyboard drawers with depth adjustability were provided for the entire cohort, they were substantially limited in height adjustability. Moreover, most participants did not use this equipment since the pointing device did not fit on the tray, or the tray and monitor were not in-line. The latter layout required operators to laterally rotate the occiput, cervical spine and upper back to view the monitor.

Although chairs were diverse with respect to manufacturer and model, all chairs swiveled, had a five wheel base of support, were moderately padded, and were adjustable for height. Most armrests were unpadded, approximately 2.5 inches wide, and limited in height and depth adjustability. The armrests did not lower and, in most situations, did not promote upper back and shoulder neutral postures; rather, the armrests moderately increased scapula elevation and shoulder abduction in a substantial percentage of the cohort. Approximately 84% of participants used wrist rests. Keyboard position varied greatly. Some participants placed the wrist rest and keyboard at the edge of the desk, while others did not use wrist rests but placed the keyboard so their forearms could be completely supported on the desk. Desk heights were approximately 29 to 30 inches, measured from the floor to the top of the desk.

## 3.0 Observational exposure assessment

Baseline and follow-up observational exposure assessment work-sampling procedures were identical for both intervention and control groups. Data were collected on posture, hand activity/upper extremity movement, body mass index (only at baseline), equipment usage, and task.

Prior to baseline the Office of Legislative Management provided approximate start of day, lunch break, and end of day work times for each. We also asked each participant on the day of their exposure assessment whether this was a typical day with an average workload.

## 3.1 Fixed interval work sampling

A fixed-interval, work-sampling approach was used to conduct the observational assessment. One of the 20 departments in the Legislative Office Building and State Capital was randomly selected soon after the start of the workday for the initial work-sampling window. The first participant encountered in the department was then observed for five 30-second time periods, for a total of one 2.5-minute interval for a series of modified RULA, modified HAL, and task measures; we reiterated this process five more times on the same participant, for a total of 15 minutes. We chose this form of work sampling approach because the workforce was highly mobile; study participants may have been called away from his/her workspace by a legislator, supervisor, or due to urgent and unanticipated legislative matters. The series of modified RULA, modified HAL, and task measures comprised: 1) Computer RULA neck/right upper back, right upper extremity, forward head; 2) Computer RULA

neck/left upper back, left upper extremity, trunk/leg; 3) right HAL; 4) left HAL; and 5) equipment checklist and task.

The participant closest to the initial participant was then observed, and so on, up to a maximum of eight participants (2 hours in the morning). This entire sequence was repeated one more time soon after the lunch break for each of the same eight participants, for another two hours of observation. Thus, 50% of the observations were conducted in the morning and 50% in the afternoon. In total, 30 minutes of observational data from each participant was obtained per 8 hour workday. This procedure was repeated three to four days per week (Monday – Thursday) until all study participants were observed.

Observations for the modified RULA involved taking a visual "snapshot" of the worker, which included glancing at the work, developing a mental picture of the postures, turning away, and recording the snapshot with pencil and paper [150]. Observations for HAL and the equipment checklist involved observing hand activity, equipment usage, adherence and alterations to recommended work technique for most of the 30 seconds and then recording what we believed to be a representative sample of the activity on paper.

For the equipment checklist, we did not have the resources to conduct daily observations on which equipment the participants were using and participants' adherence or alteration to recommended touch pad technique. Instead, we characterized these aspects of the intervention during the observational assessment days. At two time points over the day, at the end of the workers' morning and afternoon observations, we recorded what equipment was present at the participant's workstation and participant adherence to recommended equipment adjustments or positions. See "Observational Assessment" in Appendix B for both

modified RULA and HAL (Rapid Upper Limb Assessment, Hand Activity Level, respectively) methods.

## 3.2 Modified exposure measures

We did not use standard RULA or "Office RULA" scoring. We used additive, not grid-derived, composite scores [151]. We also did not use the force/load score, and the muscle use score was modified.

We employed a modified Office RULA, which we termed modified Computer Rapid Upper Limb Assessment (RULA) [152, 153] to assess trunk, neck, and upper and lower extremity posture. The modified Computer RULA provided a posture-coding framework to score neutral and non-neutral posture in the head, neck, upper back, upper extremities, trunk, and lower extremities. Overall scores for components of Computer RULA posture elements could range from: wrist 0 to 6, lower arm 0 to 6, upper arm 0 to 6, neck and upper back 1 to 6, forward head 0 to 1, trunk 0 to 6, and lower extremities 0 to 2.

We also constructed a sub-score sum termed "spine." This consisted of RULA scores for the neck, upper back, forward head, and trunk, which could range from 2 to 19. We then constructed several other sub-scores. Specifically, we constructed a sub-score sum termed Computer RULA "preferred limb." This included the sum of the wrist, and lower and upper arm scores for the upper extremity using the traditional mouse, which could range from 0-18. We constructed a sub-score sum termed Computer RULA "non-preferred limb." These included the identical regions and ranges that were used for the preferred limb. We also constructed a sub-score sum termed Computer RULA "spine and lower extremities." These

included the sum of the spine and lower extremities, which could range from 2-21. We also constructed sub-score sums termed "spine, leg, and preferred limb," and "spine, leg, and non-preferred limb," both of which could range from 2-39. Our Computer RULA that included the sum of all three upper extremity elements (bilaterally) and spine provided a score that could range between 2 and 55. This was termed "Computer Upper Body RULA."

So that findings could be more easily interpreted, low, intermediate, and high physical exposure values for Computer RULA elements can be conceptualized by dividing the scales into tertiles. Higher values represent greater physical exposure. For example, for the Computer RULA elements "spine, leg, and preferred limb," the bottom tertile (low physical exposure) ranged from 2-14; the middle tertile (intermediate physical exposure) ranged from 15-27; the top tertile (high physical exposure) ranged from 28-39.

The Hand Activity Level (HAL) scale [154] assessed hand activity using a 10-point scale with five verbal anchors. HAL was used to collect data on duration and frequency of observed pauses, and on how fast the wrists and digits were moving. HAL scores ranged from 0 to 10. Although HAL measures hand activity, distal upper extremity activity cannot effectively be accomplished without proximal stability, involving both static loading and dynamic movement [14]. Thus, hand activity in this study also implies upper extremity movement.

## 4.0 Data gathering tools

In addition to the observational exposure assessment, which collected data on posture, upper extremity movement, body mass index, equipment usage, and task, we conducted

interviewer- and self-administered surveys. These instruments collected data on 1) intervention; 2) physical and temporal load items; 3) psychosocial factors; 4) socio-demographic factors; 5) history of present illness; 6) past medical history; 7) ergonomic knowledge; 8) department and job categories; 9) health outcomes; and 10) intervention satisfaction. Socio-demographic factors, history of present illness, and past medical history were all termed "individual factors" in this study. Table 3 lists these survey domains. Appendices C-F summarize survey questions for each survey based on each domain and provide references for these questions. Excluding the observational assessment, seven surveys were used over the study. The seven surveys are provided in Appendix G.

## 4.1 Determinants that might predict or modify the association between intervention, and physical exposure and health

Determinants that might predict or modify the association between intervention, and physical exposures and health outcomes were collected using the observational assessment, and interviewer- and self-administered surveys. Determinants that might predict or modify the association between intervention and physical exposures and health outcomes were grouped into seven domains: 1) physical and temporal load items; 2) psychosocial factors; 3) socio-demographic factors; 4) history of present illness; 5) past medical history; 6) ergonomic knowledge; and 7) department and job categories.

Physical and temporal load questions consisted of 25 individual items. Psychosocial factors included four composite measures of the Job Content Questionnaire, or JCQ [155, 156], and four individual items. Socio-demographic factors consisted of sixteen individual

items. History of present illness included thirteen individual items. Past medical history consisted of four individual items. Ergonomic knowledge included four individual items [157, 158]. Department and job categories comprised two individual items.

If answers to questions were missing from the self-administered surveys, the PI attempted to fill in the missing questions by asking the participants if s/he would be willing and feel comfortable to answer the particular item, since the PI was the only person to see individual, identifiable data.

As noted above, the JCQ comprised four composite measures: 1) psychological job demands, 2) use of skills, 3) decision authority (the sum of the latter two is termed decision latitude), and 4) supervisor support. Certain items in psychological job demands, job skill use, and decision authority were reverse-scored based on JCQ algorithms[2]. All four composite measures were summed and weighted according to the algorithms in the JCQ User's Guide [155].

We examined two alternative calculations of job strain[3]: quadrant term (dichotomous) and linear function term (continuous) [159].

1. *Quadrant term* was formed by dichotomizing demands and decision latitude scores at the medians of the current sample [159]; "high job strain" was defined as the combination of demands scores above the median and decision latitude scores below the median, which defined approximately 25% of the cohort. Participants with demands and decision latitude scores both below the median or

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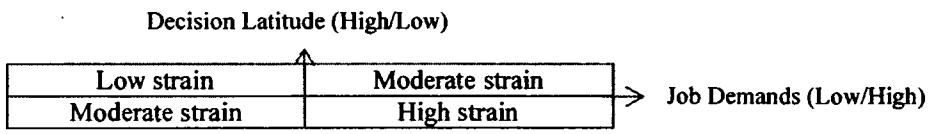
[2] For example, for decision-making authority, the algorithm equals 2*(job allows a lot of decisions on your own + you have a lot of say about what happens on job + 5 – you have little freedom to decide how to work). In this equation, subtraction of "you have little freedom to decide how to work" implies this item was reverse-scored.

[3] Karasek's job strain model states the greatest risk to physical and mental health from stress occurs to workers from high psychological workload demands or pressures combined with low control or decision latitude in meeting those demands [*www.workhealth.org/strain/briefintro.html*].

both above the median were defined as "moderate strain" (approximately 50% of the cohort). Subjects with demands scores below the median and decision latitude scores above the median were defined as "low strain" (approximately 25% of the cohort). We then compared the top and middle categories to the bottom category.

Figure 1 presents this categorization:




2. *Linear function term* is a continuous variable. Job strain was defined as y= (0.5) demands – (0.5) decision latitude [159]. We used tertiles for this continuous variable so this variable could be more easily interpreted. For example, we were then able to compare the top (high job strain) and middle tertiles with the bottom tertile (low job strain), which was used as a reference group.
3. The sum of supervisor support items was analyzed as a dichotomous variable, with the continuous value of the support scale dichotomized at the sample median.
4. We also analyzed the five JCQ standard scale items separately as continuous variables (psychological job demands, skill use, decision authority, decision latitude, supervisor support) according to the algorithms in the JCQ User's Guide.
5. Both quadrant term and supervisor support were dichotomized.

## 4.2 Health outcomes

A cohort of office workers with episodic or continuous non-specific musculoskeletal pain in at least 1 upper body anatomical region was then constructed. There were eight anatomical regions considered: 1) neck and right upper back, 2) neck and left upper back, 3) right shoulder, 4) left shoulder, 5) right elbow and forearm, 6) left elbow and forearm, 7) right wrist, hand and digits, and 8) left wrist, hand and digits.

### 4.2.a Pain severity

An interviewer-administered survey was used to collect the primary health outcome, musculoskeletal pain. We used a five point verbal rating pain severity scale, adapted from Wong et al. [160] and Hales et al. [161]. The scale collected information on musculoskeletal symptoms in the eight upper body anatomical regions listed above. An example of the pain question was: "In the past 4 weeks, how much pain, on average, did you have in your neck and upper back?" Symptom response anchors for this scale were: 1) no pain; 2) mild pain (pain present but does not limit activity); 3) nagging, uncomfortable, troublesome pain (can do most activities with rest periods); 4) miserable, distressing pain (unable to do some activities due to pain); and 5) intense, dreadful, horrible pain (unable to do most activities due to pain).

Anatomical regional pain scores were created using a dichotomized median pain score for all regions combined. Specifically, median pain scores in all upper body anatomical

regions were averaged to obtain a single median score. Among all upper body regions, pain was dichotomized between $\leq 2$ = no pain or mild pain and $\geq 3$ = uncomfortable, miserable, or intense pain.

Regions were then collapsed into 4 upper extremity anatomical quadrants. The proximal quadrant was defined as the neck, upper back, and shoulder, while the distal quadrant was defined as elbow, forearm, wrist, and digits [162]. Median pain scores were used for anatomical quadrants as pain severity data were non-parametric. An overall pain severity score was calculated for proximal and distal anatomical quadrants. This was based on the mean of all proximal and distal quadrant median pain scores at baseline.

Cut-points for dichotomized anatomical pain quadrant were created between $\leq 2$ = no pain or mild pain and $\geq 3$ = uncomfortable, miserable, or intense pain.

We attempted to collect baseline and follow-up pain severity data on the same day each participant was observed for physical exposures. Each interview took approximately 20 minutes. Due to time constraints, only eight participants per day could be interviewed. The order of these interviews was based on participants' availability at the workstation when the PI came to conduct the interview. If it was not possible to conduct interviews on any of the eight participants on the day of their observations, we interviewed any other available participant.

### 4.2.b Quality of life

Quality of life was measured using two outcome variables from the Medical Outcome Study Short Form-36 version2 (MOS) [163]: the physical component summary (PCS) and

mental component summary (MCS). The MOS collects data on quality of life health status and is designed to assess self-reported health transition over one year, and eight health concepts: bodily pain, physical functioning, limitations due to physical and emotional health problems, social functioning, general mental health, vitality and general health perceptions.

The MOS computes two values: PCS and MCS. The computed values in this study were based on a software algorithm (Quality Metric Health Outcomes Scoring Software, version 4.0, Providence, RI, USA). Participants' scores were then compared with aggregate responses from a standardized MOS obtained in 1998 from the general US population with a median of 50. Values $\geq$50 for both the PCS and MCS imply improved quality of life health status, while values below 50 imply a poorer quality of life health status [164]. Dichotomous PCS or MCS dependent variable cut-points were defined similarly.

MOS data were obtained using a self-administered survey, distributed to participants on the same day as the observational assessment and, if possible, collected from participants the next working day. Our measures of PCS and MCS were considered secondary outcomes since the follow-up time available for the study was shorter than is generally used for the MOS. Therefore, we believed the intervention would have less effect on these measures than musculoskeletal pain severity.

## 5.0 Intervention

Engineering controls were installed at night, after working hours, while all training among participants was performed on agency time at two adjacent worksites. The intervention group was given an Easy Lift 2 arm, adjustable for height, depth and pitch, a 20-

inch keyboard tray, and two 7.5 inch mouse palettes, which were installed on right and left ends of the keyboard tray (Grand Stands, Monrovia, California, USA) (Figure 1a). The tray was then securely bolted to the undersurface of the desktop, and a Smart Cat Glide Point touch pad (Cirque Corporation, Salt Lake City, Utah, USA) used in the non-preferred limb was secured to the tray immediately adjacent to the keyboard. This was installed on the left for over 98.0% of the time based on participants' preference; this placement most likely remained unchanged during the study according to follow-up observational assessment measures.

The baseline preferred limb device – usually a corded traditional optical mouse – most likely continued to be used in that upper extremity over the study for the entire cohort according to follow-up observational assessment measures. For example, if a participant used the mouse in the right upper extremity at baseline, s/he usually continued to use that device on the right throughout the study. In this example, the touch pad would have been positioned on the left to supplement right sided mousing tasks. Participants could, however, freely choose to use either pointing device in either hand.

The angle of the keyboard and mouse tray was set in a 10 degree backward or negative tilt, away from the operator; the padded gel wrist pad was integrated into the tray and immediately in front of the keyboard [165]. The dimensions of the wrist pad were 18 inches long, approximately 3 inches deep, and 0.5 inches high. The keyboard was secured to the tray with four, 2 inch diameter rubberized mats; a strip of 1 inch wide and 0.5 inch high vinyl foam (Frost King, Boston, MA, USA) was secured to the back of the tray along the entire length of the keyboard (approximately 18 inches) to ensure the keyboard maintained its position adjacent to the wrist pad. The touch pad was tented approximately 30 degrees

away from the participant (Figure 1a, Chapter 1) [54], measured by a manual Grafco goniometer (Monsey, NY), using 2.0 inch high and 0.5 wide vinyl foam. It was positioned underneath the entire length of the right side of the touch pad, if the touch pad was being used on the left. It was secured to the keyboard tray with two-sided tape. However, due to the compressibility of the foam, coupled with the weight of the non-preferred limb when using the touch pad, the tenting angle was reduced to approximately 12 degrees after less than one month of use.

Participants were trained and encouraged to use eleven features on the touch pad with their middle finger, with their hypothenar eminence and fifth metacarpal phalangeal bone of the non-preferred limb resting on the mouse tray, as this adds approximately 10 degrees of additional tenting to the elbow, forearm, and wrist. Tenting refers to the degrees the forearm is rotated away from full pronation.

Each participant received an in-depth handout of the figure of the Cirque touchpad and directions/instructions on its use (Figure 1b, Chapter 1). These included which eleven features would be used. These features were: left and right tap, double click, in which a single click functions as a double click, and can be used to open folders and icons; zoom; vertical and horizontal scroll; menu bar navigation; cursor movement and position on screen; drag lock, where an icon can be dragged to a different location on the desktop; and two additional programmable buttons in which the participants could program themselves, such as print or enter commands.

Implementation of the intervention, post-installation, lasted one hour and was administered by the PI. Rather than conducting group training, the PI explained the rationale for both engineering controls, and how to adjust and use them to each individual participant.

To prevent coercion participants were not given specific directions on how often and when to use the controls. Demonstration and supervised practice followed. Each participant in the intervention group repeated the demonstration process until s/he appeared to understand how to adjust, position, and use both devices. These participants also had the opportunity at this time to ask the PI questions regarding the equipment.

Low and negatively sloped keyboard trays are ideal for touch typists. However, hunt and peck typists require a different tray position. A dilemma exists for hunt and peck typists between maintaining neutral postures in either the neck or upper extremities. If the keyboard is high, neutral postures will likely exist in the neck, but not in upper extremities. If the keyboard is low, neutral postures will likely exist in the upper extremities, but not in the neck, as visual contact with the keyboard will require moderate to extreme degrees of neck flexion. We managed this issue by striking a musculoskeletal system balance between neutral postures in both regions based on comfort. This was accomplished through adjusting the keyboard/mouse tray to the comfort zone of the participant. Another benefit of frequent keyboard/mouse tray adjustments is the reduction of static muscle loading, particularly in, but not exclusive to proximal regions.

The PI conducted a follow-up training session soon after implementation of the intervention. During this 45 minute period he reviewed all demonstration aspects of the intervention. The PI also demonstrated and positioned these participants' hips, trunk, neck, and upper extremity joints in neutral postures and encouraged them to position their feet flat on the floor throughout the workday, approximately shoulder width apart. Although footrests were available through the Office of Legislative Management, they were not part of the

experimental design. Thus, they were not recommended to any participants and the rationale for their use was not explained.

At the follow-up training session, the PI also took an additional 45 minutes to instruct all study participants (individual rather than group training was conducted) in ten keyboard shortcuts. All participants were provided with typed instructions on each shortcut; to promote upper body symmetry, all participants were encouraged to use both right and left upper extremities simultaneously when performing shortcuts. For example, when highlighting, they were instructed to use their left hand on the left sided "shift key" and right hand on the right sided "arrow keys." The PI partially explained the rationale for shortcuts and the use of both hands: to reduce asymmetric static loading and promote musculoskeletal balance in preferred and non-preferred limbs. The PI did not discuss the reduction of repetitive motions and non-neutral postures in the upper back and upper extremities associated with the use of keyboard shortcuts. The intervention group had the opportunity to ask questions regarding the engineering controls; all participants had the opportunity to ask questions regarding keyboard shortcuts.

The PI conducted compliance worksite visits for the intervention group soon after the follow-up training session, recording participant adherence to recommended adjustments and positions of engineering controls and whether the controls were in regular use.

## 6.0 Data preparation

A trained research assistant examined each survey to ensure all surveys were completed in pencil and that all bubbles were completely filled. Scanning software (Remark

Office OMR 2008, Gravic version 7, Malvern, PA, USA) was used to import data into Excel 2007. We randomly compared and checked scanning quality of Excel spreadsheets with 24 hard copy surveys for baseline data and 24 hard copy surveys for follow-up data; this consisted of examining 6 take-home surveys, 6 interviewer-administered surveys, 6 MOS surveys, and 6 observational surveys at both time points. Data were then imported into Stata 11.

## 7.0 Intervention and control groups who performed only 1 task the entire day

To determine whether computer workers in pain change their magnitude and frequency of postural movements over the day, we examined workers in both intervention and control groups who performed only 1 task for the entire day. Both baseline and follow-up time points were examined.

Specifically, we examined whether workers in pain have greater magnitudes and less frequency of postural movements in the spine, and preferred and non-preferred limbs in the afternoon. Since this was a sub-study of the intervention study, we only had physical exposure data from the observational assessment on symptomatic workers. Thus, analyses were based on a sample of convenience, as we had no physical exposure data on asymptomatic (pain free) workers.

## 7.1 Potential computer tasks used for comparison between morning and afternoon

There were less than 10 participants performing the tasks "data entry," "data acquisition," and "programming/graphics-processing tasks" in both the morning and afternoon, and at both baseline and follow up. Statistical comparisons were not conducted on these tasks due to the limited number of observations and attendant loss of statistical power. The tasks "interactive communication" and "word processing / powerpoint" involved more participants performing the same tasks in the morning and afternoon over the study. We were able to conduct matched analyses on these tasks at baseline and follow up. We aggregated the tasks to increase statistical power. Further, one study among a symptomatic cohort found that magnitude of postural movements in different tasks did not vary over a workday in computer operators [138]. All paired analyses present magnitude and frequency of postural movements between morning and afternoon.

## 7.2 Data gathering tools

In this sub study we used the identical surveys used in the main study. Determinants used in this chapter – task, age, chronicity, pain severity – were identical to those described in the main study.

## 8.0 Statistical analyses

The main study followed an intention to treat analysis, which compared participants in both groups to which they were originally randomly assigned; we compared controls to controls, and the intervention group to the intervention group. Specifically, this is when all participants – regardless of whether they actually implemented the engineering controls or deviated from the protocol – are analyzed as if they had implemented the controls [166].

All statistical analyses were performed using Stata 11(StataCorp, College Station, TX, USA). Analyses were initially performed using histograms and scatter plots to identify outliers and incorrectly recorded observations. Univariate distributions of continuous variables were examined to determine whether data were normally distributed using histograms. The Shapiro-Wilk test was also used to test for normality. For data to be more easily interpretable or to provide a better format for statistical analyses, certain variables with normal distributions were converted to categorical variables. Regarding the latter, results from bivariate linear or Poisson regression analyses (physical exposure and health as dependent variable, respectively) were compared between determinants and outcomes; the decision of whether to use continuous or categorical variables was based on the strength of the association of each method. Contingency tables and chi-square tests were also used to examine associations between determinants. Graphical evaluations were performed using scatter-plots to examine linear (or nonlinear) relations between determinant and outcome variables and among determinants. For the former, this was to further clarify which type of regression model to use. For the latter, this was to determine whether to use a parametric or

non-parametric correlation coefficient method to examine potential collinearity prior to multiple regression analyses. Descriptive statistics examining differences among groups were assessed using the t-test for continuous variables and chi-square test for categorical variables. If continuous variables were not normally distributed, the non-parametric Wilcoxon rank-sum test for continuous variables was used. Statistical tests for categorical variables were not performed when there were less than five observations per cell [167].

## 8.1 Absolute and proportional changes in posture, hand activity/upper extremity movement, and health outcomes: main study

Absolute change scores for both intervention and control groups were calculated by subtracting baseline values from follow-up values for both physical exposures (means) and health outcomes (percentages in cells). Proportional change scores for both intervention and control groups were obtained by taking the difference of the score between follow-up and baseline values and dividing by the baseline value. Absolute and proportional scores between groups were then compared descriptively. Equation 1 presents how the proportional score was determined:

$$\frac{((Group\ followup\ score - Group\ baseline\ score)}{Group\ baseline\ score)}$$

## 8.2 Multiple regression analyses for main study: main effects models

**Exposure change:** To conduct longitudinal results, responses between baseline and follow-up surveys were matched. We used Generalized Estimating Equation (GEE) multivariable linear regression models for longitudinal analysis to examine associations between absolute physical exposure scores (posture, hand activity) as the dependent variable and intervention as the independent variable of interest, adjusting for other determinants. The effects of the intervention and all covariates were estimated by calculating the beta coefficients along with its corresponding 95% confidence interval (CI).

**Health outcomes change:** We used GEE Poisson models for longitudinal analysis to examine associations between dichotomized dependent health outcome variables (regional musculoskeletal pain and quality of life) and intervention as the independent variable of interest, adjusting for other determinants [168]. The effect of the intervention and covariates was estimated by calculating the Relative Risk (RR) along with its corresponding 95% CI. Time for the GEE analyses was set as 0 and 1 for baseline and follow-up, respectively.

The multivariable linear regression model is [169]:

$$Y = B_0 + B_1X_1 + B_2X_2 + \ldots B_kX_k + E$$

where $Y$ = dependent variable, $B_0$ = intercept or background risk, $B$ = regression coefficients (slopes: $j=1,2,\ldots,k$), $X$ = determinants ($j=1,2,\ldots,k$), and $E$ = random error. The

beta coefficients specify the amount of expected change in the dependent variable/standard deviation per 1 unit change of the independent variable/standard deviation.

The dichotomized Poisson model is [169-171]:

$$Poi(\mu_t)=\beta_0 + \beta_1 * \text{intervention} + \sum_{i=2}^{n} \beta_i * x_i + \text{offset} + \varepsilon$$

where $Poi(\mu_t)$= GEE Poisson family, $\mu_t$=probability of pain score change by time change, $\beta_0$=intercept or background probability of pain changes, $\beta_1$=coefficient of intervention effect, $i$=2 through $n$=number of determinants, $\beta_i$=coefficients of determinants, $x_i$= determinants, offset=1 for all individuals, and $\varepsilon$=error term. "Offset" was assigned the value 1 for all study participants with the assumption that observation durations were the same among all individuals.

Both multivariable linear regression and Poisson models present unadjusted and adjusted associations. Bivariate analyses was used to examine unadjusted associations between each determinant and dependent variable, while full models show the relation among the primary explanatory variable adjusted for all other determinants in the model. See Appendices F and G for unadjusted and adjusted multivariable linear regression and Poisson models, respectively.

## 8.3 Preliminary model selection

Determinants were retained in preliminary model selection if any of two criteria were met: (1) determinants were not evenly distributed between intervention and control groups at $p \leq 0.10$ at either baseline or follow-up; (2) if criterion (1) was met, the determinant was not on the intermediate pathway between intervention and outcome, i.e., not a mediator, based on past literature and prior knowledge.

After the determinants met any of the above criteria, variables were examined for potential collinearity using Spearman's rank-order correlation coefficients. Variables with only two categories (e.g. gender) were not included in Spearman's rank-order correlation. Determinants were retained in preliminary models if the inter-correlation coefficient between variables was $<0.65$. For higher inter-correlation coefficients between determinants ($\geq 0.65$), the determinant with the greater association in bivariate analysis with the outcome variable was retained for examination in final models.

## 8.4 Final model selection

We did not use conventional algorithms based on significance levels for final model selection, as this method may have poor sensitivity because potential confounders may not be retained in final models. In final model selection, we used a "change in estimate" approach implemented in a backwards stepwise fashion. Specifically, for all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the

intervention variable after its removal from the model was examined. If the variable that was removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model [172]; conversely, if the variable that was removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.

Stata runs auto-diagnostics for multi-collinearity. We further examined the potential of multi-collinearity. If determinants in final models remained strongly correlated and were not yet removed from the model, the printout stated "note: variable $X_1$ omitted because of collinearity." That is, Stata omitted variable $X_1$ based on an algorithm. To identify which determinants were correlated with variable $X_1$, we fitted a regression model using variable $X_1$ as the outcome variable; the remaining determinants from the original regression were then examined as independent variables in the new model. The output of the regression – the beta coefficients of the regression model, their 95% CIs, and the $R^2$ value – would then identify which determinants were correlated with the outcome variable [173].

## 8.5 Multiple regression analyses for sub study: interaction models

We used GEE Poisson models for longitudinal analysis to examine associations between the dichotomized dependent health outcome variable (quadrant musculoskeletal pain) and dichotomized physical exposure as the independent variable of interest, with age as the effect modifier, adjusting for other determinants [168]. Modified RULA postures and modified hand activity/upper extremity movement were fit in separate models. We chose

Poisson models as our musculoskeletal pain data (scale range=1-5) followed a Poisson distribution.

We chose to dichotomize this outcome variable as studies have shown that dichotomized Poisson models provide valid risk estimates and confidence intervals [168, 174]. Some also have suggested that relative risks (RR) are easier to interpret than odds ratios that are obtained from Logistic regression, especially for frequent outcomes [175]. The effects of physical exposure and age were estimated by calculating the RR along with their corresponding 95% CI. Time for the GEE analyses was set as 0 and 1 for baseline and follow-up, respectively.

The main effects Poisson model is [169-171]:

$$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \sum_{i=3}^{n} \beta_i \times x_i + offset + \varepsilon$$

where $Poi(\mu_t)$= GEE with Poisson distribution, $\mu_t$=probability of quadrant musculoskeletal pain change by time change, $\beta_0$=intercept or background probability of quadrant musculoskeletal pain change, $\beta_1$ =coefficient of physical exposure (either posture or hand activity), $\beta_2$= coefficient of age effect, $i$=3 through $n$=number of determinants, $\beta_i$=coefficients of determinants, $x_i$= determinants, offset=1 for all individuals, and $\varepsilon$=error term. "Offset" was assigned the value 1 for all study participants with the assumption that observation durations were the same among all individuals.

## 8.6 Interaction models

Interaction variables were entered after final main effects models were determined. The interaction hypotheses examined main effects (dichotomized physical exposure and dichotomized age) and an interaction term between dichotomized physical exposure and dichotomized age, adjusting for other determinants, to determine whether the magnitude of the effect of the physical exposure varies by age. We considered interaction terms significant at the $p \leq 0.05$ level.

For interaction analyses, GEE multiple regression models with Poisson distributions were fit with dichotomous quadrant musculoskeletal pain as the dependent variable. Dichotomous physical exposures and dichotomous age categories, and an interaction term between dichotomized physical exposure and dichotomized age, adjusting for other determinants, were then examined to detect potential effect modification.

The Poisson interaction model is [169-171]:

$$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{n} \beta_i \times x_i + offset + \varepsilon$$

where $Poi(\mu_t)$ = GEE with Poisson distribution, $\mu_t$= probability of dichotomized quadrant musculoskeletal pain change by time change, $\beta_0$= intercept or background probability of quadrant musculoskeletal pain change, $\beta_1$ = coefficient of physical exposure (either posture or hand activity), $\beta_2$= coefficient of age effect, $\beta_3$ = coefficient of interaction

term between physical exposure*age, $i$=4 through $n$=number of determinants, $\beta_i$=coefficients of determinants, $x_i$= determinants, offset=1 for all individuals, and $\varepsilon$=error term. "Offset" was assigned the value 1 for all study participants with the assumption that observation durations were the same among all individuals.

## 8.7 Sample size: main effects

Based on the total number of participants, we estimated the power of our study in advance. There would be approximately 28 participants in intervention and control groups. Based on past literature, we estimated a difference in change score between groups equal to 23.0% on a dichotomized musculoskeletal pain severity scale [176]. We would have 80% power to detect an effect size of 0.55 [177]. If the value of the median upper extremity pain score in all quadrants at baseline was 2.0 on a 1 to 5 scale [178], this would correspond to the intervention group having 11.5% less likelihood of an adverse musculoskeletal pain outcome than the control group (0.23/2.0).

## 8.8 Sample size: interaction models

Based on the total number of participants, we estimated the power of our study in advance. We examined the effect of the intervention separately between workers <44 years old and those ≥44 years old. With approximately 28 participants per age group and a difference in change score between age groups equal to 27.0% on a dichotomized musculoskeletal pain severity scale [176], we would have 80% power to detect an effect size

of 0.39 [177]. If the value of the median upper extremity pain score in all quadrants at baseline was 2.0 on a 1 to 5 scale [178], this would correspond to younger workers having 13.5% less likelihood of an adverse musculoskeletal pain outcome than older workers (.27/2.0).

## 8.9 Statistical analyses for second sub study

The plan used for analyses was that only participants from both the intervention and controls groups who performed the same task over the entire workday were used in the analyses. We stratified by intervention and control group. Thus, all participants were matched by task in which we assumed they performed the same 1 task over the entire workday based on our work sampling method. We used this identical method at both baseline and follow-up. For example, if a participant performed word processing in the morning but not in the afternoon at baseline, the participant was not matched on word processing and was not included in the paired analysis. Conversely, if the participant performed word processing in both the morning *and* afternoon at baseline, the participant was matched on word processing at baseline and was included in the analysis.

We first examined the overall magnitude and frequency of postural movments over the day and over the study period by intervention and control group. We then stratified magnitude and frequency postural movement by pain chronicity, pain severity, and age.

# III. RESULTS: MAIN INTERVENTION STUDY

## 1.0 Descriptive statistics of determinants and health outcomes for intervention and control groups at baseline

Four participants (all controls) were lost to follow-up and were not included in the analysis. There were n=109 participants included in all analyses. Results from Tables 4-9 present baseline determinants. Tables 2-8 were collected by self- and interviewer-administered surveys. Table 9 presents data collected by observational exposure assessment. Table 10 presents baseline musculoskeletal pain severity and quality of life, collected by interviewer- and self-administered surveys, respectively.

Table 4 presents individual determinants at baseline. Trouble sleeping was the only statistically significant difference among determinants between intervention and control groups at baseline.

Table 5 revealed 1 borderline statistically significant finding for physical and temporal loads: the control group worked more weekly hours on a pointing device. There were no statistically significant differences between intervention and control groups for any psychosocial determinant in Table 6.

Table 7 shows departments and job categories at baseline. Twenty departments where support staff to legislators and "non-partisans" worked were categorized into 3 conceptually similar departments: 1) caucuses (democratic and republican parties), 2) technical branches (information technology, fiscal analysis, legislative research, program review), and 3)

management (commissions, management, administration). Eleven job titles were categorized into 3 conceptually similar job titles: 1) assistants (assistants, press, aides, secretaries), 2) directors (attorneys, directors, administrators, coordinators), and 3) analysts (information technology analysts, researchers). There were no statistically significant differences among determinants between intervention and control groups.

Table 8 presents office ergonomics knowledge at baseline. Table 9 shows observational exposure assessment measures between intervention and control groups for posture and hand activity at baseline. Table 10 shows musculoskeletal pain severity by anatomical region and quality of life between intervention and control groups at baseline. No statistically significant differences were seen for any of these measures.

## 2.0 Descriptive statistics of determinants and health outcomes for intervention and control groups at follow-up

Tables 11-14 present determinants at follow-up. Table 11 shows there were no statistically significant differences between groups at follow-up for individual determinants; difficulty sleeping was now essentially the same between groups.

Table 12 shows that 2 statistically significant findings were present for physical and temporal loads: the control group had more upper extremity support while working on the computer. They also held objects by pinching with their fingers less than the intervention group. Table 13 shows there was 1 significant difference and 1 borderline significant difference between intervention and control groups for psychosocial determinants at follow-up; the control group had higher job strain for the trichotomized linear function term than the

intervention group. The intervention group had a higher continuous value of job skill use than the control group. Department and job categories at follow-up remained unchanged (data not shown).

Table 14 shows follow-up results for ergonomic knowledge. The intervention group had significantly more knowledge of what is an ergonomically correct posture and workspace than the control group. We then examined the intervention and control groups' ergonomic knowledge over the study period to help identify whether contamination from the intervention to control group occurred. We also examined this domain to determine the magnitude of change in and the application of ergonomic knowledge between groups. Table 15 presents improvements or reductions of ergonomic knowledge over the study between groups. Both groups had similar reductions in moderate or expert overall ergonomic knowledge. Although both groups had reductions in moderate or expert ergonomic knowledge of ergonomic risk factors, the control group had a substantially larger reduction of knowledge. Moreover, the intervention groups' reduction of knowledge for "risk factors" was only ~ 2%. While the intervention group had large improvements in moderate or expert ergonomic knowledge for both "ergonomically correct posture and workspace," the control group had substantial reductions of knowledge in both of these items.

Table 16 shows observational exposure assessment measures at follow-up between intervention and control groups. Four significant differences between groups were observed. There were significant differences in non-neutral postures modified RULA in preferred and non-preferred limbs between intervention and control groups. There were also significant differences in modified hand activity/upper extremity movement in preferred and non-

preferred limbs between intervention and control groups. Table 17 showed no statistically significant findings for regional musculoskeletal pain or quality of life at follow-up.

### 3.0 Absolute and proportional changes in physical exposure and health outcomes

Table 18 shows there were greater proportional decreases in non-neutral posture in 4 of 5 modified RULA elements in the intervention group over the study; 2 of these were significant, while 1 reached borderline significance. Although both intervention and control groups showed proportional increases in non-neutral posture in the spine and lower extremity, the intervention group had significantly smaller increases than the control group. While both groups showed proportional increases in hand activity/upper extremity movement in the preferred limb over the study, the intervention group had less increased hand activity/upper extremity movement than the control group; this finding was significant. A significant finding was also found in the non-preferred limb for hand activity/upper extremity movement; the intervention group showed a proportional increase in hand activity/upper extremity movement in the non-preferred limb over the study, while no change was observed in the control group.

Table 19 shows there were greater proportional decreases in 6 of 8 anatomical regions in musculoskeletal pain in the intervention group compared with the control group over the study; 3 of these findings were significant. We observed a greater proportional increase in musculoskeletal pain severity in the proximal quadrant of the non-preferred limb of the intervention group compared with the control group. These findings were not significant.

Likewise, the intervention group had smaller proportional improvements in the MOS PCS and larger proportional decrements in the MCS than the control group.

## 4.0 Multiple regression analysis

**Linear models:** Table 20 reports results of GEE multivariable linear regression models examining the association between physical exposure and posture. In adjusted models, we observed the intervention had a protective effect against greater non-neutral posture in all 5 modified RULA elements at follow-up; 3 were statistically significant. This table also shows the intervention had a non-significant protective effect against high hand activity/upper extremity movement in the preferred limb, while the intervention significantly increased hand activity/upper extremity movement in the non-preferred limb. Appendix F shows unadjusted and adjusted multivariable linear regression models for associations between intervention and each physical exposure.

**Poisson models:** Table 21 shows the results of GEE Poisson models for the effect of intervention on dichotomous musculoskeletal pain outcomes. Nine of 12 anatomical regions showed less likelihood of an adverse musculoskeletal pain outcome following the intervention. Six of these findings were significant. Two regions showed the intervention resulted in no effect on the likelihood of an adverse regional musculoskeletal pain outcome, while 1 region (forearm of non-preferred limb) showed the intervention resulted in a small, significantly greater likelihood of an adverse musculoskeletal pain outcome.

## 5.0 Compliance

These results were based on observational assessments. For the intervention group, compliance for the item "keyboard and mouse tray in regular use" was 94.5%, while compliance for the item "touchpad in regular use" was 65.5%. Adherence to recommended equipment adjustments and positions was 92.7% for the keyboard tray and 96.4% for the touch pad. Alterations to recommended technique were 1.8% for the keyboard tray and 34.5% for the touch pad.

## 6.0 Effect of engineering controls and training on pain, preference, ease of use, and productivity

Table 22 presents reported results on the effects, preference, and ease of use of the intervention; these were based on the self-administered survey at follow-up. The intervention group reported the keyboard tray decreased overall pain by 73%, while nearly 43% reported the touch pad decreased overall pain. Nearly 20% reported the keyboard tray had no effect on pain, while approximately 48% reported the touch pad had no effect on pain. Almost 88% reported they liked using the keyboard tray, while 50.0% reported they like using the touch pad. Approximately 9% stated they disliked using the tray, while just over 38% stated they disliked using the touch pad. Just over 91.0% of the intervention group reported the keyboard tray was not difficult to use, while 50.0% reported the touch pad was not difficult to use.

It was not feasible to assess productivity measures based on employer tracked metrics due to the varied daily task assignments and tremendous task variability for each participant. Tasks changed daily due to legislator or legislative needs. Moreover, the Office of

Legislative Management did not maintain productivity records for support staff of legislators or non-partisan departments. Thus, the effect of the intervention on productivity was evaluated at follow-up in the intervention group using only employee self-report measures. Just over 46% of the intervention group reported they believed the keyboard and mouse tray increased work productivity, while approximately 12% reported they believed the touch pad increased work productivity. Almost 54% believed the keyboard tray decreased or had no effect on work productivity, while nearly 88% believed the touch pad decreased or had no effect on work productivity.

## 7.0 Further examination of contamination

To further explore whether contamination may have occurred from the intervention to the control group, we conducted exit telephone interviews to determine intervention satisfaction for 24 randomly selected participants in both intervention and control groups approximately 1 month after the study ended. We asked participants if they were "more or less satisfied with work after the intervention compared with work before the intervention." Just over three-quarters of the intervention group (78.6%, or 11 out of 14 participants) stated they were more satisfied with work following the introduction to engineering controls and training on their use, and keyboard shortcuts, while 80% (8 out of 10 participants) of the control group stated they were more satisfied with work following the introduction to keyboard shortcuts.

## 8.0 Non-participants and loss to follow up

Nearly 64% of employees in the agency (n=418) either actively (contacted the PI) or passively (non-respondents) refused to participate in the study. We compared the study cohort (n=113) to those who refused, ineligible employees, and non-respondents, which were collectively termed "non-participants" (n=305) to examine response characteristics between participants and non-participants.

We were only able to obtain 6 variables to examine response characteristics from all non-sessional, non-participant employees: age, gender, job title, department, years working at agency, and income. Table 23 presents these findings. Two significant differences were found: gender and department.

Of the 305 non-participants, we only had present or absent musculoskeletal pain data on 74 non-participants, which was based on the screening interview. We further examined screening response characteristics among non-participants with respect to present musculoskeletal pain. Almost 42.0% of non-participants had musculoskeletal pain present in the neck or at least 1 upper extremity region.

We also examined screening response characteristics between gender and musculoskeletal pain for non-participants. Of the 74 non-participants, 45.1% (n=23) of female non-participants had musculoskeletal pain in the neck or at least 1 upper extremity region. For males, 34.8% (n=8) of non-participants had musculoskeletal pain in the neck or at least 1 upper extremity region. The statistical difference for present musculoskeletal pain between female and male non-participants was p=0.41.

We then examined screening response characteristics among departments and musculoskeletal pain for the 74 non-participants. Distributions of present musculoskeletal pain by non-participants in "caucus," "technical branch," and "management" were 14 (35.0%), 7 (41.7%), and 10 (41.9%), respectively.

Four participants were lost to follow-up. All 4 participants were in the control group. An exit interview was given to each of these participants to determine the reason for leaving the study. Two participants were laid off, 1 participant became a legislator, and the other participant declined to participate in the follow-up.

# IV. RESULTS: SUB STUDY - EFFECT MODIFICATION

Tables 24-29 show descriptive statistics for baseline determinants between dichotomized age groups. Table 30 shows descriptive statistics for baseline musculoskeletal pain severity by quadrant between dichotomized age groups. Table 24 shows younger participants had a greater proportion of higher education than older participants (borderline statistically significant). Older participants had more elder care obligations than younger participants (statistically significant). Length of time since MSD onset was substantially longer for older workers, while work ability was substantially lower for older workers. The latter findings demonstrate that older workers have more unpaid work and MSD chronicity than younger workers. This type of unpaid work can increase non-occupational physical and psychosocial exposures, increase cumulative exposure, increase the vulnerability of older workers to greater persistence of musculoskeletal illness, which may lead to additional work-related physical exposures, such as altered movement strategies to accomplish a work task in an efficient manner [73]. Greater MSD chronicity may indicate that medical management will be more difficult.

Table 25 shows that younger workers used their keyboards and pointing devices significantly more hours per week than older workers. The amount of finger effort required at work and weekly hours spent on PDA or cell phone use was substantially greater for younger workers. Older workers were employed significantly more years at the agency and used a computer over their lifetime for significantly more years than younger workers. Older participants worked more years in a specific job title than younger participants (borderline

statistically significant). These findings indicate that although younger workers were exposed to more finger effort at work and spend more hours per week on peripherals (e.g., pointing devices, keyboard) than older workers, older workers have accumulated more occupational exposure over the years. Once again, this might suggest that greater accumulation of exposure over time may increase older workers' vulnerability to musculoskeletal illness severity and lead to additional work-related exposures. Regarding the latter, MSDs can alter efficient motor patterns among workers to allow them to complete a task, however maladaptive this response may be [73-75].

Table 26 shows that older participants had greater decision latitude than younger participants (borderline statistically significant). Some researchers have suggested that greater job control may mitigate the effects of adverse, cumulative occupational exposures [34, 76]; it may also provide greater opportunity for acquiring new ergonomic skills and training.

Table 27 shows a greater percentage of younger participants worked in the caucus or technical branch departments, while a greater percentage of older participants worked in management. A greater percentage of younger participants worked in the job title, "assistant," while a greater percentage of older participants worked in the job title, "director." These findings indicate that older workers are employed in more supervisory positions. As noted above, this may lead to greater job control, and provide greater opportunity for acquiring new ergonomic skills and training, and arranging jobs to be less physically stressful.

Table 28 shows that older workers have more familiarity in all aspects of ergonomic knowledge than younger workers, although "moderate or expert familiarity" in all aspects of

ergonomic knowledge in older workers was ≤20%. While both groups of workers had low ergonomic knowledge prior to the intervention, older workers were more knowledgeable in ergonomics. This might have been due to more years on the job and greater job experience, combined with greater cumulative ergonomic training knowledge over their working life.

Table 29 shows similar distributions in all modified RULA postures and modified hand activity/upper extremity movements between age groups. Table 30 shows there were similar proportions of musculoskeletal pain severity in both proximal quadrants and the distal quadrant in the non-preferred limb in both age groups; however, the older age group had substantially higher pain levels in the distal quadrant of the preferred limb. These data were based on pre-intervention findings, when workers used their traditional mouse in the preferred limb. Younger workers spent more time on peripherals in the preferred limb, such as mice, yet older workers have higher pain levels in the distal quadrant of the preferred limb. This might once again suggest that older office workers have accumulated greater physical exposure in their preferred limb, usually the right upper extremity in ~88% of the general population. This may increase MSD vulnerability in this limb.

Tables 31 through 35 present descriptive statistics for determinants that were obtained post-intervention by dichotomized age groups. Table 36 shows descriptive statistics of follow-up quadrant musculoskeletal pain severity by dichotomized age groups. Table 31 shows that older participants continued to experience significantly more elder care obligations than younger participants. Similar to baseline findings, work ability was substantially lower in the ≥44 age group. Once again, these findings demonstrate the possibility of greater physical and psychosocial exposures for unpaid work and a greater vulnerability in terms of abilities required to handle occupational demands.

Table 32 shows younger participants continued to use their pointing devices significantly more hours per week than older workers. Older workers took substantially more frequent rest breaks after <1 hour of work than younger workers. Similar to baseline findings, the amount of weekly hourly time on PDA or cell phone use was substantially greater for younger workers. Younger workers also reported greater static postures in proximal musculature, working more than 1 job, and using the home computer more than older workers. These findings may indicate that while younger workers were exposed to higher physical stressors or physical stressors for longer periods of time over the week, older workers still required more frequent recovery breaks per week over shorter periods of time. No significant results were seen for psychosocial determinants between age groups in Table 33.

Table 34 shows there were now similar percentages in all aspects of ergonomic knowledge at follow-up between age groups. Younger workers increased their ergonomic knowledge at follow-up and were now equally knowledgeable as older workers regarding office ergonomics.

Table 35 shows younger workers had significantly more hand activity/upper extremity movement in the preferred limb than older workers. With the exception of hand activity/upper extremity movement in the preferred limb in younger workers, other aspects of physical exposure in posture and hand activity/upper extremity movement did not significantly vary between age groups at follow-up.

Musculoskeletal pain severity by quadrant in Table 36 shows that younger workers had substantially more uncomfortable pain (or greater) in the preferred proximal limb than older workers at follow-up, while older workers had substantially more uncomfortable pain

(or greater) in the preferred and non-preferred distal limbs than younger workers at follow-up. Younger workers had greater upper extremity movement in the preferred limb at both baseline and follow-up and greater pain in the proximal preferred limb quadrant; an apparent exposure/dose/response relation. Curiously, although younger workers had greater hand activity/upper extremity movement in this limb at both time points, older workers had greater pain in the distal quadrant of the preferred limb at follow-up. Once again, does this suggest that greater cumulative exposure, chronic overload due to an imbalance between physical work capacity and physical workload, longer recovery time after an illness, and co-morbidity in older workers lead to greater vulnerability within their musculoskeletal system?

Table 37 shows absolute change scores in $\geq$ uncomfortable musculoskeletal pain severity over time by age (follow-up pain severity-baseline pain severity). Change scores revealed that older workers had greater reductions in pain in the preferred limb, while younger workers had greater reductions in pain in the non-preferred limb. Interestingly, younger workers had greater hand activity/upper extremity movement and higher pain severity in the preferred limb at follow-up; older workers had greater hand activity/upper extremity movement and higher pain severity in the non-preferred limb at follow-up. This latter finding once again suggests an apparent exposure/dose/response relation. It also suggests that since older workers had a greater increase in absolute change score in hand activity/upper extremity movement in both preferred and non-preferred limbs over the study, they may have employed the touch pad and bilateral keyboard shortcuts more frequently than younger workers. Indeed, Summary Table 38 change scores suggest these findings.

As noted above, Summary Table 38 lists the distribution of physical exposures between age groups by time. Figures 1-7 that were used to create this Table are listed in

Appendix J1, while the text that explains these Figures are described in Appendix J2. The table shows for modified Computer RULA at baseline, older workers had 1 less non-neutral posture in an anatomical region than younger workers. At follow-up, the reverse was seen. Thus, of the 5 modified RULA elements that were examined over the study (a total of 10 anatomical regions), both age groups had a similar number of non-neutral postures in anatomical regions.

Interestingly, 1 pattern was observed between age groups for posture; this was seen in the spine and lower extremity. Specifically, at baseline and follow-up, younger workers had fewer non-neutral postures in these regions than older workers. Deep, intrinsic spinal muscles provide core stability during both static and dynamic activities. Although few studies have examined this topic in workers, authors have suggested that postural stability is greatest in the second and third decade, with "striking" losses in postural stability after the fifth decade. The authors attributed changes in postural stability to mechanical, muscle, and phasic power differences between age groups [77]. This may indicate that core stability among older workers is compromised. This might then lead to higher physical exposures in musculature directly adjacent to the spine (e.g., proximal upper quadrant musculature) and an attendant increased risk of MSDs in these quadrants.

In this same table, younger workers had greater hand activity/upper extremity movement in the preferred limb at baseline and follow-up than older workers. While younger workers had greater hand activity/upper extremity movement in the non-preferred limb at baseline, older workers had slightly greater hand activity/upper extremity movement in the non-preferred limb at follow-up.

We then examined absolute mean physical exposure changes (follow-up – baseline) over time. Table 38 also presents these findings. Both age groups had a similar number of reductions in non-neutral postures; however, scores indicated that younger workers had a slightly greater reduction in the magnitude of non-neutral postures (younger workers had a 2.5 unit greater reduction of non-neutral postures on a combined modified RULA scale, which ranged of 6-129; this was based on the aggregate score of the 5 RULA elements in Table 38).

Absolute mean changes in hand activity/upper extremity movement in the preferred limb was slightly greater in older workers. In the non-preferred limb, hand activity/upper extremity movement was substantially greater in older workers. These changes may indicate that older workers were more compliant with the touch pad and keyboard shortcut aspect of the intervention than younger workers. It may also indicate a greater willingness to learn precision equipment and activities in older workers.

We present intervention compliance results between age groups in Table 39 to tease apart Table 38 findings. With the exception of "adherence to recommended adjustments to the keyboard/mouse tray," all aspects of compliance for the keyboard/mouse tray were similar between age groups. Older workers complied more with the recommended adjustments to the keyboard/mouse tray. Older workers also complied more with all aspects of touch pad compliance. Large differences were seen for "is equipment used regularly" and "adherence to recommended adjustments." This suggests compliance among older workers was slightly greater in keyboard/mouse tray use and substantially greater than younger workers in touch pad use. While this may explain why an absolute mean increase in hand activity/upper extremity movement in the non-preferred limb was observed more in older

than younger workers over the study, it does not explain why there were slightly greater magnitudes of improvement in non-neutral postures in younger workers.

A possible explanation may be found in the human performance literature. For example, older workers may have impaired steadiness [78] and a decline in the ability to perform precision tasks [39]; their muscle contractions may become disorganized, and they may experience a greater overall reduction in motor function compared with younger workers [12].

Summary table 40 lists interaction terms and their corresponding main effects for postural exposures and age. Summary table 41 lists interaction terms and their corresponding main effects for hand activity/upper extremity movements and age. Tables of main effects of physical exposures and age, and their corresponding interaction models are listed in Appendix J1, while accompanying text that explains these Tables are described in Appendix J2.

Table 40 shows that in the preferred proximal upper extremity quadrant, the direction of the interaction terms suggested the joint effects of 4 of 5 non-neutral postural regions and older age increased the likelihood of adverse musculoskeletal pain outcomes in this quadrant. Two of these findings were statistically significant. In the non-preferred proximal upper extremity quadrant, the direction of the interaction terms suggested the joint effects of 2 of 5 non-neutral postural regions and older age increased the likelihood of adverse musculoskeletal pain outcomes in this quadrant. However, both non-neutral postural regions included the null in this latter quadrant.

In the preferred distal upper extremity quadrant, the direction of the interaction term suggested the joint effects of non-neutral postural regions and older age provided a protective

effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant. One finding was statistically significant. Similar results were found in the non-preferred distal upper extremity quadrant. In total, 2 of 14 (14.3%) interaction terms reached statistical significance for an increased likelihood of an adverse musculoskeletal pain outcome; both of these were located preferred proximal upper extremity quadrant.

Table 41 shows that in the preferred proximal upper extremity quadrant, the direction of the interaction terms suggested the joint effects of high hand activity/upper extremity movement in both preferred and non-preferred limbs and older age provided small protective effects against the likelihood of adverse musculoskeletal pain outcomes in this quadrant. One finding was statistically significant, while the other reached borderline significance. In the non-preferred proximal upper extremity quadrant, the direction of the interaction terms suggested the joint effects of high hand activity/upper extremity movement in the preferred limb and older age increased the likelihood of adverse musculoskeletal pain outcome in this quadrant. However, the CI included the null.

In the preferred distal upper extremity quadrant, the direction of the interaction term suggested the joint effects of high hand activity/upper extremity movement in the preferred limb and older age provided a protective effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant, although the CI included the null. In the non-preferred distal upper extremity quadrant, the direction of the interaction term suggested the joint effects of high hand activity/upper extremity movement in the non-preferred limb and older age increased the likelihood of adverse musculoskeletal pain outcome in this quadrant. A borderline statistically significant result was observed. In total, 1 of 6 (~17%) interaction

terms reached (borderline) significance for an increased likelihood of an adverse musculoskeletal pain outcome.

# V. RESULTS: SUB STUDY – MAGNITUDE AND FREQUENCY OF POSTURAL MOVEMENTS AMONG WORKERS WITH PAIN PERFORMING ONLY 1 TASK OVER THE DAY

Results from Table 42 show that for dichotomized RULA postural elements, the magnitude of 5 of 7 postural movements increased in the afternoon. The continuous measurement, Upper Body RULA, also showed an increase in the magnitude of postural movements in the afternoon. This table also shows that the frequency of postural movements decreased in the afternoon in both preferred and non-preferred limbs.

Table 43 shows the magnitude and frequency of postural movements by dichotomized RULA postural elements and pain chronicity. Similar to Table 42, there were greater magnitudes of postural movements in the afternoon in participants with greater chronicity: 5 versus 4 increases in the magnitude of postural movements in participants with greater chronicity compared with those with less chronicity. Conversely, the continuous measurement shows a greater increase in the magnitude of postural movements in the afternoon among participants with less chronicity. Likewise, participants with less chronicity had more frequent reductions of postural movements in the afternoon in both preferred and non-preferred limbs.

Table 44 shows the magnitude and frequency of postural movements by dichotomized RULA postural elements and pain severity. There were greater magnitudes of postural movements in the afternoon in participants with less pain severity: 6 versus 3 increases in the magnitude of postural movements in participants with less pain severity compared with those with more pain severity. Conversely, the continuous measurement shows there were 3 of 4 a greater increases in the magnitude of postural movements in the afternoon among participants with more pain severity. Likewise, participants with more pain severity had more frequent reductions of postural movements in the afternoon in both preferred and non-preferred limbs.

Table 45 shows the magnitude and frequency of postural movements by dichotomized RULA postural elements and age. There were greater magnitudes of postural movements in the afternoon in the older age group: 5 versus 1 increase in the magnitude of postural movements in the older age group compared with the younger age group. Conversely, the continuous measurement shows there were a greater increase in the magnitude of postural movements in the afternoon among the younger age group. The older age group had slightly more reductions in the frequency of postural movements in the afternoon in the preferred limb and an equal reduction in the frequency of postural movements in the non-preferred limb.

# VI. DISCUSSION

The specific aim of the main study was to examine the effectiveness of 2 engineering controls consisting of a fully adjustable keyboard/mouse tray and touch pad pointing device, and training on posture, hand activity/upper extremity movement, pain, and quality of life health status among workers with substantial occupational computer use and neck and upper extremity musculoskeletal pain.

## 1.0 Evidence (dis)agreeing with hypotheses

**Hypothesis 1** predicted a keyboard and mouse tray adjusted to promote neutral postures, with training in its adjustment and use, will reduce non-neutral postures in the neck, upper back, and preferred and non-preferred limbs in the intervention group more than in the control group. The data suggested that the intervention was associated with a reduction in non-neutral posture in all modified RULA elements (Table 18).

These findings might be explained as follows: the negatively tilted keyboard and mouse tray reduced scapula elevation and shoulder abduction and flexion, bilaterally; the tray increased the elbow angles toward extension, bilaterally; and the tray reduced wrist extension, bilaterally. The effects of the adjustable tray on each of these postures may have led to greater reductions of non-neutral postures in these regions. The use of a tented touch pad may have led to further reductions of non-neutral postures in elbow, forearm, and wrist regions in the non-preferred limb compared with full forearm pronation, which is associated

with traditional keyboard and mouse use. Moreover, a touch pad located on the left side of the keyboard is usually associated with the absence of a numeric keypad on that side. The lack of a numeric keypad on the left has been shown to reduce non-neutral postures in the left upper extremity and upper back [80].

**Hypothesis 2** predicted a keyboard and mouse tray that is adjusted to promote neutral postures, with training in its adjustment and use, will reduce musculoskeletal pain severity in the neck, upper back and upper extremities, and improve quality of life of the intervention group. With the exception of the forearm in the non-preferred limb, the data indicated there was less likelihood of an adverse musculoskeletal pain outcome following the implementation and training on the keyboard and mouse tray in 75% of anatomical regions (Table 19).

The increased likelihood of an adverse musculoskeletal pain outcome in the forearm of the non-preferred limb in the intervention group appears to be due to the increased use of the touch pad in the non-preferred limb. The use of a wrist rest while keying in the non-preferred limb of the intervention group may have exacerbated this finding. For example, researchers reported a wrist rest was associated with increased risk of incident distal upper extremity MSDs in a prospective study, while forearms that were supported on the desktop were related to a reduction of risk of incident proximal upper extremity MSDs [55]. A laboratory study that examined the effect of wrist rests on wrist postures and electromyography throughout the upper extremity and upper back noted that wrist rests may be associated with higher loading forces in proximal musculature [182]. However, neither of these studies examined health outcomes after the implementation of low, negatively tilted

keyboard tray, nor the use of a second pointing device in the non-preferred limb. Thus, these explanations remain tentative.

As noted above, wrist rests used by the intervention group may have led to less proximal upper extremity support [182]. This may have led to greater static loading forces in the muscle bellies of the forearm to compensate for the lack of proximal support, and to allow the wrist and digits greater mobility [75]. Likewise, the contractile tissues and muscle actions in the muscle groups that operated the touch pad – the muscle bellies in the non-preferred limb forearm – may have been exposed to a greater magnitude and duration of loading forces than the other upper extremity regions due to the lack of proximal support.

Another possible explanation for these results concerns the greater use of the non-preferred limb to operate the touch pad combined with unilateral use of the left upper extremity to perform keyboard shortcuts in the intervention group. This may have led to greater hand activity in the non-preferred limb. For example, when using keyboard shortcuts, it is common for computer users to toggle through windows (alt and tab commands) using their left upper extremity. Similarly, cut (ctl x) and paste (ctl v) are frequently performed with the left upper extremity, as these characters are located near each other on the left side of a traditional keyboard. Unfortunately, we did not have the resources to observe the separate effects of keyboard shortcuts on the cohort during the work-sampling procedure; thus, this explanation is tentative.

We further explored why the forearm of the non-preferred limb in the intervention group had a greater likelihood of an adverse musculoskeletal pain outcome. This finding appeared paradoxical, as reductions in non-neutral postures in all modified RULA elements

of the intervention group at follow-up should hypothetically have led to a reduced likelihood of an adverse musculoskeletal pain outcome in the forearm.

Among all physical exposures in the intervention group, the largest proportional increase occurred in hand activity/upper extremity movement in the non-preferred limb (Table 16). This finding suggested increased hand activity/upper extremity movement in the non-preferred limb may have contributed to these findings.

This hypothesis also predicted the intervention would improve quality of life. Our findings did not agree with this hypothesis for quality of life. The data indicated there were small but greater likelihoods of adverse PCS and MCS outcomes in the intervention group, although estimates were not statistically significant. An explanation for the increased likelihood of an adverse quality of life outcome was the MOS was a secondary outcome; the effect of the intervention was hypothesized to have less impact on quality of life than on musculoskeletal pain.

**Hypothesis 3** predicted the introduction of a touch-pad pointing device in the non-preferred limb of the intervention group, plus training, would reduce repetitive motions and non-neutral postures in the preferred limb. Hypothesis 3 also predicted an increase in repetitive motions and non-neutral postures in the non-preferred limb of the intervention group. The data suggested that the touch-pad in the non-preferred limb decreased repetitive motions and non-neutral postures in the preferred limb of the intervention group. The data also suggested the touch-pad in the non-preferred limb increased repetitive motions and decreased non-neutral postures in the non-preferred limb of the intervention group.

We hypothesized the touch pad would increase non-neutral postures in the non-preferred limb of the intervention group. The use of a touch pad requires substantial proximal

joint movement involving shoulder abduction, flexion, and external rotation, and shoulder horizontal abduction and adduction. This device also required substantial distal joint movement involving forearm rotation, and wrist extension, flexion, and deviation, with a hypothesized attendant increase in non-neutral postures.

The greater decreases in non-neutral postures in the non-preferred limb of the intervention group was unexpected, as touch pad use in the non-preferred limb involved precision work, albeit gross motor. Precision work was hypothesized to substantially increase postural and movement loads throughout the non-preferred limb.

Several reasons might explain these reductions: over 98% of the intervention group used the touch pad on the left side of the keyboard, which did not have a numeric keypad; the touch pad was also immediately next to the keyboard. Both factors have been shown to mitigate non-neutral postures in the left upper extremity [80]. The touch pad was tented approximately 12 degrees in the non-preferred limb elbow, forearm, and wrist; the use of the middle digit, with the hypothenar eminence and fifth metacarpal phalangeal bone resting on the mouse tray, increases the tenting angle of the elbow, forearm, and wrist approximately 10 degrees. That is, to a maximum of 22 degrees. This may have led to greater neutral postures in these regions.

**Hypothesis 4** predicted the introduction of a touch pad would reduce musculoskeletal pain severity in the neck, upper back, and preferred limb, and improve quality of life compared with a control group. Our data agreed with this hypothesis involving pain severity. The data indicated that there was less likelihood of an adverse musculoskeletal pain outcome in the intervention group throughout the neck, upper back, and preferred limb. The least

likelihood of an adverse musculoskeletal pain outcome was greatest in the preferred limb wrist and hand (Table 19).

Two possible explanations for less likelihood of an adverse musculoskeletal pain outcome in distal musculature of the preferred limb was the low, negatively titled keyboard tray, which was predicted to promote neutral postures in the distal anatomical regions of the preferred limb. The other explanation is that the touch pad in the non-preferred limb reduced the magnitude, duration, and repetition of non-neutral posture and upper extremity movement in the distal musculature of the preferred limb.

Our findings did not agree with this hypothesis for quality of life. In addition to the possible explanations for these findings described above, another possible reason for these results is the brief follow-up time. The truncated follow-up was due to the time it took to obtain a Certificate of Confidentiality, which was required before we could begin recruitment. Moreover, recruitment was then initiated during legislative session, which increased our estimated recruitment time by 2 months. Thus, time at follow-up for MOS measurements was shorter than for follow-up periods usually reported in the literature [183, 184]. This may have reduced the effect of the intervention on quality of life constructs.

**Hypothesis 5** predicted the introduction of a touch pad in the non-preferred limb would not be associated with an exacerbation of musculoskeletal pain in the non-preferred neck or limb regions of the intervention group. There was 3% significantly greater likelihood of an adverse musculoskeletal pain outcome in the non-preferred limb forearm of the intervention group.

As noted above, although there were reductions of non-neutral postures in the non-preferred limb in the intervention group at follow-up, there was an increase in hand

activity/upper extremity movement in the non-preferred limb. Likewise, the largest improvement in musculoskeletal pain, located in the distal region of the preferred limb (Table 19), might be due to decreased hand activity/upper extremity movement in the preferred limb and increased in hand activity/upper extremity movement in the non-preferred limb.

The increase in hand activity/upper extremity movement in the non-preferred limb may also have breached an exposure-dose-response threshold [4] in the forearm. This may have led to a greater likelihood of an adverse musculoskeletal pain outcome in the forearm of the intervention group. In addition, the tenting angle of the touch pad was initially set at 30 degrees; participants were trained to use their middle fingers to operate the touch pad, which increased the forearm angle to approximately 40 degrees from full pronation. This neutral forearm posture (approximately 40 degrees) should have led to less musculoskeletal strain in the distal region of the non-preferred limb than during full forearm pronation or substantially smaller tenting angles [54]. However, due to the compressibility of the foam that was used to tent the touch pad, coupled with the weight of the non-preferred limb when using the touch pad, the tenting angle of the touch pad was reduced to approximately 12 degrees after less than 1 month of use. The additional 10 degrees gained from using the middle digit positioned the forearm angle to approximately 22 degrees from full pronation. This postural change in the forearm – a reduction from an anticipated 40 degrees to 22 degrees from full forearm pronation – may have further lowered the exposure-dose-response threshold in the non-preferred limb forearm among symptomatic participants.

Likewise, although the mechanism in which forearm rotation (i.e., full pronation) increases strain in the distal upper extremity remains unclear, researchers proposed a possible

explanation: the proximal boundary of the "effective" carpal tunnel space, defined by forearm flexor muscle bellies, may "translate" and change its shape during forearm rotation [54]. Thus, the reduction of an anticipated 40 degrees to 22 degrees from full forearm pronation of the touch pad may have altered the shape of the forearm flexor muscle bellies, which are primarily located in the mid-forearm.

Moreover, forearm rotation, wrist flexion, extension, and deviation, and finger flexion and extension muscle actions that increased hand activity to operate the touch pad arise primarily from flexor and extensor muscle bellies located in the forearm. While both skeletal muscle and tendons are composed of contractile tissue, the greatest density of contractile tissue is located intramuscularly – in the forearms – rather than in the tendons of the wrist flexors, extensors or deviators, or finger flexors or extensors. Greater contractile loads in this region may have contributed to these unexpected findings.

## 1.1 Summary assessment of the intervention

The inferences that can be drawn from the results are the introduction of a touch pad in the non-preferred limb and a keyboard and mouse tray adjusted to promote neutral postures may reduce non-neutral postures in the neck and upper extremity, bilaterally, reduce hand activity/upper extremity movement in the preferred limb, and increase hand activity/upper extremity movement in the non-preferred limb, albeit with modest effects. The engineering controls also appeared to reduce the likelihood of adverse musculoskeletal pain outcomes in all but three anatomical regions of the neck, upper back, and upper extremities,

distal greater than proximal. However, once again, anatomical regional pain reduction effects were modest, but the follow up interval was short.

Clinical relevance is often considered in terms of a patient's perspective, and often defined with respect to a "minimally clinically important difference." This is when improvements in clinical pain are experienced following an intervention compared with pre-intervention clinical pain status. Unfortunately, a "minimally clinically important difference" has not been substantially examined for quality of life or increases in pain [185, 186]. The greater distal pain changes in the preferred limb that were reported by participants might be considered clinically relevant. Specifically, a consensus document on interpreting outcomes of chronic pain in clinical trials noted a 10% to 20% reduction of pain on numeric rating scales may be considered a minimally clinically important difference, while a 30% to 50% reduction of pain may be considered moderately important [186].

The intervention was hypothesized to allow the preferred limb to recover from repetition and duration of upper extremity movement and proximal static loading; to recover from the magnitude, repetition, and duration of non-neutral postures over the workday while the non-preferred limb is being used; and to reduce musculoskeletal pain. The intervention was also hypothesized to improve the quality of life among the participants [80], although to a lesser degree than musculoskeletal pain. Since use of the non-preferred limb touch pad was designed to *augment* the preferred limb, an exacerbation of musculoskeletal pain in the forearm of the non-preferred limb of the intervention group, albeit a small increase was unexpected. Specifically, based on nearly 2 decades of clinical ergonomic experience, we did not expect posture and upper extremity movement exposure in the non-preferred limb to breach a dose-response threshold.

A similar intervention design was described in a cohort of sonographers, although the physical exposures associated with this job are likely greater than those related to computer use. This study examined sonographers who were trained to scan with both preferred and non-preferred limbs as a possible method to reduce repetitive movements and pain in the preferred neck and limb, and improve musculoskeletal system balance. At baseline, all sonographers used the transducer for the entire workday in the preferred limb (100% in the right upper extremity). These researchers hypothesized pain would be reduced in the neck and preferred limb, while there would be no incident MSDs in the non-preferred limb since this limb was designed to augment transducer use in the preferred limb. Researchers found reductions in pain severity in the neck and upper back of the preferred limb; no change in pain status was reported in the preferred limb. There were no incident MSDs in the non-preferred limb [187]. Unfortunately, the potential of MSD exacerbation in the non-preferred limb was not reported.

### 1.2 A greater reduction of pain in the control group

Although Table 17 shows proportional reductions in pain severity in 6 of 8 regions in the intervention group, the proximal quadrant of the non-preferred limb demonstrated proportional increases in pain severity. There are several possible explanations for this, which include: 1) underreporting of pain by the control group; 2) the episodic and complex nature of pain; 3) upstream organizational changes unrelated to the intervention; 4) contamination of the control group by informal transfer of ergonomic knowledge from the

intervention group; 5) knowledge gained from keyboard shortcuts in the control group; and 6) the so-called Hawthorne effect.

### 1.3 Ergonomic knowledge

Similar findings between intervention and control groups in overall ergonomic knowledge were not unexpected. The intervention was primarily targeted to reduce 3 exposures: proximal static loading, and movement and non-neutral postures in the upper back and upper extremity of the preferred limb. The intervention rationale that was provided was based on these exposures. The PI did not comprehensively review all aspects of office ergonomics with the cohort. Conversely, other aspects of ergonomic knowledge in the intervention group showed either a large improvement in knowledge or remained relatively unchanged at follow-up. The control group had reductions in all aspects of ergonomic knowledge at follow-up.

### 1.4 Participants' perceptions of the intervention

Subjective reports regarding effects of the engineering controls revealed a greater proportion of participants stated the keyboard tray reduced pain more than the touch pad (Table 20). A smaller proportion of participants also reported the keyboard tray had no effect on pain severity compared with the touch pad. More participants stated they liked using the keyboard tray, and more reported the keyboard tray was easier to use. Participants also stated the keyboard tray improved productivity more than the touch pad. A smaller proportion of

participants also stated the keyboard tray reduced or had no change in productivity compared with the touch pad.

## 1.5 Past literature

Our study appeared to corroborate other research in the literature. Two studies focused on what effect a keyboard tray may have on distal upper extremity posture; curiously, the effect of the tray on a pointing device was excluded from these studies [41, 188]. Hedge et al. found that using a negatively sloped keyboard tray decreased wrist extension; more typing movements were also spent in a neutral wrist posture compared with a traditional keyboard on a desktop that was not negatively pitched [41, 188]. Woods and Babski-Reeves found that when using a negatively tilted platform, wrist posture was within a neutral zone for a greater percentage of the time for wrist flexion and extension, defined as <15 degrees extension and <30 degrees flexion [189]. Our study showed there were greater reductions in distal non-neutral postures in preferred and non-preferred limbs in the intervention group.

Delisle and colleagues examined bilateral mouse use, although not simultaneously [80]. They found that when using a standard keyboard, left sided mousing reduced postural exposures in the left upper extremity, while postural exposures increased with right sided mousing. We found similar results in the non-preferred limb when the touch pad was located on the left side of the keyboard.

Our findings also agreed with other studies regarding repetitive motions and pain in the preferred limb. Researchers found a pointing device in the non-preferred limb reduced

repetitive motions in the preferred limb [80, 82, 187]. Other studies have reported that reductions in both non-neutral postures and repetitive motions associated with computer work in general and mouse work in particular improved pain severity in the preferred limb [80].

Gustafsson and Hagberg found a decrease in wrist extension and ulnar deviation when participants used a right sided vertical mouse; these researchers also found when a traditional mouse was located on the right, there was an increased level of discomfort in the right shoulder and wrist when the forearm was in full pronation relative to when the forearm was 90 degrees from full pronation [43]. Conlon et al. found improvements in neutral right upper extremity postures when using a right sided vertical mouse compared with a traditional mouse [42]. Both studies appeared to corroborate our findings regarding reductions in non-neutral postures when using an alternative pointing device. Unfortunately, these studies were not directly comparable with our study, as they did not use bilateral pointing devices. Further, the alternative pointing devices used in these studies were only located on the right.

Lotters and Burdof noted when physical exposures were reduced by at least 14%, a concurrent reduction in incident MSDs may occur if adequate time is allowed for the intervention to be effective [190]. Although our study involved a secondary intervention and comprised less than a 4 month follow-up time, it is biologically plausible that participants with low levels of musculoskeletal pain – as was found in our study – may experience similar results. That is, a reduction in physical exposure and a concurrent reduction in MSD severity. For example, there was a 16.4% proportional reduction in hand activity/upper extremity movement in the preferred limb in the intervention group at follow-up. There was a concomitant proportional improvement in distal pain severity in the preferred limb.

In a systematic review that examined duration of computer use and MSDs, IJmer et al. found there was "moderate evidence" of an association between duration of mouse use and incident distal upper extremity symptoms. Interestingly, risk estimates were greater for the association between mouse use and MSDs than keyboard use and MSDs. In terms of exposure-response findings, these authors found an increased risk over increasing exposure duration categories between mouse use and distal upper extremity symptoms [191]. In our study, because the non-preferred limb only supplemented the preferred limb, we hypothesized that physical exposure and pain severity would be reduced in the preferred limb. One mechanism for these proposed decreases in exposure and pain might be a reduction in duration of mouse use in the preferred limb.

Likewise, researchers found that duration of computer use predicted distal symptoms for heavy computer use; hand-wrist symptoms were associated with mouse use for at least half of the work time [78]. Other studies found a high prevalence of MSD symptoms among computer aided designers who used a computer mouse [77, 192]. Lassen et al. reported an association between mouse use and distal upper extremity pain [79]. These investigators also found that increasing mouse use time was associated with increasing risk of distal upper extremity pain.

Over 98% of our participants used a traditional mouse in the right upper extremity during the study. The baseline weekly mean value of mouse use in our study for the entire cohort was over 22 hours. Our results showed that of any neck or upper extremity region, the largest reduction in musculoskeletal pain severity was seen in the distal preferred limb. This may be due to an increased frequency of using the touch pad pointing device, , which may have been the result of increased hand activity/upper extremity movement in the non-

preferred limb in the intervention group. It may also have been due to decreased duration and repetition of mouse use in the preferred limb.

We found no field studies that explicitly examined the simultaneous effect of 2 pointing devices in right and left upper extremities. One study examining symptomatic office workers recommended that a left-handed trackball, coupled with a traditional right sided mouse, could be used as an engineering control [193]. However, it was unclear, as no data were presented, whether 2 devices were used or whether data were examined to determine the relation between 2 devices and musculoskeletal health.

## 2.0 Sub-study: Effect modification by age

The objectives of this paper were to examine whether physical exposures were different by age at baseline and follow-up, and examine whether the relation between physical exposure and musculoskeletal pain severity varied by age over time. The specific aims were to examine the relation between posture and age, and hand activity and age at baseline and follow-up; examine absolute physical exposure change scores by age over the study; examine whether age modifies the association between posture and musculoskeletal pain severity; and examine whether age modifies the association between hand activity/upper extremity movement and musculoskeletal pain severity.

## 2.1 Evidence (dis)agreeing with hypotheses

**Hypothesis 1** predicted that non-neutral postures would be greater in older than younger workers at baseline and follow-up in the spine, lower extremities, and preferred and non-preferred limbs. Modified RULA spine and lower extremity postures showed that older participants had more non-neutral postures than younger workers at baseline and follow-up. Modified RULA preferred limb postures showed that older workers had fewer non-neutral postures at baseline and follow-up than younger workers. While both age groups had similar modified RULA non-preferred limb postures at baseline, older workers had fewer non-neutral postures at follow-up. Modified RULA spine, lower extremity, and preferred limb postures showed that older workers had fewer non-neutral postures at baseline but more non-neutral postures at follow-up. While modified RULA spine, lower extremity, and non-preferred postures were similar at baseline between age groups, older workers had more non-neutral postures at follow-up. All findings between age groups were small.

Our findings disagreed with all aspects of this hypothesis for modified RULA posture elements over the study. That is, both age groups had the identical number of mean ranges of non-neutral postures when all modified RULA elements were examined during the study (Table 15). Moreover, while both age groups had the same number of reductions in absolute mean change scores, the magnitude of these reductions was slightly greater in younger workers. Overall, this suggests that improvements in neutral postures following the intervention did not substantially vary by age.

We predicted non-neutral postures would be greater in older than younger participants at both time points based on biological plausibility: steadiness may be impaired

in older workers [18]; there is a decline in the ability to accurately perform precision tasks in older workers [109]; muscle contractions become disorganized [18]; older workers have more co-morbidity, which may lead to abnormal movement patterns in order to accomplish precision tasks [10]; and there are declines in memory and spatial abilities, which begin in the third decade of life [10].

Although the number of reductions of absolute mean change scores were identical by age, there was a greater change in the magnitude of postural reductions in younger workers, although the change in magnitude was small. Decrements in motor function and higher co-morbidity in older workers may partially explain these results. However, the proportion of variance in posture that was explained by age was under 10%. Since these differences were so small, the results do not suggest that younger workers implemented the keyboard/mouse tray to a greater extent than older workers. Indeed, the increased hand activity/upper extremity movement in the non-preferred limb in older workers should have increased non-neutral postures in the non-preferred limb, resulting in greater overall postural improvements in younger workers. Moreover, absolute mean change scores showed that younger workers had greater reductions in non-neutral postures in the spine, lower extremity and non-preferred limb, further suggesting that younger workers should have had greater overall postural reductions.

Greater use of keyboard shortcuts in younger workers most likely does not explain the greater neutral postures in absolute mean change scores in the spine, lower extremity and non-preferred limb in younger workers. Keyboard shortcuts would most likely increase non-neutral postures in these regions; we observed the opposite effect in younger workers. Further, keyboard shortcuts would also most likely increase hand activity/upper extremity

movement in the non-preferred limb. Absolute mean change scores showed that hand activity/upper extremity movement in the non-preferred limb was greater in older workers.

Thus, both age groups had the identical number of mean ranges of greater non-neutral postures when all modified RULA elements were aggregated, and the same number of absolute mean change score reductions. This may suggest postural exposures associated with computer work might not be as great a risk for persistent MSDs as other physical exposures related to computer work. Specifically, despite age-related decrements in the musculoskeletal system in older workers, postural exposures did not substantially vary by age at baseline or follow-up.

Curiously, the non-preferred limb showed the largest improvement in neutral postures in older workers, even though older workers demonstrated increased hand activity/upper extremity movement in non-preferred limb quadrants. This may have to due to the tenting of the touch pad and greater use of the touch pad when it was located on the left, as the left side of the keyboard doesn't have a numeric keypad. Although the keyboard/mouse tray was predicted to improve neutral postures in all upper body regions, the improvement in neutral postures in the non-preferred limb in older workers coupled with increased hand activity/upper extremity movement in non-preferred limb quadrants, the latter of which was predicted to increase non-neutral postures in this limb, makes it difficult to tease apart the effect of engineering controls.

Both the implementation of the touch pad and lower psychosocial exposure in older workers may have also contributed to these results. For the latter explanation, older workers may have had less job demand and more job control, affording them greater opportunities to learn new technology and movement patterns. Specifically, although findings were not

significant, older worker had lower job strain in the highest job strain category in the quadrant term at both baseline and follow-up, and a borderline significant value for higher baseline decision latitude.

**Hypothesis 2** predicted that hand activity/upper extremity movement would be greater in younger than older participants at baseline and follow-up in preferred and non-preferred limbs. Hand activity/upper extremity movement in the preferred limb showed that upper extremity movement was greater in younger than older workers at baseline and follow-up. While hand activity/upper extremity movement in the non-preferred limb was greater in younger than older workers at baseline, a small but opposite effect was observed at follow-up: hand activity/upper extremity movement in the non-preferred limb was slightly greater in older than younger participants. Thus, we correctly predicted that hand activity/upper extremity movement would be greater in younger than older workers 75% of the time. Nevertheless, the proportion of the variance in hand activity/upper extremity movement that was explained by age was under 10%.

Interestingly, absolute change scores over time showed that older workers had a small increase in hand activity/upper extremity movement in the preferred limb and a substantial increase in hand activity/upper extremity movement in the non-preferred limb compared with younger workers. We predicted hand activity/upper extremity movement in preferred and non-preferred limbs would be greater in younger than older participants over the study based on biological plausibility: muscle strength declines with increasing age, largely due to loss of muscle mass [107]; and the decline in strength is accompanied by a reduction in speed of upper extremity movement, beginning at 40 years of age and substantially increasing after 50 years of age [108].

Another possible explanation for why hand activity/upper extremity movement was substantially greater in younger workers at baseline and follow-up in the preferred limb might be the physical demands related to hand activity/upper extremity movement are greater than the physical demands related to posture during work-related computer use. This may suggest that decrements in physical functioning and greater co-morbidity might become more apparent when older workers are exposed to hand activity/upper extremity movement than non-neutral postures during computer work.

A recent review on proximal pain among computer workers found that both upper extremity movement and non-neutral postures were associated with proximal pain [133]. However, the paper did not provide strengths of associations or consistency among studies between specific physical exposures and proximal pain. Conversely, the NRC examined the epidemiologic evidence regarding associations between physical exposures and incident upper extremity MSDs among all occupations (Table 4.3). Risk estimates for repetitive motion ranged between 2.3 and 8.8. Posture was not included in this table, although the NRC indicated that the multiplicative effects of posture and other physical exposures increase the risk of distal upper extremity MSDs [37].

Fluid knowledge shows continuous declines beginning in early adulthood, as indicated by difficulties in the extrapolation of associations, novel problem solving, memory of unrelated information, efficiency of transforming or manipulating unfamiliar information, and real-time processing in dynamic environments [10]. Thus, we also predicted younger participants would be more likely to use the alternative pointing device and keyboard shortcuts to a greater extent in their non-preferred limb. The follow-up results in the non-preferred limb – older participants had greater hand activity/upper extremity movement than

younger participants – may be because older participants implemented the touch pad pointing device and keyboard shortcuts to a greater extent than younger workers.

**Hypothesis** 3 predicted the association between non-neutral postures in the spine, lower extremities, and preferred and non-preferred limbs and an adverse musculoskeletal pain outcome would be greater in older than younger workers. Two statistically significant findings for this hypothesis were seen in the preferred proximal upper extremity quadrant. The direction of joint effects between high exposure to 1) non-neutral modified RULA postures in the non-preferred limb and older age, and 2) in the spine, lower extremity, and preferred limb and older age suggested an increased likelihood of an adverse musculoskeletal pain outcome in this quadrant. Thus, the association of 2 out of 5 postural exposures and pain severity in this quadrant suggested that older age increased the likelihood of an adverse pain outcome.

There were no statistically significant findings that indicated the direction of joint effects between high exposure to non-neutral modified RULA postures and older age in the non-preferred proximal upper extremity quadrant increased the likelihood of an adverse musculoskeletal pain outcome.

In the preferred distal upper extremity quadrant, the direction of joint effects between high exposure to non-neutral modified RULA postures in the spine, lower extremity, and preferred limb and older age suggested a statistically significant protective effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant.

In the non-preferred distal upper extremity quadrant, the direction of joint effects between high exposure to non-neutral modified RULA postures in the non-preferred limb

and older age suggested a statistically significant protective effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant.

**Hypothesis 4** predicted the association between high hand activity/upper extremity movement in the preferred and non-preferred limbs and adverse musculoskeletal pain would be greater in older than younger workers. In the preferred proximal upper extremity quadrant, the direction of joint effects between high hand activity/upper extremity movement in the non-preferred limb and older age suggested a statistically significant small protective effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant.

In the non-preferred proximal upper extremity quadrant, the direction of the joint effects between high hand activity/upper extremity movement in preferred and non-preferred limbs and older age suggested there was no association of an increased likelihood of an adverse pain outcome in this quadrant.

In the preferred distal upper extremity quadrant, the direction of joint effects between high hand activity/upper extremity movement in preferred limb and older age suggested there was no association of an increased likelihood of an adverse pain outcome in this quadrant.

In the non-preferred distal upper extremity quadrant, the association between high hand activity/upper extremity movement in the non-preferred limb and older age suggested there was a border line significant increased likelihood of an adverse pain outcome in this quadrant.

One reason why our hypothesis did not agree with many results may partially be explained by the healthy worker effect (HWE) [194]. This is a phenomenon that leads to a selection process: those who remain employed tend to be healthier than those who leave employment, and the HWE generally attenuates an adverse effect of exposure. Checkoway

and colleagues noted the HWE is likely in outcomes involving MSDs [195]. As another researcher noted, the propensity for ill employees to leave work or transfer to less exposed jobs are more commonly seen phenomena in occupational morbidity studies than mortality studies; she continued, "when one stops to consider the endpoints [such as MSDs] for each type of study, it is clear there is greater potential for HWE to be operating in studies of morbidity" [196]. Thus, MSDs will often lead to work transfer to less hazardous jobs by the choice of affected employees or mandated by the employer [195].

The literature on aging suggests that older workers have greater MSD severity, longer impairment and disability, more lost workdays, and are less likely to return to work than younger workers [197]. As Winkel and Westgaard noted, many studies may fail to show age as a risk factor due to the HWE [198]. For example, in a study that compared younger and older workers and their work-related injuries, Pransky et al. did not find any age-related differences regarding functioning at work (work ability) after an injury occurred and in which the employee returned to work [199]. Along with greater job satisfaction among older workers, these authors attributed the findings to the HWE. We found no substantial differences between job satisfaction by age groups at baseline or follow-up. This may indicate findings were partially due to the HWE.

Studies have found a trend that non-fatal injury and illness prevalence among younger workers is greater than older workers [200]. In a study that examined health care workers, older workers reported a 43% prevalence of work-related pain, while their younger colleagues reported a 47% prevalence [201]. In this same study, 22% of younger workers were considering changing jobs, while 10% reported they had changed jobs because of their injury. This compared with 17% of older workers who were considering changing jobs, while

0% reported a job change. The physical and psychological exposures among health care workers are substantially greater than in the office environment; the literature shows the HWE may be more prevalent among higher exposed jobs [105]. However, the 0% job change rate among older workers might also suggest that, in general, older workers are healthier than their non-working peers. It may also indicate the older workers are more satisfied with their jobs than younger workers.

The HWE appeared to have played a protective role when we compared older workers exposed to high physical loads and musculoskeletal pain severity outcomes to all other exposure categories. Similarly, our findings may also be explained by a greater capacity among older workers to tolerate and buffer higher physical exposures to the same extent or better than younger workers [199].

## 2.2 Summary assessment of findings: inferences and implications

Overall, the inferences that can be drawn from the study are that postural exposures did not substantially vary by age groups at baseline and follow-up. The number of absolute mean reductions in non-neutral postures also did not vary by age. Although the magnitude of these absolute mean reductions were greater in younger workers, the difference was small. Hand activity/upper extremity movement in the preferred limb was greater at both time points in younger workers. Although hand activity/upper extremity movement in the non-preferred limb was greater at baseline in younger workers, hand activity/upper extremity movement in the non-preferred limb was slightly greater in older workers at follow-up.

Further, absolute change scores over the study indicated hand activity/upper extremity movement in the non-preferred limb was substantially higher in older than younger workers.

This may indicate greater compliance with the intervention among older workers. Interestingly, despite age related decrements in motor control and cognitive function in older workers, postures did not vary by age. This may indicate that not only was compliance greater in older workers, they adjusted the keyboard/mouse tray more effectively. Further, older workers appeared to have implemented the touch pad more frequently, as seen by greater hand activity/upper extremity movement in the non-preferred limb. Moreover, the latter engineering control requires much greater cognitive load and adaptability in terms of learning new office ergonomic technology and techniques. These results may suggest there was more willingness to learn new technology, and greater functional progress and neuromuscular reeducation regarding the implementation of the alternative pointing device in older workers.

Curiously, despite increased hand activity/upper extremity movement in the non-preferred limb, older workers still had less non-neutral postures in the non-preferred limb than younger workers at follow-up. This might have been due to tenting of the touch pad and effective positioning of the keyboard/mouse tray.

Additional inferences include: the direction of the joint effects between high exposure to postural loads and older age suggested an overall protective effect against the likelihood of an adverse musculoskeletal pain outcome in all but the preferred proximal upper extremity quadrant. That is, despite our small sample size, 4 out of 5 (80%) postural loads increased the likelihood of an adverse musculoskeletal pain outcome in the preferred proximal upper extremity quadrant. Interesting, a significant interaction effect was seen in this quadrant in

the modified Computer RULA non-preferred limb, possibly suggesting propagation and spread of musculoskeletal pain. Conversely, 2 of 9 (~22%) postural loads increased the likelihood of an adverse musculoskeletal pain outcome in the 3 remaining upper extremity anatomical quadrants. Both of these postural loads (2 of 5, or 40%), albeit non-significant, were located in the non-preferred proximal upper extremity quadrant.

None of the postural loads in distal quadrants showed an increased likelihood of an adverse musculoskeletal pain outcome. This may suggest the propagation and spread hypothesis involving motor control mechanisms in proximal musculature during low, physically demanding tasks may be, in part, correctly specified [83, 130, 202].

The direction of the joint effects between high exposure to hand activity/upper extremity movement and older age suggested a protective effect in the preferred proximal upper extremity quadrant for both preferred and non-preferred limbs. No clear patterns emerged with respect to interaction effects in either the upper extremity proximal quadrant of the non-preferred limb or either distal upper extremity quadrants.

For example, high hand activity/upper extremity movement in the preferred limb (in approximately 98% of cases, the right upper extremity) decreased the likelihood of an adverse musculoskeletal pain severity outcome in the distal upper extremity preferred limb quadrant. Conversely, high hand activity/upper extremity movement in the non-preferred limb increased the likelihood of an adverse musculoskeletal pain severity outcome in the distal upper extremity non-preferred limb quadrant.

The propagation and spread hypothesis may also be a viable explanation for hand activity/upper extremity movement. Specifically, high hand activity/upper extremity

movement in the preferred limb non-significantly increased the likelihood of an adverse musculoskeletal pain severity outcome in the proximal quadrant of the non-preferred limb.

The only pattern where we observed consistently fewer non-neutral postures at both time points, greater in younger than older workers was the spine and lower extremity. If older workers have compromised core stability, this might increase physical exposures in quadrants adjacent to the spine. Indeed, although most interaction terms included the null, we observed that 7 of 20 (35%) physical exposure*age interaction terms increased the likelihood of an adverse musculoskeletal outcome in proximal quadrants. Conversely, we observed that 1 of 20 (5%) physical exposure*age interaction terms increased likelihood of an adverse musculoskeletal outcome in distal quadrants. These adverse findings among product terms in proximal quadrants (despite a low sample size), when considered with propagation and spread hypotheses, may indicate the association between physical exposure and MSD severity might vary by age and anatomical quadrant. That is, older workers may be at greater risk of persistent, severe MSDs in proximal more than distal musculature.

## 2.3 Which exposure is more hazardous by age: posture or hand activity/upper extremity movement?

Based on the absolute change scores, an uncertainty arises: we found that postural exposures did not substantially vary by age over the study. Conversely, younger workers had greater hand activity/upper extremity movement in the preferred limb at both time points. Younger workers had greater hand activity/upper extremity movement than younger workers at baseline, while older workers had greater hand activity/upper extremity movement than

younger workers at follow-up. The absolute mean change scores for high hand activity/upper extremity movement in preferred and non-preferred limbs were greater in older workers.

Absolute change scores in pain severity suggested that younger workers had greater reductions in the non-preferred limb, while older workers had greater reductions in the preferred limb. An exposure-dose-response explanation is apparent, as younger workers had higher hand activity/upper extremity movement in the preferred limb at baseline and follow-up, while older workers had higher hand activity/upper extremity movement in the non-preferred limb at follow-up. However, older workers experienced the greatest absolute mean reduction of non-neutral postures in the non-preferred limb. This may be explained as follows: compared with younger workers, older workers have numerous disadvantages within their musculoskeletal system, such as loss of muscle mass and strength; restricted range of motion; more severe MSDs; poorer healing capacity; longer recovery time; more chronic illnesses that might lead to functional impairment; and lower work ability. These factors might make them more vulnerable than younger workers to illness and impairment when examining age groups with similar job demands. Moreover, this may suggest that hand activity/upper extremity movement may increase the risk of persistent MSDs more than non-neutral postures.

## 2.4 Unexpected findings

Effect modification occurs when the statistical association between a physical exposure and health outcome varies by levels of a third variable (the effect modifier). Many of our product terms were unexpected. Based on biological plausibility and patterns of

evidence, we predicted that older participants would have a greater likelihood of an adverse musculoskeletal pain outcome with respect to high physical exposure. For all interaction effects involving both posture and hand activity/upper extremity movement, we found only 8 of 20 (40%) terms demonstrated a greater likelihood of an adverse musculoskeletal outcome, and only 3 were either statistically significant or borderline statistically significant.

In addition to the HWE, another possible reason for our inconsistent findings, albeit different from Fredrick Taylor's description [203], is the concept called "soldiering." This is similar to transferring to a less exposed job, but may not include the adverse "side effects." Work slowdown or "soldiering" may have beneficial effects from a health and social standpoint: it may allow ill workers to recover and cope with their illness while remaining in their exposed job titles. Specifically, short term soldiering may allow workers to remain on the job, not have to transfer to a less exposed job title, and possibly maintain their salary if they remain employed in the same job title. Soldiering may be a short term, protective, healthy response among workers with MSDs to allow recovery. Job transfer was not an option for this cohort. It would be difficult to determine whether posture and hand activity/upper extremity movement changed prior to baseline, as we have no data to examine possible physical exposure changes. Further, it would be difficult to determine, for example, whether improvements in neutral postures in both age groups, which occurred after the intervention, were from soldiering or intervention effects.

More tenure and job experience in older workers, or reporting behaviors (younger workers tend not to report severe illnesses compared with older workers) [204] should also be considered as possible explanations for these unexpected protective relations between high physical exposure, older age, and less likelihood of an adverse musculoskeletal pain

outcome. Older workers may also have more job commitment and loyalty to work [205], or continue to work for financial reasons.

## 2.5 Despite these unexpected findings

Although age appeared to modify the likelihood of an adverse musculoskeletal pain outcome in 40% of the cohort, the protective effects against the likelihood of an adverse musculoskeletal pain outcome in 60% of the cohort was unexpected. The small sample size may have precluded us from observing statistically significant increased likelihoods of adverse musculoskeletal pain outcomes due to aging effects. However, this would not have changed the percentage of adverse musculoskeletal pain outcomes we found, only the stability of CIs. These findings notwithstanding, because of the possibility of impaired physical functioning and lost workdays in an employed aging population, and as aging begins at birth, even small non-significant adverse aging effects on the musculoskeletal system may reduce the capacity of older workers to tolerate low levels of physical work-related exposures.

Moreover, the aging literature suggests there will be a greater number of older workers employed in the 21$^{st}$ century. The implications are that both primary and secondary prevention among all age groups are required in the US if this country is to *become* relatively economically viable, with a strong middle and "working" class, as it had been in the past.

## 2.6 Past literature

In a cluster randomized office ergonomic intervention, younger workers in the intervention group had greater improvements than older workers in monitor placement, and greater reductions in non-neutral neck postures following a training intervention [87]. We found mixed results. The above study corroborates 3 out of 5 modified RULA elements we examined at follow-up. However, modified RULA preferred and non-preferred limb postures showed the opposite effect: younger workers had greater increases in non-neutral postures at follow-up than older workers. These authors also found the number of beneficial workstation component changes, such as a copy holder at the same height as the monitor, was greater for younger workers in both intervention and control groups compared with older workers [87]. Conversely, while posture did not substantially vary by age, hand activity/upper extremity movement in our study increased at follow-up in the non-preferred limb in older workers, suggesting that for at least 1 workstation component – touch pad use – greater change was seen in older workers.

These same authors found the prevalence of MSD symptoms decreased in younger workers in both intervention and control groups at follow-up [87]. Once again, we found mixed results. There were greater decreases in absolute change scores in the proportion of $\geq$ uncomfortable pain from baseline to follow-up in older workers in proximal and distal preferred limbs. The opposite effect was observed for proximal and distal non-preferred limbs: there were greater increases in absolute change scores from baseline to follow-up in the proportion of $\geq$ uncomfortable pain in older workers. An explanation for the former finding may be absolute mean change improvements in neutral postures in 4 of 5 RULA

elements and less hand activity/upper extremity movement in the preferred limb in older workers. The former finding may be due to proper keyboard/mouse tray adjustment over the study in older workers; the latter finding may be due to increased hand activity/upper extremity movement in the non-preferred limb over the study in older workers.

These authors also found that time from onset of symptoms for younger workers was less than for older workers in both intervention and control groups [87]. These findings were similar to our results in that older workers presented with greater MSD chronicity. Duration on the computer has been associated with incident and prevalent MSDs [206]. Researchers in the above study reported the proportion of workers who spent >25 hours per week working on the computer was higher for younger than older workers [87]; we found similar results at both time points for keyboard and pointing device use. However, although younger workers spent more time on these devices than older workers, there were greater absolute reductions from baseline to follow-up in $\geq$ uncomfortable pain in proximal and distal non-preferred limbs in the younger age group. This may suggest that less chronic conditions appear more reversible, or that younger workers may have a greater capacity of MSD recovery.

These authors noted that possible explanations for their findings included: younger workers may be more inclined to make workstation changes because they spent more time on the computer; because younger workers worked in their jobs for shorter periods of time, their work habits may have been more modifiable; since the onset of MSDs was shorter in the younger workers, their MSDs may have been more reversible than more chronic conditions; younger workers may have a higher capacity of MSD recovery, or the recovery period may be shorter; younger workers had a greater prevalence of MSDs at baseline, which may indicate there's greater opportunity for a reduction of MSDs [87].

Montreuil and colleagues examined exposure profiles (workstation characteristics and work content) prior to ergonomic training 1) to report whether postural exposures were observed; 2) to estimate the association between a reduction of postural exposures following training and musculoskeletal pain; and 3) to assess the relation between reduction of postural exposures and types of changes made following training [207]. The cohort was divided into 4 classes. Class I had the highest proportion of younger workers (<40 years old), had the most adjustable equipment, and made workstation adjustments 33% of the time. Class II had one of the highest proportions of older workers (≥40 years old), had some adjustable equipment, and made about 17% of adjustments to their workstations and equipment. Class III also had one of the highest proportions of older workers, had very little adjustable equipment, and changed their postural exposures by purchasing new equipment. Similarly, almost all of Class IV workers were over 36 years old, had very little adjustable equipment, and made workstation adjustments 13% of the time or purchased new equipment. The authors reported the majority of workers over 40 were in Class IV; conversely, the majority of workers in Class I were under 40, had the most adjustable equipment, and made the highest proportion of adjustments to their equipment. Montreuil et al. concluded, which was corroborated by previous research from one of the contributing authors [208], that workers over 40 seemed to be provided with more older equipment than younger workers and, subsequently, were unable to make workstation adjustments. They also noted that Class III and IV (the majority of workers were over 40) equipment was less adjustable than the other classes and conjectured that old equipment appeared to be given to older workers.

Given the same amount of training and adjustable equipment, our data suggested that older workers made similar adjustments to, or used alternative equipment more than younger

workers following the intervention. This can be inferred by the lack of variation in non-neutral postures by age groups, despite older workers having greater disadvantages in their musculoskeletal system (such as greater loss of muscle mass and motor control than younger workers), and increased hand activity/upper extremity movement in the non-preferred limb at follow-up.

Garg reported that declines in the physical capacities of older workers can be accommodated by improved workstation design, thereby improving employment opportunities, particularly where computer work was performed [23]. In a quasi-experimental study, May et al. examined whether the association between workstation design and employee reactions to these designs varied by age [209]. May and coworkers hypothesized that training and ergonomic improvements were expected to benefit younger workers more than older workers due to better musculoskeletal recovery and more adaptable work styles. Based on past research [210, 211], May and coworkers also hypothesized that older individuals tended not to modify consolidated perceptions even when information was available and accessible. This hypothesis was consistent with a model developed by Tyler and Schuller called the "impressionable years" model [211], which stated perceptions and attitudes remained relatively stable after an initial impressionable induction period. Moreover, relatively greater susceptibility to change existed among the young, until early adulthood, after which susceptibility decreased; in addition, the model stated that attitudes grow more stable with age.

Based on this model, May and coworkers hypothesized that ergonomic improvements were more likely to affect younger than older workers' health and views. Younger workers were more likely to perceive positive ergonomic qualities in their workstation than older

workers who received the same improvements. May and colleagues also hypothesized that attitudes and satisfaction with their ergonomic improvements would be greater in younger than older workers.

The results of the May et al. study are listed below. The interaction between high physical exposure*older worker on an adverse upper back and upper extremity pain outcome was not significant compared with reference groups. We found inconsistent results when we examined high physical exposure*older worker with reference groups. Specifically, we found that for high postural loads, there was a significantly greater likelihood of an adverse musculoskeletal pain outcome in 2 out of 14 interaction terms (~14%) in older workers; for increased hand activity/upper extremity movement, there was a borderline significantly greater likelihood of an adverse musculoskeletal pain outcome in 1 out of 6 interaction terms (~17%) in older workers.

May et al. found the interaction effect between workstation design*age on perceived ergonomic qualities at their workstation was significant (younger workers perceived they had better ergonomic qualities at their workstations than older workers), while the association between workstation design*age on satisfaction was not significant. Although we did not measure workers' perceptions on ergonomic qualities of their workstation design, we found no significant association between younger and older workers regarding job satisfaction at either baseline or follow-up.

Taking the "impressionable years" model into account, May et al. concluded older workers' perceptions may have been less affected by ergonomic improvements (improved workstation design). With respect to the interaction workstation design*age on satisfaction, the authors speculated that older workers may value other aspects of a job more than

workstation design and improvement, such as job security and benefits, or a threshold of "attitude change" may exist that was not breached in this study. Regarding the interaction high physical exposure*older age on pain, the authors conjectured that ergonomic improvements may not have been adequately effective, not enough time had passed from intervention to follow-up (4 months), or younger workers may have responded more positively to workstation design and older workers to training, canceling out any age-related effects on pain.

In an office ergonomic intervention study among newspaper employees, Cole et al. found that for every 10 year increase in age from baseline to a 5 year follow-up, there was an increase in pain severity, albeit effects were small [212]. Adverse preexisting health status at baseline was an important predictor for worse health status at follow-up. Our results showed that preexisting comorbidity was similar between age groups at both time points. Our results disagreed with Cole et al. regarding pain severity. While older workers had substantially greater pain in both distal limbs at follow-up, younger workers had substantially greater pain severity in the proximal preferred limb at follow-up.

Werner and colleagues examined existing elbow tendinopathy among automobile manufacturing workers [213]. They noted that after an illness, age can influence recovery. These authors hypothesized that older workers would less likely recover from their MSD than younger workers. In their study, a seniority system existed at the plant that allowed workers with more seniority to request jobs that they perceived as less physically stressful. Despite this seniority system, Werner et al. found that older workers with jobs associated with greater exposure to non-neutral and repetitive distal upper extremity postures were less likely to recover from their elbow tendinopathy. Our findings were inconsistent. Older

workers who were exposed to more non-neutral postures and hand activity/upper extremity movement were only ~43% and ~33% more likely to experience an adverse musculoskeletal pain outcome, respectively.

In our study, the older age group had over 41% more MSD chronicity that lasted ≥3 years than younger workers. Madeleine [122] noted that in chronic clinical pain conditions, as in our study, "hyperactivity hypotheses" may partly explain the pathomechanism of chronic, persistent MSDs [83]. Specifically, over time, group III and IV afferents activate the gamma system, increasing hyperactivity within the musculoskeletal system, which may then lead to the propagation of pain through a positive feedback loop. High physical or psychosocial exposure may exacerbate this pathomechanism. Our findings had mixed results regarding the hyperactivity hypotheses literature. Although over 56% of older workers experienced pain for ≥3 years, the interaction term high physical exposure*older age showed that ~40% of these joint effects increased the likelihood of an adverse musculoskeletal pain outcome in all upper extremity quadrants.

Our results disagreed with the literature on aging workers and the design process, which suggested that age-related change involved reductions in hand strength, dexterity, precision, coordination, joint mobility, and sensitivity, and a concomitant reduction in upper extremity function [214]. Hand activity/upper extremity movement increased in the non-preferred limb at follow-up in older workers substantially more than in younger workers. The use of the touch pad in the non-preferred limb and keyboard shortcuts required high degrees on dexterity, precision, coordination, joint mobility, sensitivity and function.

In the applied physiology literature, Enoka and coworkers found that functional fluctuations existed in the motor output between younger and older study participants

performing goal-directed and precision tasks. These differences increased with advancing age: there was a greater deterioration of motor output with increased age [215]. Enoka also reported that older adults use a greater amount of muscle co-activation to complete an activity, and that motor contractions in older individuals involved more than the requisite number of muscle groups needed to accomplish a task [107]. Larsson et al. reported that age-related changes in skeletal muscle may be the result of a combination of loss of contractile tissue related to fiber atrophy, a decreased ability to generate adequate force via cross-bridge formation between actin and myosin filaments, and an altered coordination and disorganization of contractile properties at the motor unit level [216]. The authors concluded these factors seemed to have a strong impact on age-related impairment in muscle function.

In the movement science literature, Galley and Forster noted learning new motor patterns and movements are based, in part, on past training [217]. Coury reported that several factors may inhibit learning, such as difficulties involved in changing established movement patterns [218]. In an intervention study among assembly workers that examined inexperienced workers (just hired) and experienced workers (more than 1 year on the job), Parenmark et al. found that although experienced workers received the same instruction and needed less training time, it was easier to train newer workers than retrain experienced workers in order to maintain lower levels of upper back muscular activity when performing work tasks [219]. These authors concluded that in addition to ergonomically designed workstations, training and modification of movement patterns are required, with the caveat that it is more difficult to change established working techniques.

Our intervention comprised engineering controls; however, without training, active participation, motivation, and learning, the effectiveness of these controls would be

remarkably limited in both age groups [220]. A possible explanation for the lack of differences in absolute mean postural exposures between age groups, despite numerous functional and cognitive disadvantages that may be experienced by older workers, might be that older workers were more willing to learn. This may have led to more effective use of the keyboard/mouse tray and symmetrical use (both right and left upper extremities) of both pointing devices than younger workers, resulting in similar absolute reductions in non-neutral postures in 4 of 5 anatomical regions and greater absolute increases hand activity/upper extremity movement in the non-preferred limb. Regarding the former explanation, because of limited financial resources and time constraints, we did not measure whether older workers actually made effective keyboard tray adjustments more often than younger workers during each week over the study period. Thus, this explanation is tentative.

Most interestingly, however, was that while hand activity/upper extremity movement in the non-preferred limb increased in older workers following the intervention, this group had greater absolute reductions in non-neutral postures in the non-preferred limb than younger workers. That is, older workers were still able to maintain neutral postures in their non-preferred limb despite increased hand activity/upper extremity movement in their non-preferred limb. This finding was unexpected, as the literature reported that older workers have impaired steadiness [18]; a decline in the ability to perform precision tasks [109]; use a greater amount of muscle co-activation to complete an activity with an attendant increase in joint perturbation [107]; and disorganized muscle contractions [18]. This might be explained by the HWE, work experience, use of compensatory mechanisms, or lower proportions of job strain in the high strain quadrant category at both baseline and follow-up. The latter implying

older workers may have higher control and lower demand within their work environment, which affords them more time and opportunity for learning novel equipment and techniques.

One of the most important results from our study disagreed with much of the literature. For example, Coury reported the factors that may inhibit learning include difficulties involved in changing established movement patterns, and that this may explain why older workers may not learn as well as younger workers when faced with novel situations [218]. In addition to a past study described, other research showed decrements in the ability for older adults to learn new motor patterns and movements, although the findings vary between laboratory and field research [219, 221].

In a review on aging and training [221], the researchers found that older adults had less mastery of the training content than younger adults, and required more time to cover training material. In this review, however, age categories varied considerably among studies. The authors did not seem to explicitly define dichotomous age categories or comparisons between different age groups. Other ageist models include: the "general slowing model" [222] suggests that older adults would be slower in acquiring new skills; the "limitations in working memory" model [223] suggests that older adults would have difficulty learning new information when "effortful processing" was required; the "reduced inhibition-attention" model [224] suggests that older adults would be "differentially penalized" when managing more complex material.

However, field research refutes much of the laboratory findings [221]. Unlike many of the aforementioned laboratory findings, research in the field showed that older workers can exhibit stable job performance when they rely on behaviors already acquired [221], or that they can maintain competence on the job through the development of compensatory

mechanisms and expertise [225]. Since hand activity/upper extremity movement increased in the non-preferred limb in older workers, this may imply that older workers were more easily trained, acquired new skills, managed complex functions, changed their established movement patterns to a greater extent than younger workers, and used compensatory mechanisms and expertise. It appears that our study corroborates results on aging effects found in the field.

These findings notwithstanding, wouldn't pain be a potent motivator in both age groups to reduce non-neutral postures and hand activity/upper extremity movement in the preferred limb, and increase hand activity/upper extremity movement in the non-preferred limb, if an exposure-dose-response relation existed in the preferred limb, as reported in past literature [226]? This may be explained as follows: among both age groups there were larger percentages of ≤mild pain than ≥uncomfortable pain in both proximal and distal quadrants at baseline and follow-up; larger proportions of severe musculoskeletal pain may have led to different results.

## 3.0 Sub-study: Magnitude and frequency of postural movements

The specific aim of the study was to assess whether symptomatic workers change their magnitude and frequency of postural movements over the day in the spine, and preferred and non-preferred limbs in workers performing identical morning and afternoon tasks at baseline and follow-up.

## 3.1 Interactive communication and word processing tasks

**Hypothesis 1** predicted for identical tasks performed over the day, symptomatic workers would have greater magnitude and less frequency of postural movement in the afternoon. We found greater magnitude and less frequency of postural movements in the afternoon in 6 of 7 RULA measurements. The preferred and non-preferred limbs showed less frequent upper extremity movement in the afternoon.

Our hypothesis correctly predicted that an increase in the magnitude of postural movements would occur in the afternoon and there would be less frequent upper extremity movement in preferred and non-preferred limbs.

**Hypothesis 2** predicted for identical tasks performed over the day, workers with MSD chronicity $\geq 1$ year would have a greater magnitude of postural movements and less frequent upper extremity movements in the afternoon than workers with MSD chronicity $\leq 1$ year. We found a greater magnitude of postural movement workers with MSD chronicity in the afternoon by dichotomized RULA elements. Conversely, for the Upper Body RULA and frequency of postural movements, we found a greater magnitude of postural movements and less frequent upper extremity movements in the afternoon among workers with less chronicity.

Our hypothesis correctly predicted there would be a greater magnitude of postural movements in workers with longer pain chronicity in RULA posture elements in the afternoon. Our hypothesis – workers with longer MSD chronicity would have a greater magnitude of postural movements in the Upper Body RULA and less upper extremity movement in preferred and non-preferred limbs in the afternoon – was incorrect.

**Hypothesis 3** predicted for identical tasks performed over the day, workers with > MSD severity would have a greater magnitude and less frequent upper extremity movement of postural movements in the afternoon than workers with < MSD severity. We found a greater magnitude of postural movements in workers with low symptom severity in the afternoon by individual RULA elements. Conversely, when we examined the magnitude of postural movements as a continuous measure, workers with low symptom severity had a greater magnitude of postural movements than workers with high symptom severity in the afternoon. Likewise, workers with low symptom severity had less frequent upper extremity postural movements in the afternoon than workers with high symptom severity.

Our hypothesis incorrectly predicted there would be a greater magnitude of postural movements in workers with high symptom severity in RULA posture elements in the afternoon. However, we correctly predicted there would be a greater magnitude and lower frequency of postural movements among more symptomatic workers in the afternoon.

**Hypothesis 4** predicted for identical tasks performed over the day, workers ≥44 years old would have a greater magnitude and less upper extremity movement in the afternoon than workers <44 years old. We found that older workers had a greater magnitude of postural movements in the afternoon by dichotomized RULA element. Conversely, we found that for the continuous Upper Body RULA, younger workers had a greater magnitude of postural movements in the afternoon. For frequency of postural movements, we found that older workers had a slightly lower frequency of postural movements in the afternoon than younger workers in the preferred limb.

## 3.2 Why findings did not consistently agree with hypotheses?

From a biological perspective, several studies suggested that increased joint perturbation, possibly associated with impaired motor control and proprioception [21, 83, 227], may occur if fatigue appears, and if pain develops or increases over the workday; this occurs more frequently among symptomatic workers. One possible explanation that higher physical exposures resulted in lower magnitude of postural movements in the afternoon was that the tasks used in this study, based on the findings from individual, RULA elements and the continuous Upper Body RULA, were less physically demanding than other computer tasks, such as computer aided design [42, 228]. This would most likely lead to less fatigue and pain in that region than a more physically demanding task, with a concomitant lower magnitude of postural movement in the afternoon. Interestingly, the 2 anatomical regions in which an increased magnitude of postural movements was seen in the afternoon were the spine and preferred limb, upper arm regions. This may indicate that fatigue and pain were highest in these regions and increased over the day. Indeed, the upper spine and proximal quadrant in the preferred limb is usually exposed to both static and dynamic loading, while the distal quadrant is usually exposed primarily to dynamic loading because of mouse use in the preferred limb. This may have increased cumulative physical exposure, leading to greater joint perturbation in these regions in the afternoon. Researchers examining posture among word processors found that compared with the non-preferred limb, the preferred limb demonstrated greater magnitudes of non-neutral shoulder flexion, abduction, and external rotation, and wrist ulnar deviation [76].

Another possible explanation for the unexpected findings in the magnitude of postural movements was the healthy worker effect (HWE). Self-selection via job transfer based on health status would distort any exposure-dose-response relation. Moreover, when there is compelling evidence that the physical exposures under study are suspected to be hazardous, the lack of adverse health effects among the higher exposed group can provide indirect evidence of the HWE. Likewise, indirect evidence of the HWE due to transfer bias can be seen when employees with more exposure demonstrate better health outcomes than less exposed workers [196]. When we examined symptom severity, a greater magnitude in Upper Body RULA posture and less upper extremity movement in preferred and non-preferred limbs were greater among (or in some cases, equal to) workers with less symptom severity in the afternoon.

Another possible explanation for the inconsistent results in our hypotheses for both tasks was low statistical power. That is, was the sample size large enough to have a reasonable probability of detecting and estimating an effect if one existed [195]? For example, when examining RULA elements, many of our cells had less than 5 observations per cell. An additional explanation may have been that pain levels were low. Higher pain levels may have resulted in greater alterations in motor patterns with respect to both the magnitude and frequency of postural movement.

The inconsistencies between individual, RULA element findings, and Upper Body RULA may also be explained by biomechanical linkages and myofascial connections. That is, RULA elements examined individual regions, while both the Upper Body RULA and upper extremity movement examined composite regions. Researchers have noted that upper extremity and trunk movement, both static and dynamic, are dependent on each other [14,

229, 230]. Likewise, Laville and Dutia reported the need for proximal stabilization of the trunk and upper extremity quadrants during precision, dynamic hand work and the need for trunk and cervical stabilization while reading a monitor [231, 232]. Thus, the discrepancy between tasks and our hypotheses by posture and movement might be explained by variation when examining 1 anatomical region versus multiple, linked anatomical regions.

## 3.3 Inferences and implications

The findings suggested that workers with musculoskeletal pain, in general, had greater magnitudes in RULA elements in the afternoon. Conversely, although workers with musculoskeletal pain showed greater magnitudes and less upper extremity movement in the afternoon, in general, there were greater change scores in the Upper Body RULA and hand activity among workers.

Different tasks and exposure assessment by individual anatomical regions and summative anatomical regions led to different results for posture and movement in the afternoon. That is, exposure assessment of single regions and summative regions led to differences in proportions of risk for physical exposure. Moreover, posture and movement varied over the day and between baseline and follow-up.

This implies 1 observation over the workday may not provide a valid estimate for physical exposures associated with computer work among symptomatic workers. This is particularly interesting, as computer work is usually associated with lower posture and movement variability than manufacturing work. Moreover, 1 postural measurement may not be adequate for symptomatic workers, as the literature suggested that these workers have

greater posture and movement variability than asymptomatic workers. Further, as Hale and colleagues noted, for computer operators, measurement error might be introduced when measuring posture in workers at only 1 point in time over a working day [161]. A similar concept can be applied to hand activity levels across the day.

Rather, work sampling or time and motion studies appear to be more informative and valid, albeit at greater cost and time. Work-sampling techniques collect data at intervals of time. For example, data might be collected by determining a worker's posture 2 times each hour. Data are collected by observing the worker at a point in time (an interval). Interval observations can be of fixed duration or can occur at randomly chosen times. Another work sampling approach uses worker self-reported logs. In either situation, an inference is usually made about the proportion of overall work time spent on an activity or task, based on the percent of observations with respect to that activity or task [236].

Time-and-motion techniques use an observer to record how much time a worker spends on each activity or task. This is a more labor-intensive method of data collection, as it requires one-on-one observation. The observer usually follows the subject continuously for extended periods of time. Each activity and its duration is recorded on a data collection instrument [236].

Another study implication is that different work practice and engineering controls may be required over the workday for symptomatic workers since posture and movement exposures might adversely vary over the day. Symptomatic office workers should be provided with a flexible work environment to promote healthy posture and movement variability. For example, flexible work-rest periods, job enlargement, part-time employment, choices of engineering controls, including speech recognition and sit-stand workstations, and

allowances for ill employees to seek off-site medical care to maintain health, function, and quality of work.

## 3.4 Past literature on altered motor patterns and the magnitude of postural movements

Our results showed inconsistent patterns over the day and at baseline and follow-up for individual, modified RULA elements and modified Grand RULA posture. Other studies have found relations between constrained, static postures, fatigue, pain, and increased joint perturbations, although few have examined these factors and outcomes among workers over a workday. In an animal model, Byl and coworkers reported that neurophysiological mechanisms may lead to the loss of sensory differentiation in an overused upper extremity with attendant altered motor patterns and changes in posture [237].

The "Neuromotor Noise Model" of motor control stated that motor performance is the optimized outcome of oscillatory recruitment signals to particular muscles performing a task; this neuromotor signal controlling motor output may be noisier when workers are engaged in mentally challenging tasks involving precision [238]. The model also stated that posture variability is related to the capacity of the motor control system to manage the signal to noise ratio. The model assumed that disturbed sensory information processing will lead to more variable and uncertain motor pattern strategies (greater joint perturbation); pain and fatigue can further affect sensory processing [237].

Based on this model, Bloemsaat et al. conducted a study involving a computer task among symptomatic and asymptomatic participants that examined limb stiffness with respect

to motor control. The authors hypothesized that increased limb stiffness, due to co-contractions of agonist and antagonist proximal stabilizing muscles in precision tasks would be greater in the symptomatic group. Although the authors reported this may be a mechanically effective method of endpoint accuracy, the increased limb stiffness can result in increased musculoskeletal proximal loading and higher muscle energy; moreover, continuing postural movements during increased limb stiffness was hypothesized to be an inefficient motor strategy that may lead to or exacerbate MSDs [239].

Bloemsaat and colleagues found that the symptomatic group had more resistance and difficultly initiating postural movements and more abrupt increases in limb stiffness during movement; altered sensory information processing may explain these results [239]. That is, unable to perform precise movements, the symptomatic group adopted a different motor pattern strategy to allow them to complete the task. Indeed, Byl and colleagues noted a positive relation between changes in processing and awareness of sensory information and patients with MSDs [240].

Similarly, Fallentin et al. [241] found that sustained static muscle loading in the proximal musculature, often seen among computer workers, may lead to fatigue, and tactile and proprioceptive abnormalities. Interestingly, Bloemsaat et al. concluded that while inefficient postural movement strategies may be responsible for the onset of fatigue and pain, other mechanisms – most likely central or peripheral neurophysiological pathways – may lead to the persistence of pain and concomitant inefficient postural movement strategies after prolonged physical exposure has ceased [239].

In a review examining task-related biomechanical constraints and MSDs, van Dieen et al. reported that 1 important constraint is related to stability: the ability of the proximal and

distal upper extremity to return to their original postural trajectories after a joint perturbation following a task. In a very constrained task, such as computer work, these authors hypothesized that sustained recruitment of motor units occur, and the attendant, sustained, constrained tasks can lead to fatigue, disturbances in local homeostasis, and impaired proprioception [137].

In an experimental study that examined constrained postural motions of the elbow joint during voluntary, active flexion and extension movements, healthy subjects demonstrated perturbed postural trajectories and positional disturbances during dynamic movements of up to 23 degrees of elbow range of motion [242]. These authors concluded that reaction forces during keyboard work may lead to substantial joint perturbations in upper extremity positions. That is, to use the next key correctly, perturbations with substantial magnitudes must be quickly corrected. Muscle stiffness provides instantaneous corrections, reducing perturbation effects on kinematics. Muscle stiffness can be achieved through increased co-activation of static postures between agonists and antagonists; this prevents large positional disturbances. However, these co-contractions between agonist and antagonist muscle groups lead to decreased accuracy in information transmitted by primary muscle spindle sensory afferents in agonists and antagonists. This results in fatigue and concomitant adverse effects on proprioception and kinesthesia in proximal stabilizing musculature [243, 244].

Increased precision demands also increase fatigue. Co-activation of agonists and antagonists can accelerate fatigue, which in turn may require more co-activation to maintain precision. If proprioception deteriorates during sustained static loading, as van Dieen and coworkers have suggested, precision will likely be affected. Less precise control can lead to

more frequent and larger perturbations. To manage these larger perturbations, increased co-activation in proximal musculature is required. A positive feedback loop may be increased during mentally demanding tasks [137].

Revel and coworkers examined participants with neck pain and asymptomatic controls during activities that required substantial postural movements. The symptomatic group had reduced proprioception and disturbed motor control in the cervical spine [245]. In a review of animal model studies, de Jong and Bles reported when proprioception was impaired in the cervical spine, substantial disruptions in motor coordination resulted [246]. (The distribution of muscle spindle sensory afferents is not uniform: there are more spindle sensory afferents in proximal joints and decrease in distal joints [247].) Interestingly, more participants in our study had greater pain in proximal than distal quadrants. This might provide an explanation for why, in general, greater joint perturbation in overall modified RULA postures, and modified RULA postures by age, length of MSD onset, severity, and job strain was seen more in proximal musculature at baseline and follow-up for both tasks.

Bergenheim suggested that pain leads to altered proprioception, and that primary muscle spindle afferents play an important role in motor control and proprioception [248]. During dynamic, repetitive work, primary muscle spindle afferents are hypothesized to be activated. These leads to reflex-mediated muscle stiffness via the gamma muscle spindle system, increases in muscle metabolites, alterations of primary muscle spindle afferent activity, changes in motor control and proprioception, and inefficient work techniques. The increased level of muscle metabolites can also excite the sympathetic nervous system, which can alter blood flow and disrupt the elimination of muscle metabolites from working muscles.

Muscle fatigue can also affect the capacity of the primary muscle spindle afferents to transmit correct kinesthetic information. Decreased accuracy of the information transmitted by primary muscle spindle afferents due to fatigue in ipsilateral muscles effects kinesthesia [248]. Since kinesthestic feedback is important for optimal motor control, Bergenheim suggested that neural capacity for motor control is affected by fatigue [248].

Pedersen et al. investigated muscle fatigue in shoulder muscles and found fatigue reduces proprioceptive acuity in the shoulder. Specifically, Pedersen et al. found, albeit at dynamic maximum voluntary contractions, a reduced ability to distinguish between speeds of movement in the dominant shoulder following muscle fatigue [244]. Similarly, Taimela et al. found that detection of lateral trunk rotation was diminished after fatiguing the lumbar musculature [249]. In a study that examined shoulder proprioception acuity following repetitive, low intensity work to fatigue in a light industrial assembly task involving constrained movements, investigators found an increase in shoulder repositioning error [250]. This can lead to decreased precision during motor performance. Bergenheim further noted there is a decrease in postural sense acuity during muscle fatigue, which has implications for precision of motor performance and greater risk of MSDs [248]. Moreover, the reduction in postural sense acuity by either muscle fatigue or muscle pain will lead to impairment in motor performance, leading to increased co-activation of proximal stabilizing musculature, increasing the load of working muscles.

Passatore and Roatta reported that the sympathetic nervous system is involved in skeletomotor function, muscle fatigue, modulation of proprioceptive information from muscle spindle receptors, and may modify conductive properties of afferent nerve fibers, thus further modulating sensory information [251]. As described above, muscle spindles are used

for moment to moment reflex control of motor learning, ongoing postural movement control, and the planning of voluntary movements. The sympathetic nervous system functions to reduce stretch sensitivity of muscle spindles and depress muscle spindle length in slow, fine movements, which can affect motor stability and precision of fine movements and lead to inefficient muscle patterns. Although this may promote alternative movement strategies for improving precision, it may lead to co-contraction of agonists and antagonists and is also costly from an energetic viewpoint.

## 3.5 Past literature on altered motor patterns and the frequency of postural movements

Our results also showed inconsistent patterns over the day and at baseline and follow-up for upper extremity movement in preferred and non-preferred limbs. A few studies have found relations between constrained, static postures, fatigue, pain, and reductions in distal upper extremity movement [21], although hypotheses of pathomechanisms regarding impaired motor patterns, movement, and pain vary among studies. Conversely, other studies have found relations between constrained, static postures, fatigue, pain, and increased distal upper extremity movement [144]. However, few studies have examined these factors and outcomes over the working day, which make comparisons with our study problematic.

In a review of the effects of physical exposures on proprioception, Djupsjobacka noted sensory information from muscle spindle afferents can be decreased from muscle pain and work-related physical exposures, which result in activation of muscle chemoreceptors and nociceptors [119]. These findings may impair kinesthesia and lead to derangement of

motor function. Djupsjobacka also observed that chemo- and noci-sensitive muscle afferents can be stimulated by muscle metabolites, inflammation, and ischemia, and suggested that patients with neck and shoulder MSDs may show disturbances in coordination and speed of movement [119].

In an animal model, Barbe and colleagues found that prolonged, low physical repetitive reaching tasks led to an inflammatory response that was hypothesized to activate chemosensitive muscle afferents. These muscle chemoreceptors and nociceptor afferents may substantially influence muscle spindle sensitivity. Reductions in movement speed and precision in the forelimb that performed the raking and scooping tasks were reduced over the study [84].

In a laboratory study involving experimentally induced pain, Pedersen et al. found that injections of bradykinin in proximal musculature adversely affected muscle spindle activity throughout the region, bilaterally, even though injections were only given to 1 proximal upper extremity quadrant [252]. Djupsjobacka hypothesized that a decrease in quality of muscle spindle afferent inflow (sensory data going into the central nervous system) may lead to imprecise motor control and reduction of speed of movement, particularly for multi-joint movements, such as shoulder muscles. A compensatory mechanism might then lead to increased muscle co-activation, reduced muscle relaxation periods, and fatigue [119]. A positive feedback loop may appear, leading to additional imprecise motor control and alteration in speed of movement.

In addition to muscle spindle afferents affecting perception of movement of the body segments relative to each other, they are responsible for direct feedback of movements and recalibration for shaping motor commands. Reaching movements in novel dynamic

conditions primarily depend on proprioceptive afferent information [119]. Ghez and Sainburg showed that functionally de-afferented patients (i.e., patients suffering from loss of thick myelinated primary afferents, which can been seen in median and ulnar mononeuropathies) demonstrated deranged motor control in multi-joints of the upper extremity with attendant reduced movements during novel dynamic tasks [253].

Low back studies showed that symptomatic patients have different motor patterns compared with healthy controls during test conditions. Marris et al. [254] examined trunk range of motion, velocity, and acceleration between healthy participants and patients with low back pain. The researchers observed decreased trunk velocity and acceleration among all subjects as the experiment became more asymmetric. Compared with the healthy group, trunk velocity and acceleration were significantly reduced in low back pain patients. These authors also reported that low back pain patients, compared with healthy controls, performed slower trunk movements.

Conversely, Vollestad and Roe noted that altered muscle performance and movement patterns only affect some workers with clinical pain, but not others. Moreover, at the individual level, these responses have not been closely associated with pain. These authors concluded that large physical exposure variations in tasks and between-worker variation make results difficult to interpret [255].

Szeto et al. [256] reported the mounting of evidence of altered muscle activation patterns in symptomatic computer workers. These researchers found trends of increased upper extremity movement in symptomatic participants compared with controls with respect to typing speed. Interestingly, this did not vary over the day. The researchers suggested the greater variability in muscle movements found in their study may actually represent less

efficient motor control strategies, and highlighted that the greater upper extremity variation in muscle movement in their study involved tasks lighter forces [139]. These findings disagree with our results; we observed less upper extremity movement variability over the day in tasks involving low loading forces.

Likewise, Madeleine et al. observed joint and muscle stiffness and less movement variation in symptomatic participants during tasks, although these tasks involved substantially higher loading forces (meat cutting tasks) [21]. Madeleine and co-workers also found that subjects with clinical pain demonstrated a decreased working rhythm [131].

The importance of motor variability, in general, was supported by Madeleine and colleagues' field studies in "real" work environments, as changes in task timing and movement kinematics were related to painful upper extremity conditions [21]. That is, Madeleine found size of movement kinematic variability decreased in the region of discomfort. The prognostic hypothesis of an increased risk of MSDs related to reduced movement variability was also supported by these same field studies: motor variability was higher in experienced, healthy butchers.

Szeto et al. hypothesized that greater or lesser forms of motor variation may be an adaptive response to MSDs, and that different altered movement strategies may be seen in different individuals performing different types of tasks. Nonetheless, these authors concluded that MSDs are associated with higher muscle activity levels and greater movement in computer work [256]. Moreover, this was consistent with their "Altered Motor Control Model", which was based on altered kinematics and muscle recruitment [139]. Interestingly, they concluded that movement patterns in symptomatic subjects were not influenced by current task discomfort or pain, but rather were pre-programmed.

Graven-Nielsen et al. noted that clinical pain affects muscle performance and movement patterns during dynamic work [121]. These authors stated that muscle pain was related to changes in movement coordination during dynamic tasks [257]. In an experimental study involving experimentally induced muscle pain, Graven-Nielsen et al. found decreased movement in agonist muscles, and hypothesized this decreased activity in the painful muscle may be a functional adaptation of motor coordination to limit movements [257].

Similarly, the "Pain Adaptation Model" predicted a reduction in movement frequency in painful muscles [258, 259]. Proposed by Lund et al. to account for clinical findings on muscle activity in pain syndromes, the model hypothesized that reduced agonist muscle activity and a concomitant increase in antagonist muscle activity lead to reduced changes in magnitude and velocity of movement of the affected upper extremity [259].

To explain these changes in the motor patterns, Lund et al. proposed a hard-wired neuro-physiological model based on modulation of excitatory and inhibitory interneurons. The model hypothesized that through brainstem or spinal cord motor circuits (involving reflexive, lower central nervous system pathways), pain leads to alterations in muscle activity that limit motion. The effect of these changes was to limit movement excursions and make movements slower and smaller to reduce the chance of aggravating the injury, and promote healing. Thus, the model speculated that pain-adaptation was protective and not the cause of pain.

Graven-Nielsen and coworkers predicted the Pain Adaptation Model in their experimental laboratory study [257]. Pain induced in the human gastrocnemius muscle was found to decrease movement of this muscle during gait, while increase movement in the

antagonist, tibialis anterior muscle. The reverse was found when pain was induced in the tibialis anterior muscle.

The Pain Adaptation Model also seemed to concur with a review on pathomechanisms of craniofacial muscle pain [260]. Svensson and Graven-Nielsen reported that during mastication following experimentally induced pain, magnitude and velocity of jaw movements were reduced [260]. They noted that reflex circuits in the brain stem seemed important for the adjustment of sensorimotor function in the presence of craniofacial pain. They concluded that changes in somatosensory and motor function may therefore be the consequences of pain and not etiological factors of pain. Likewise, Schaible and Grubb observed by electromyography that agonist muscle activity was reduced during oral surgery, resulting in smaller and slower jaw movements [261].

However, in a review that examined trunk activation in low back pain patients, van Dieen and colleagues concluded that trunk muscle recruitment did not fit the Pain Adaptation Model [262]. Rather, disturbances of motor control often lead to activation patterns that were not likely to be adaptive, that changes in activation patterns were task-dependent, related to a specific MSD (ligamentous versus disc), and highly variable between and within individuals (as opposed to the hard-wired neural pathway as the pain-adaptation model suggested). These authors proposed that changes in trunk muscle recruitment in patients were functional rather than reflexive, as they reduced the probability of deleterious tissue doses by reducing movement magnitude and frequency and providing stabilization of the spine. To that end, these authors purposed an alternative (unnamed) model in which motor control changes in patients were functional to enhance spinal stability.

Similarly, in an experimental study that examined the effects of mandibular pain and muscle pain on masticatory motor behavior, researchers did not consistently observe that experimental or clinical pain on jaw muscles decreased electromyography activity in agonist muscles or increased in antagonist muscles relative to control (pain free) participants [263].

Peck and coworkers found similar results: in an experimental study in which pain was induced in the masseter muscle of humans, results were inconsistent; they concluded it was not possible to attribute a uniform effect of pain on motor activity in agonist or antagonist muscle groups during movement [264]. These authors also noted that although pain and limitation of movement are 2 symptoms of MSDs, it remained unclear how both affected each other [264]. (Temporal effects also remain unclear, as many of these studies involved only symptomatic participants or participants with experimentally induced pain. Thus, does fatigue and pain lead to an alteration of motor patterns, or do adverse motor patterns lead to fatigue and pain?)

In an effort to explain the differences found in experimental and field studies that did not explain the Pain Adaptation Model, Peck et al. proposed a new model called the Integrated Pain Adaptation Model. As previously noted, the Pain Adaptation Model hypothesized that pain leads to changes in muscle activity to limit movement and protect the sensory-motor system from further injury. Peck et al. sought to expand this model: pain and limitation of movement were influenced by the complexity of the sensory and motor systems and multidimensional nature of pain. The new integrated model stated that pain results in a new recruitment strategy of motor units influenced by biological and psychosocial factors of the pain experience [264].

This model may help to explain our study's inconsistent findings across measurements and tasks. That is, the integrated model proposed the effect of pain on motor activity depended on the interaction of biopsychosocial factors. These factors comprise the individual's pain experience, coupled with anatomical and functional aspects of the individual's sensory and motor systems. In terms of anatomical and functional complexity (i.e., joint and muscles involved, central neural control, specific nature of the task being performed) and the multidimensional nature of pain, it was proposed that the pain's location, intensity, duration, quality, and motivational and cognitive dimensions that comprised the experience of pain needed to be considered in determining the effects of pain on motor activity. Considering all of these factors was beyond the scope of our study.

The Integrated Pain Adaptation Model further stated: The multiple dimensions of pain influencing motor activity can be conceptualized as a homeostatic emotion of an adverse condition requiring autonomic and motor behavioral responses; different types of pain employ specific responses [265]. Therefore, each pain experience (in terms of its quality, location, intensity, duration) in an individual may be associated with a particular pattern of change in muscle activity and movement.

Moreover, in the presence of pain, the model suggested that an individual's multidimensional pain experiences interact in a unique way with that individual's sensory and motor system. A new strategy of muscle activation would be formulated to help maintain homeostasis. One important aspect in maintaining homeostasis may be the need to minimize the generation of future pain during a subsequent movement. The particular pattern of activation that would be selected in the individual would be determined by the anatomical and functional complexity of the sensory and motor systems and the multidimensional pain

experience. The multidimensional nature of pain would influence the sensory and motor systems through connections that the peripheral and central sensory and motor systems have with the limbic system, the hypothalamo-pituitary-adrenal axis, and the autonomic nervous system. Muscle strategies would then be developed to maintain homeostasis, and minimize pain and metabolic cost.

**Strengths**

Randomized allocation: A primary strength of the study is that this was a randomized controlled intervention, often considered the "gold standard" of field studies [92], and random assignment of study participants was concealed from the PI until after baseline measurements were obtained.

Cost: This was one of the few experimental studies to use inexpensive engineering controls and training in their use to examine the effect of an office ergonomic intervention among symptomatic workers [93].

Improvements in physical exposure and health beyond the implementation of keyboard shortcuts: We implemented work practice controls – keyboard shortcuts – for both groups. This was done for ethical reasons and to examine contamination. Regarding the latter, if the engineering controls were effective, any reductions in physical exposures or improvements in health outcomes in the intervention group might more likely be attributed to engineering controls.

Meeting most quality metrics: In a recent systematic review of ergonomic intervention studies on computer operators for primary and secondary prevention, Brewer et

al. assessed articles for methodological quality [93]. Examples of criteria included "was the intervention allocation randomized" and "was a control group used." Using these criteria, the authors found only 9 studies that could be classified as "high quality," although 4 of the 9 did not describe the potential for contamination between groups, and 6 did not report the reasons why participants were lost to follow-up. This study was designed to meet most of the quality assessment items.

Measurement of multiple exposure characteristics: Radwin described 3 dimensions – frequency, duration, and magnitude – that characterize physical exposures related to a task; these dimensions interact to quantify the external loading acting on a body [64]. Much of the exposure assessment in ergonomic experimental studies has considered 1 or 2 of these dimensions during computer-related tasks. This study examined frequency and magnitude, but also examined the distribution of task exposures over a workday. For example, the frequency of repetitive hand motion and magnitude of non-neutral posture were collected using a work-sampling method for 4 hours of an 8 hour work day to collect information on task distribution.

Individual exposure assessment: This was one of the few experimental studies that used individual rather than group observational exposure assessments to examine the effect of an office ergonomic intervention among symptomatic workers [93].

Observational exposure assessment: Data indicate that self-reported ergonomic exposure measures have low validity and reproducibility [94]. For neck and upper extremity MSDs, data appear to be inconsistent regarding the degree and situation in which self-reported ergonomic exposures are misclassified [95]. In our study, validity in exposure

assessment may have been improved with the use of both observational exposure assessments and exposure interviews, rather than solely with the use of self-reports [96]. Although there are concerns about the use of observational exposure assessment methods due to their subjectivity [97], our method may provide a "third way" between self-report and bioinstrumentation; the latter is expensive and often not practical in field studies. In addition, observational exposure assessment can more easily examine several physical exposures in real time than bioinstrumentation [98].

Avoiding potential inter-observer disagreement: We had limited resources and only used one ergonomist to conduct the observational exposure assessments and exposure and health interviews. This has the advantage of avoiding potential inter-observer disagreement.

Regression to the mean: When repeated measurements are taken on physiological variables, second and subsequent measurements for individuals with initially extreme values will, on average, tend to converge toward the group mean. The phenomenon, "regression to the mean (RTM)," can be attributed to both the inherent variation of the phenomenon being measured and the variability of the measurement itself [99]. Davis [99] and Checkoway et al. [100] noted RTM is a type of selection bias and can be affected by whether a sample was randomly allocated. In randomly assigned experimental studies, the random sample usually covers the full range of physiological values. Participants in follow-up measures are usually not chosen based on extreme values, and follow-up values should, on average, be similar to baseline values absent an intervention. However, RTM is problematic when individuals are *preferentially* selected for follow-up measurements, such as in disease screening for high blood pressure. Bias from RTM can be substantially reduced when repeated measurements are taken on the entire sample of randomly allocated participants [99, 100]. With the

exception of the 4 participants who were lost to follow-up and were not included in any analyses, we measured all 109 participants at baseline and follow-up.

Reducing correlation of repeated observations: GEE analyses for longitudinal data were used to compare slopes or proportion changes of intervention and control groups between baseline and follow-up. Thus, GEE analyses takes into account the correlation of repeated observations [101].

Compliance: Intervention compliance for ergonomic field studies is often problematic; worksite interventions usually report low to moderate compliance [102]. In an attempt to promote compliance, the PI was physically onsite for 25 of the 29 weeks (7 months).

Adjustment of co-interventions: Co-interventions are often problematic among ergonomic intervention studies [14]. Our study examined certain co-interventions (medication, medical care or rehabilitation for an MSD, missed workdays due to an MSD) and controlled for them in multiple regression analyses.

Substantial biological plausibility: There is considerable biological plausibility in the literature corroborating our interaction hypothesis: the effects of high physical exposure and older age would result in a greater likelihood of an adverse musculoskeletal outcome in older workers.

Examination of work demands and aging: In numerous work environments, work demands for older workers are at the same level as for younger workers [117]. However, because of decreasing working capacities among older workers (for example, from the third decade of life to the seventh, the total body fat proportion doubles, there is a loss of muscle fibers and attendant strength, and there is an increase of bone loss [118]), the resulting

workload may change from an acceptable load for younger workers into physical overload for older workers, which may then result in chronic musculoskeletal discomfort and cascade into other symptoms [42]. Thus, older workers are different from younger workers due to physical age-related changes. This research begins to examine work demands, work capacity, and aging.

Limited studies on older working populations: There are limited studies on older working populations [119]. Authors noted that researchers should explore how age-related changes in biological systems (e.g. musculoskeletal) interact when performing complex tasks [24]. Regarding complex tasks, other researchers stated that examining interaction effects between computer use and other determinants of MSDs remained an under-examined issue [47]. This is one of the few papers that examined age effects on the association between physical exposures and MSD pain.

Prioritizing ergonomic research in aging: In a review paper that focused on prioritizing ergonomic research in aging for the 21$^{st}$ century, Schwerha and McMullin [120] noted the goals of research should not be to change older workers into younger workers, but rather improve the work environment and working life to allow the older worker to function successfully and remain productive as long as s/he desires; moreover, they stated research should explore interactions between age and the work environment in order to develop effective interventions among all age groups.

Limited intervention research on exposure, aging and health outcomes: To the best of our knowledge, Brisson et al. [36] and May et al. [98] appear to be the only 2 office ergonomic intervention studies that explicitly examined whether the association between physical exposures and MSDs vary by age following an intervention, while a paper by

Montreuil and colleagues [95] was a continuation and extension of the Brisson et al. investigation.

Older workers in the service sector are increasing: Studying whether age modifies the relation between physical exposures among workers "exposed" to an office ergonomic intervention and MSDs is important because the proportion of older workers in the service sector is increasing due to several factors: increasing life expectancy due to improved medical care and nutrition, increasing retirement age, and increasing socioeconomic demand for older workers to remain employed [119].

Exposure characterization: Because of increased heterogeneity of older workers, inter-individual variability in motor performance increases with increasing age. Therefore, descriptions of average behavior by group, such as job title, across age groups may be less valid for an individual's performance as the age group increases [12]. Thus, characterizing physical exposures in workers by job title, which is commonly done is ergonomic epidemiologic studies, may result in less valid estimates of exposure in a worker's task compared with individual exposure assessment [121].

Addressing physical exposures that affect aging: The biological control mechanisms for homeostasis tend to decrease with age; this is one reason why older workers take longer to recover from an illness than younger workers [122]. Occupational ergonomic interventions that reduce physical exposure to repetitive motions and non-neutral postures – exposures that have been associated with increasing the aging process – and improve work efficiency are required for older workers who want to continue to work or must continue to work due to economic concerns [24].

**Limitations**

Blinding issues: It was impossible to blind the PI or participants once intervention assignment was determined, as engineering controls were used for the intervention group. The PI also conducted the intervention and performed all measurements. Misclassification may have occurred by the PI or participants because both knew who was receiving the engineering controls. For example, the PI may have unintentionally differentially misclassified exposure with respect to the intervention in either the intervention or control group.

Validated exposure measures, although not used as originally described: We chose RULA and HAL observational methods because they have been validated, although we used modified versions of both [103, 104]. Specifically, RULA has been validated among computer operators, although their sample size was small [103]. Although similar to the original version, Computer RULA, developed by Corlett, Barson and Lueder has been refined to enhance its application for the evaluation of computer work [105]. We modified Computer RULA because we felt it incorrectly assigned exposure scores and inadequately described physical exposures for certain elements. For example, it assigned the highest exposure score to the elbow as it extends and lowest score at 90 degrees of elbow flexion; the trunk assumes unrealistic extreme hip flexion postures while sitting, even for computer work; and there was no measure of forward head posture. We found that over 98% of participants assumed this latter posture at both baseline and follow-up. HAL, an observational rating system that characterizes hand activity and forceful exertion, has been validated in occupations involving manual work, such as installing subassemblies, but not in computer

work [104, 106]. We modified this exposure assessment since physical demands involved with computer work are usually lighter than manufacturing jobs.

Low participation rate and generalizability: Participation rate was low: 27%. Our participation rate, based on Brewer's criterion for office ergonomic intervention studies [93], which they assigned as greater than 40%, was not achieved. As noted in a New York Times letter to the editor (April, 27, 2010) from Case Western Reserve University, there are many reasons for low participation rates in randomized controlled studies. Although inadequate financial support plays an important role, "as a society, we have done a poor job emphasizing the importance of this type of research as an integral component of quality medical care. We should take note of the marketing skills that have contributed to the adoption of unhealthy behaviors and apply them to the widespread recognition that this type of research may represent some of the most novel interventions the medical" and health communities have to offer. The low participation rate may have affected the generalizability of the study.

Limits on observational exposure assessment: We had limited resources and only used one ergonomist to conduct the observational exposure assessments and exposure and health interviews. This has the disadvantage of imposing limitations on the total amount of observation time. It also had the potential for measurement error to proceed undetected.

Unexpected improvements in pain severity at follow-up in control group: Proportional change scores showed larger improvements in pain severity in the proximal quadrant of the non-preferred limb of the control group. These findings may have been due to: 1) underreporting by the control group; 2) the episodic and complex nature of pain [107]; 3) upstream organizational changes unrelated to the intervention; 4) contamination of the control group by informal transfer of ergonomic knowledge from the intervention group

[108]; 5) recovery effects over time; 6) work demands, which may have decreased more in the control group during the study; 7) more proximal loading and increased hand activity/upper extremity movement of the non-preferred limb in the intervention group; 8) the so-called Hawthorne effect (the tendency of study participants to change behavior in an experiment due to attention they are receiving from researchers, rather than from manipulation of variables); 9) incomplete adjustment for confounding; and 10) effect of shortcuts.

Reporting issues: As Westgaard and Winkel observed, due to the cyclical nature of MSDs workers may temporarily report improvement in health independent of an intervention. These authors speculated whether observed musculoskeletal symptom improvements are due changes in the tendency to report complaints or actual improvements of musculoskeletal health [108].

Complex nature of pain: Although the evaluation of symptoms is important, the proportion of symptomatic workers who suffer from a clinically documented MSD has been shown to vary among working populations; thus, symptom severity without a concomitant physical examination and occupational history may be an unstable measure of the severity of work-related MSDs [66].

Individual and organizational factors and pain: Pain may be influenced by individual or other non-work-related factors, such as socioeconomic determinants [109], or by the effect of an MSD on work capacity and work demands [31]. Cole and Wells reported that factors which improve or worsen health outcomes may be due to organizational and operational changes unrelated to an intervention, such as increased production demands, poorly

maintained or inadequate equipment to meet production demands, or "downsizing" due to financial uncertainties in the organization [110].

Contamination: Contamination from the intervention to the control group may have occurred, even though 80% of the control group reported they were more satisfied with work after implementation of their keyboard shortcuts than with their pre-intervention work. The work practice intervention - the keyboard shortcuts - may also have been effective in reducing physical exposure [111, 112], as participants in the control group were provided the rationale for using this work practice control. Moreover, the increase in knowledge of both keyboard shortcuts and informal knowledge gained by the control group may have contributed to greater proportional reductions of pain in the proximal quadrant of the non-preferred limb of the control group. However, the control group did report lower levels in 3 of 4 aspects of ergonomic knowledge than the intervention group from baseline to follow-up, which may provide evidence that contamination was not substantial.

Recovery effects and pain: Recovery effects over time may have played a role in the reporting of symptom severity reduction among the control group. Approximately 35% of the control group had a $\geq$ uncomfortable baseline pain severity in the proximal quadrant of the non-preferred limb; the median pain at baseline in this quadrant for the control group was 2.5 (mild to uncomfortable pain, on a range from 1-5). Pain severity to lower levels may have occurred over time. In a prospective cohort study that examined manufacturing, construction, and healthcare occupations, where considerably higher upper extremity physical exposures may have existed compared with computer work, Gardner et al. reported 32% of workers with baseline carpal tunnel syndrome symptoms were asymptomatic at 6-month follow-up [113]. It is biologically plausible that if the control group had greater baseline pain levels,

there may not have had a reduction of musculoskeletal pain. Indeed, continued physical exposure at the computer may have increased regional pain.

Change in workload: The item, "typical day with an average workload" did not substantially change between baseline and follow-up within groups. Work demands remained essentially unchanged, as this study was conducted during the "interim," and most employees worked a 40 to 45 hour week, rather than a 60-80 hour week, as is often required during the legislative session. Descriptive statistics showed that there were no significant changes in JCQ psychological job demands throughout this time period. Moreover, responses from the exit phone interviews from the 24 randomly selected participants revealed that work demands had not markedly changed from baseline to follow-up. Recovery may have occurred during the interim for both groups

Increased proximal loading and hand activity/upper extremity movement in the preferred limb of the intervention group: In her book on clinical kinesiology, Brunnstrom noted that distal upper extremity mobility required proximal upper extremity stability [25]. Greater proximal stability and static loading, and increased distal mobility were required to operate the touch pad in the non-preferred limb. This may have partially explained the greater reductions of pain severity in the non-preferred limb of the proximal upper extremity quadrant of the control group.

Self-report of missed workdays: We attempted to obtain administrative data for "days missed due to an MSD in past 2 months." The Office of Legislative Management did not have these data. Therefore, this information was self-reported. Studies indicate that missed work days over the past several months may be an important predictor among symptomatic individuals of future musculoskeletal morbidity [114]. However, in both intervention and

control groups, differences for missed workdays over the past 2 months were not statistically significant at baseline or follow-up.

Insufficient time to follow up: Although there are no consensus documents regarding limits to baseline and follow-up observation times for intervention studies, evidence indicates that at least 1 year follow-up should be used for the ascertainment of health status; shorter follow-up times may still provide important information, but a follow-up time of less than 6 months is problematic for assessment of health outcomes [108, 115]. Due to legislative demands of the legislators, the new election cycle that brought in a new governor and legislators, and their accompanying support staff, and because we were unable to obtain worksite access after approximately the seventh month of the study, we used a 2.5 to 3.5 month follow-up period after the intervention was implemented.

Use of 2 engineering control and a work practice control: We were unable to tease apart the effects of both engineering controls and keyboard shortcuts. For example, was the reduction of non-neutral postures in the non-preferred limb of the intervention group due to the keyboard/mouse tray, a tented touch pad that was immediately adjacent to the non-preferred limb of the keyboard in the intervention group, or use of both upper extremities when performing keyboard shortcuts?

Macro versus micro ergonomics: The literature noted the effect of the organization on downstream occupational exposures and the importance of addressing the macro (e.g. ergonomic policy) and micro (e.g., work station) levels of organization when conducting ergonomic intervention studies [16, 116, 117] to maximize effectiveness of the intervention. Due to resource constraints and organizational policies, we were only able to address the worker and workstation through a physical intervention. For example, we were unable to

change work/rest recovery times; insufficient recovery has been associated with proximal upper extremity MSDs [118].

Incorrect or misunderstood language: Both intervention and control groups had reductions in "moderate or expert ergonomic knowledge" on risk factors from baseline to follow-up. Regrettably, the phrase "risk factor" was not used by the PI when he implemented the interventions and conducted the training; rather, he used the phrase "physical exposure." As noted by Stock and colleagues [119], this cohort may not have understood and interpreted that these 2 phrases were similar, if not identical. Thus, the term "risk factor" may not have been meaningful to these workers.

Insufficient sample size: The sample size calculation showed that with 80% power we would be able to detect an effect size of 0.55, which corresponded to a 10.8% reduction of musculoskeletal pain severity in the intervention group compared with the control group. However, we may still have had limited statistical power to determine with a reasonable probability of detecting and estimating an effect if one existed [120]. For example, when creating variables with more than 2 categories, cell sizes for both intervention and control groups often had fewer than 5 observations per cell.

Potential for collinearity: Although we performed several methods to reduce the number of independent variables due to the potential of strong correlations in multiple regression analyses, the possibility of multicollinearity between determinants may still have existed. These models may have underestimated the associations between the intervention and physical exposure, pain, and quality of life [121].

Premature ending for follow-up: Initially, we designed the study for a second round of repeated measures on both determinants and outcomes; this would have taken place 3

months after the first follow-up. However, legislative session began immediately after our first follow-up. We were told by the Office of Legislative Management that it would be difficult or unattainable to accomplish this second follow-up. We also wanted to conduct exit telephone interviews on the entire cohort to determine whether work demands changed from baseline to follow-up. Moreover, we wanted to inquire about work before and after the intervention among the entire cohort to examine contamination. However, as noted above, the study ended at the beginning of the legislative session. We were told by both study participants and the Office of Legislative Management that it would be difficult or unattainable to interview the entire study cohort, as they would be unavailable or unwilling to respond to telephone interviews during legislative session. We chose to randomly interview 33% of the study cohort (n=36) as a sample of convenience, but were only able to interview 22% (n=24) of study participants.

Healthy worker effect: the HWE can be considered an example of selection bias (self-selection of workers out of the workforce or job transfer). It often results in an underestimation of the association between occupational exposures and health outcomes. "Transfer bias" among participants would more likely have occurred than self-selection of workers out of the workforce in our study since we examined the same participants with baseline and follow-up data. The HWE would have resulted in workers transferring to less physically exposed jobs. This lower exposure group would then become an inappropriate reference group. Our intra-cohort comparison between groups might have increased "transfer bias" toward the null. However, for transfer bias to occur, workers must link adverse health conditions to exposure [83]. This makes teasing out the occurrence of the HWE in morbidity studies difficult.

Low statistical power: Despite a sample size calculation that showed with 80% power we would have the ability to detect an effect size of 0.39 for the interaction analyses, we still may have had limited statistical power to determine with a reasonable probability of detecting and estimating the hypothesized effect if one existed [82].

Dichotomize or not dichotomize: We dichotomized both determinants in the interaction term for easier interpretation of effect estimates of these terms. Cut-points between low and high physical exposure (modified RULA and HAL) were based on a reference to the median exposure distribution within the sample [123]. Justifications for dichotomization and choices of thresholds include following practices used in past research and using clinically significant cut-points [124]. However, cut-points based on practices used in past research are often arbitrary [50], and the literature does not cite consensus documents for permissible exposure limits (PELs) for computer work [47, 53] and, in particular, PELs based on the RULA and HAL assessment methods. For example, does a cut-point of >5.0 on the HAL scale imply increased risk for a distal upper extremity MSD for computer work? Dichotomization leads to interrelated problems, including a quantifiable loss of information; a result in an underestimation of the magnitude of the bivariate relation; a lowering of statistical power for detecting true effects [125].

Validated exposure measures, but not how authors originally intended: Although RULA was validated for computer work, HAL was validated primarily in the manufacturing sector, where physical demands may be substantially higher. We modified HAL; we used hand activity/repetitive motion constructs, but not forceful distal upper extremity exertions, as initially described in HAL. Further, it remained uncertain whether HAL provided sufficient construct validity. That is, when the observer measured "hand activity and

movement," was he actually measuring hand activity and movement for computer work or manufacturing-related work? In addition, the ability to provide adequate variability of distal hand activity for computer work remained uncertain when using HAL. Specifically, the last verbal anchor for HAL included "difficulty keeping up," which did not apply to computer tasks in this study. This reduced HAL exposure variability between age groups, perhaps restricting the level of detail required to examine the association between an interaction term (e.g., high hand activity preferred limb*older age) and pain severity [123]. Likewise, we modified Computer RULA because we felt the "RULA employee worksheet assessment" [126] was inappropriate for the study; for example, the "force/load score" was neither measured in this study nor is a primary physical exposure among computer operators [94]. Moreover, our "muscle use score" was used as an individual item in the physical and temporal load survey. We also modified Computer RULA because we believed it incorrectly assigned exposure scores and inadequately described physical exposures for certain elements. For example, it assigned the highest exposure score to the elbow as it extends and lowest score at 90 degrees of elbow flexion; the trunk assumes unrealistic extreme hip flexion postures while sitting, even for computer work; and there was no measure of forward head posture.

Limited pain scale variability: We used a pain scale from 1 to 5, which may have limited the variability of the scale's response choices between age groups at baseline and follow-up, and thus reduced the ability to distinguish significant changes among participants with low levels of musculoskeletal pain severity. (Two other office ergonomic intervention studies also found low baseline pain severity levels, which was similar to our study [127, 128].) A scale with more categories, such as a "0 to 10" or "0 to 100" scale may have

provided more variability, greater sensitivity regarding musculoskeletal pain severity (i.e., the proportion of severe cases that are correctly identified as having a severe condition) and perhaps an improved level of detail leading to additional associations between interaction terms (e.g., high hand activity preferred limb*older age) and pain severity.

Limited follow-up time: Many of our findings were inconsistent with the literature. This might have been due to our relatively short follow-up period. Although there are no consensus documents regarding limits to baseline and follow-up observation times for intervention studies, evidence indicates that at least 1 year follow-up should be used for the ascertainment of health status; shorter follow-up times may still provide important information, but a follow-up time of less than 6 months is problematic for assessment of health outcomes [49, 129]. Due to legislative demands of the legislators, the new election cycle that brought in a new governor and legislators, and their accompanying support staff, and because we were unable to obtain worksite access after approximately the seventh month of the study, we used a 2.5 to 3.5 month follow-up period after the intervention was implemented.

Seasonal variations: The study began in the summer and ended mid-winter. Seasonal variations, such as extreme cold weather may have influenced the findings. For example, in a study that examined cold food processing centers, Sormunen and colleagues found that cold temperature, longer work duration, and increasing age were associated with an increased prevalence of MSD symptom severity and impaired functional activities [130].

Generalizability: The study examined symptomatic computer operators, in which participants had higher musculoskeletal pain severity levels than non-participants; thus, the study may not be generalizable to asymptomatic computer operators. The homogeneity of the

study sample (86.7% where of white European ancestry) may also limit the generalizability of the study. Additionally, contamination and the lack of blinding of both the PI and participants may impair study validity if measurement error occurred in the exposure assessment or exposure interviews, or when obtaining individual determinants or health outcomes in the self-administered surveys. These factors may also have compromised the generalizability of the study.

# VII. CONCLUSIONS

## 1.0 Main study: Intervention

We believe our study can be compared with other studies as follows: the study can be generalized to symptomatic computer operators in the public and private sectors. The potential for contamination and the lack of blinding of both the PI and participants, however, are not trivial. The lack of heterogeneity in our study (over 85% of our study participants were of white, European origin) may also limit the generalizability of the study to other racial/ethnic groups, although we have no evidence that other groups would respond differently to the interventions.

In view of the study objectives and limitations, the overall interpretation of results suggested that the implementation of a fully adjustable keyboard and mouse tray appeared to reduce non-neutral postures in the upper back and upper extremities compared with a control group. The implementation of a touch pad for the non-preferred limb seemed to reduce non-neutral postures and repetitive motions in the preferred limb compared with a control group. The touch pad also appeared to reduce non-neutral postures and increase repetitive motions in the non-preferred limb.

These factors seemed to have reduced musculoskeletal morbidity – in distal greater than in proximal regions in the preferred limb – among computer operators with low levels of pain and used computers at work at least 4 hours per day (Table 19). Small improvements in musculoskeletal pain severity in the intervention group were also observed in 3 anatomical

regions of the non-preferred limb: the neck/upper back, shoulder, and wrist. The intervention had no effect on the likelihood of an adverse musculoskeletal outcome in the elbow and digits of the non-preferred limb, while the forearm demonstrated an increased likelihood of an adverse musculoskeletal outcome in the non-preferred limb. There was also a small likelihood of adverse quality of life outcomes in both the PCS and MCS of the intervention group.

Compliance was high in the intervention group for the keyboard and mouse tray, but low for the touch pad. Participants reported using the keyboard and mouse tray 29% more of the time over the study period than the touchpad. This could have been anticipated, as the touch pad required higher cognitive processes than the keyboard and mouse tray. Ideally, additional training sessions on the touch pad should have been conducted. However, time constraints limited training sessions. The keyboard tray appeared to be more effective in reducing overall pain and was easier to use; it also enhanced work productivity more than the touch pad. This also could have been anticipated, due to the greater cognitive processes involved with using the touch pad. Once again, additional training sessions on the touch pad may have reduced the differences between keyboard and mouse tray use and touch pad use reported by participants.

## 2.0 Sub-study: Effect Modification

Taking the objectives, hypotheses, limitations, analyses, and results from other studies into account, this study suggested postural exposures did not substantially differ between age groups at baseline and follow-up. Hand activity/upper extremity movement in

the non-preferred limb was slightly greater in older workers at follow-up. Moreover, while absolute mean change scores revealed that hand activity/upper extremity movement increased more in the non-preferred limb of older workers, absolute mean change scores revealed that older workers were still able to reduce non-neutral postures in their non-preferred limb.

Both postural exposure and hand activity/upper extremity movement findings indicate there may have been greater intervention compliance, more willingness to learn new technology, and greater functional neuromuscular reeducation among older workers. These findings might also be explained by greater work experience and the use of compensatory mechanisms in older workers.

Although not significant, older workers had lower proportions of job strain in the highest strain quadrant category at both baseline and follow-up, implying higher job control and lower job demand within their work environment. This may have provided additional opportunities for older workers to learn new technology and motor patterns.

Our results disagreed with much of the literature on aging workers and the design process. The literature stated that age-related change involved substantial reductions in dexterity, precision, coordination, and joint mobility, and a concomitant reduction in upper extremity function [104]. Results also disagreed with much of the literature on factors that inhibit learning in older workers, which include difficulties involved in changing established movement patterns, and that older workers do not learn as well as younger workers when faced with novel situations [108].

Results from our study demonstrated an equal number of small but consistent reductions in change scores for postural loads following an ergonomic intervention in both

age groups (except in the preferred limb), although the magnitude of these reductions were slightly greater in younger workers. Despite several motor function disadvantages reported in the literature among older workers, older workers were still able to reduce the same number of non-neutral postures as younger workers; further, the magnitude of improved changes in non-neutral postures in younger workers was small. Moreover, hand activity/upper extremity movement increased in the non-preferred limb of older more than younger workers. These findings suggest greater intervention compliance and appropriate motor patterns to effectively use engineering controls in older workers. Further, the use of the touch pad required substantial cognitive loads, dexterity, precision, coordination, joint mobility, and upper extremity function.

Our interaction models demonstrated for high postural loads and older age, there was significantly greater likelihood of an adverse musculoskeletal pain outcome in ~14% of the interaction terms. For increased hand activity/upper extremity movement and older age, there was significantly greater likelihood of an adverse musculoskeletal pain outcome in ~17% of the interaction terms, although many of the results for both posture and hand activity/upper extremity movement included the null. Based on the aging literature regarding increased severity, impairment, and disability among older individuals, the low proportion of adverse associations between interaction terms and MSDs was unexpected and appeared to be due, in part, to the HWE.

Interestingly, while 8 interaction terms between physical exposure*age showed a greater likelihood of an adverse musculoskeletal outcome, 7 of 8 (~88%) of these terms were located in proximal upper extremity quadrants, and 4 of 8 (50%) were located in the right proximal quadrant.

The only consistent patterns of fewer non-neutral postures in younger than older workers at baseline and follow-up were located in the spine and lower extremity. The upper portion of the spine, comprising the thoracic and cervical spines, is integrated into the upper back and shoulders. This might suggest proximal quadrants in older workers have a greater likelihood of an adverse musculoskeletal outcome than distal quadrants. Moreover, an physical exposure-dose-response relation has been suggested in the literature among computer operators, particularly in the mousing upper extremity [131]. Over 87% of this cohort was right hand dominant and over 98% used the mouse on the right. Interaction terms in the right proximal upper extremity quadrant suggested a greater likelihood of an adverse MSD outcome than any other quadrant. This may indicate that of all upper extremity quadrants, the right proximal quadrant may be at greatest risk of persistent MSDs in older workers. This may have implications for prioritizing controls in the office environment in all workers.

We believe the longitudinal and randomized nature of the study, the examination of numerous determinants in bivariate and multivariable analyses, and individual observational exposure assessments for the entire cohort (rather than self-reported exposure data or examining group exposure, such as "job title") improved the validity of the study among symptomatic computer operators. This study can be generalized to both public and private sector symptomatic employees.

## 3.0 Sub-study: Magnitude and frequency of postural movements

The study suggested that symptomatic computer workers employed in a public sector, non-unionized state agency showed overall modest increases in joint perturbation, and greater joint perturbation by age, MSD onset, and severity for modified RULA elements among workers performing interactive communication in the afternoon, although findings were inconsistent over the day and across the study. We also found overall modest increases in joint perturbation, and greater joint perturbation and less hand activity by age in the afternoon when we examined modified Grand RULA and preferred and non-preferred limb movements among workers performing interactive communication.

Among workers performing word processing, we found modest increases in joint perturbation by age and MSD onset in the afternoon for modified RULA elements. Overall modest increases in joint perturbation, and greater joint perturbation by age, MSD onset, and job strain was seen when we examined modified Grand RULA. Less upper extremity movement was observed during overall preferred and non-preferred limb movement and by chronicity and job strain.

Possible explanations for why our hypotheses did not agree with many of our findings – that older workers, individuals with a longer MSD onset, individuals with more pain severity, and high job strain would have greater joint perturbation and less upper extremity in the afternoon – included the healthy worker effect, lack of statistical power, low pain severity levels in all body regions in interactive communication and word processing groups at baseline and follow-up, cut-points may not have been sensitive enough, or the musculoskeletal pain severity scale may have limited the variability of the scale's response

choices by task and severity, thus reducing the ability to distinguish significant changes among workers with low levels of musculoskeletal pain severity.

Other possible explanations include altered muscle performance and movement patterns only affect some workers with clinical pain; at the individual level, these responses have not been closely associated with pain. Moreover, large task variations and between-worker variation make results difficult to interpret [100].

Based on other research, authors have concluded that motor control patterns within symptomatic subjects may not be influenced by current task discomfort or pain, but rather are reflexive, pre-programmed connections between central and peripheral nervous systems. These researchers hypothesized that persistent and chronic increases in joint perturbation may be habitual and remain consistent across task and time; differences in observed postures between symptomatic workers may also be due to the presence of discomfort, individual habits in postural variation, or types of tasks performed [27].

Our findings' inconsistencies across the study may also be explained by pathomechanism models [129]: possible pathomechanisms for deranged motor control and coordination may occur via multiple pathways and feedback systems; these pathomechanisms may not be mutually exclusive, but rather interact at different time points over the course of an MSD.

In view of the study objectives and limitations, the overall interpretation of results suggested that in these symptomatic workers performing interactive communication and word processing, there was a modest pattern of greater joint perturbation and less upper extremity movement in the afternoon across the study.

We believe the study can be generalized to other symptomatic computer operator cohorts, both unionized and non-unionized, in public and private sectors. However, contamination and the lack of blinding of both the PI and participants were not trivial. The healthy worker affect may also have led to selection bias and measurement error. The small sample size may have affected the generalizability of the study [67]. The lack of heterogeneity in our study (approximately 86% of our study participants were of white, European origin) may have also limited the generalizability of the study.

# VIII. RECOMMENDATIONS

## 1.0 Main study: Intervention

We used a micro-ergonomic approach, as this was a more practical, albeit less comprehensive intervention for improving the office work environment. We examined an adjustable keyboard and mouse tray and bilateral pointing devices. The alternative pointing device required gross rather than fine motor control, while the traditional, corded, optical pointing device required fine motor control. Overall, the intervention appeared to improve distal greater than proximal upper extremity musculoskeletal pain and in the preferred limb greater than in the non-preferred limb.

The results suggested the touch pad increased the likelihood of pain in the forearm of the non-preferred limb. However, we believe this may have been due to the reduction of the tenting angles from an intended 40 degrees to 22 degrees; this places greater loading forces in this region. Thus, these results notwithstanding, we suggest the computer workstation configuration that was used in this study, or some similar alternative configuration that employs two alternative pointing devices. To distribute physical exposure more uniformly and change the exposure profile of right sided mousing, pointing devices should be used bilaterally. We also suggest a stable, negatively tilted work platform that can hold a keyboard and two pointing devices as an alternative work system for both symptomatic and asymptomatic employees, rather than a more traditional physical workstation layout. Repeated ergonomic training on work practice and engineering controls is essential to

promote motor learning among employees in their work environment. Further, we believe that if padded forearm supports, rather than armrests or wrist rests were used in our study, and a stable bi-level work platform rather than a keyboard tray, lower levels of proximal static loading may have occurred in the intervention group. This may have led to greater reductions in bilateral pain severity in proximal and distal quadrants of the intervention group [44, 55, 193].

Commitment, in which all stakeholders who are involved in the intervention consider the study as their own and give it high priority, is also crucial [220]. Vink and coworkers noted the importance of involving workers and management to increase the success of the intervention and in developing the most effective and meaningful interventions for employees. These investigators suggested a stepwise, participatory approach to achieve this objective [301].

## 2.0 Sub-study: Effect Modification

Chaffin and Ashton-Miller [302] noted advanced age decreases the capability of the average individual's spine to tolerate physical stress. Additionally, because age-related changes include a slowing of muscle contractions, response reaction times, and sensory-motor coordination, the interaction of age and hazardous working conditions may increase the risk of low back pain (LBP) [302]. These authors recommended controls to reduce the risk of LBP, but these controls can also be applied to the neck and upper extremity and computer use. They include: avoid prolonged static trunk postures by providing a workspace that positions objects, controls, and displays in locations that reduce prolonged trunk or hip

flexion, and lateral rotation and flexion of the trunk; use seats and workstations that adjust to individual anthropometry; have appropriate lumbar support, and support to reduce loading of the thoracic and cervical spines; alternate among different trunk and upper extremity positions and postures throughout the working day; with age, more time is required to adjust to a sudden increase in work load and job demands.

Due to current anti-regulatory trends in the US, the responsibility for employee health, safety, and wellness will most likely remain within an agency or organization, and often within their Human Resources (HR) department [209]. As Chaffin and Ashton-Miller state, morbidity in the aged worker may be attributed to a single event or cumulative occupational exposure, but the "sequela is a life-span happening." HR should make efforts to discuss the working environment and potential computer-related hazards with younger and older workers in order to understand their employees' attitudes and perceptions. HR should also extend the length of ergonomics training for both younger and older workers, and have them attend multiple training workshops to reinforce training and appropriate motor patterns specific to their job [209]. In addition, as Aaras [303] and Kilbom [304] reported, observed variations in pain over study periods highlight the importance of long term intervention studies to evaluate the effectiveness of an intervention. To this end, HR should monitor physical discomfort throughout an employee's tenure and provide an array of work practice and engineering controls for both younger and older employees over their working life in the office environment. That is, physical capacities will change as workers age, and this will dictate which controls a worker may implement over time.

Because the course of disease and health endpoints are more severe following an acute medical condition, or after an intense, frequent, or prolonged exposure in the work

environment, interventions for older workers should *ideally* involve a multidisciplinary approach, consisting of macro, meso, and micro-ergonomic workplace modifications [305], medical management, and physical rehabilitation. However, due to market-based constraints and an industry's production demands and financial survival [281], this is often not feasible. Nevertheless, simpler, less comprehensive intervention approaches are available, such as ergonomic interventions at the micro level that affect individual workers. It is also suggested that ergonomic interventions directed at individual workers may reduce lost work-days and productivity, training costs of new hires to replace those injured and out of work, and Workers' Compensation premiums [306].

There are many stereotypes regarding the capabilities of older workers. These include they are less productive; they won't learn new skills; they are a poor value for retraining [93]. However, all workers meet demands through a variety of resources. While maximum strength gradually declines after approximately 30 years of age, few jobs, particularly computer-related jobs, require maximum physical capacity or effort [93]. Moreover, while older workers have more difficulty performing certain experiment-based cognitive functions, such as processing complex information and retrieving novel information [307], studies involving actual work performance do not agree with results from these experiment-based cognitive performance tests [93, 308]. As shown in our study, older workers appeared to be more compliant with all aspects of the intervention, and more effective when implementing the engineering controls. Of particular note, the aspect of the intervention that involved the touch pad, which required more memory load and cognitive commands than the keyboard/mouse tray adjustment showed that older workers were able to integrate complex technology in order to perform precision tasks.

Although certain adaptations by older workers and physical accommodations by employers may be required to enhance the work ability of older workers, among workers who remain in the same or similar job and who perform familiar tasks, it can be expected that age-related deficits in cognitive functioning should not adversely affect health or job performance [10] (page 96). Likewise, based on past research [309], authors have reported that growth and intellect in individuals show "selective optimization and compensation." That is, refinement and specialization in areas that are frequently used and compensation in areas that are less frequently used [93].

Perhaps most important, however, is that to understand the consequences of age-related change, it is essential to examine how change in particular systems, such as the musculoskeletal and neuromuscular systems interact to alter the competence of complex work-related tasks; these interactions may be more crucial than solitary decrements in individual systems among older workers [93, 310].

## 3.0 Sub-study: Magnitude and frequency of postural movements

Although physical exposures associated with computer work may be lower than physical exposures associated with manufacturing or health care, the ubiquitous use of computers in industrialized societies – 6 out of 10 Canadian employees used computers at work in 2000 [91] – suggests that even low physical exposures associated with computer use can have important public health consequences.

This study begins to provide information about symptomatic workers' posture and movement during computer work over the workday. Since posture and movement vary over

the day among symptomatic workers, flexible workspace environments including different engineering controls, training on efficient motor control strategies, and effective management of MSDs should be considered for this population.

Specifically, to reduce the impact of deranged motor control, proproiception, fatigue, pain, and attendant changes in joint perturbation and upper extremity movement that might occur over the workday and over time among symptomatic office workers, we recommend a micro, meso, and macro (state or federal level) ergonomic approach [40]. At the individual level, this consists, in part, of reduction of non-neutral postures, static loading in proximal musculature, upper extremity repetitive, monotonous, stereotyped movements, and forceful musculotendon loading in distal musculature of the upper extremity. This micro ergonomic approach can be accomplished via engineering controls by allowing workers the time at work to test and choose products over the day. Engineering controls might include a fully adjustable, split level sit/stand workstation (to vary posture), forearm supports (to reduce static muscle loading), the use of bilateral pointing devices (to reduce hand activity, static proximal loading, and non-neutral postures in the mousing upper extremity) and speech recognition (to reduce hand activity and non-neutral postures). This should be based on the individual's level of fatigue, discomfort, and pain.

A micro ergonomic approach can also be accomplished by integrating engineering and work practice controls. For example, by providing adequate work and rest schedules by reminding workers to take recovery pauses with computer "take-a-break" software programs. This might, however, be difficult to accomplish based on the company's economic viability and production demands.

At the meso level, addressing work organization is crucial, as it dictates policies and procedures, and affects physical and psychosocial exposures [40]. Work organization controls in an office environment may include recovery pauses, reducing total task duration, increasing task variability and job content, and job enlargement. Although job rotation can be effective, there are often limited opportunities in the office environment, particularly in unionized office environments, where job rotation is often not a feasible option due to arranged and specified hierarchical job duties among union members. Another aspect of work organization is to allow ill employees the time to receive appropriate and comprehensive medical management and rehabilitation. This can be accomplished by allowing employees to take time off (in the office environment, this is often at a different location than the worksite) for medical treatment.

There were inconsistent patterns of joint perturbation and upper extremity movement over the day and during the study by age, length of onset, pain severity, and job strain. This suggests that ergonomists should consider additional factors to explain altered patterns of motor activity and attendant changes in posture and movement over the day. This can include considering the interrelation among exposures and the context in which they occur [40].

The inconsistencies in joint perturbation and movement over the day and during the study by age, length of onset, pain severity, and job strain using RULA and HAL within participants performing the same task also suggest that an exposure assessment method be developed specifically for computer work. There is a need to establish integrated exposure profiles between symptomatic and asymptomatic office workers and among symptomatic office workers by severity. Work sampling offers 1 option, although the data collected are

subjective. An easy to use, quantitative method that can capture data on multiple physical exposures over the workday and a large sample would be ideal.

Both the RULA and HAL exposure methods did not adequately capture the physical exposures involved with computer work. For example, HAL may have provided inadequate variability when measuring upper extremity movement, as the last verbal anchor was inappropriate for most computer operators (other than perhaps call centers). Individual differences, such as work technique also appear to be important in explaining posture and movement variation among workers performing the same computer task.

Thus, the development and evaluation of a new exposure assessment method for computer use should ideally incorporate adequate construct, content (the extent to which a measure represents all facets of a given ergonomic construct), and convergent (the assessment is related to what it should theoretically be related to) validity. The method should also adequately measure the primary computer physical exposures and their dimensions: posture, movement, force, and magnitude, duration and frequency, respectively. The development of a simple to use, inexpensive, long term digital video capture and analysis of upper body posture and movement, combined with fingertip force measurements might be 1 option.

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# MAIN STUDY

## Table1. Recruitment

418 potential support staff of legislators and "non-partisan" departments

→ 231 **non-responders** with 6 individual & work factor variables (data obtained from the OLM)
→ 35 responded and **refused** to participate, but answered screening survey (determinant and health outcomes)
→ 152 responded and wanted to participate
→ 39 responded but were **ineligible** based on screening survey
→ There were 113 remaining, eligible subjects who participated

**Participation rate = 113/418 = 27.0%**

35 refused + 39 ineligible + 231 non-responders = 305 non-participants.
113 participants.
Total 113 participants + 305 non-participants = 418.

FIGURE 1A

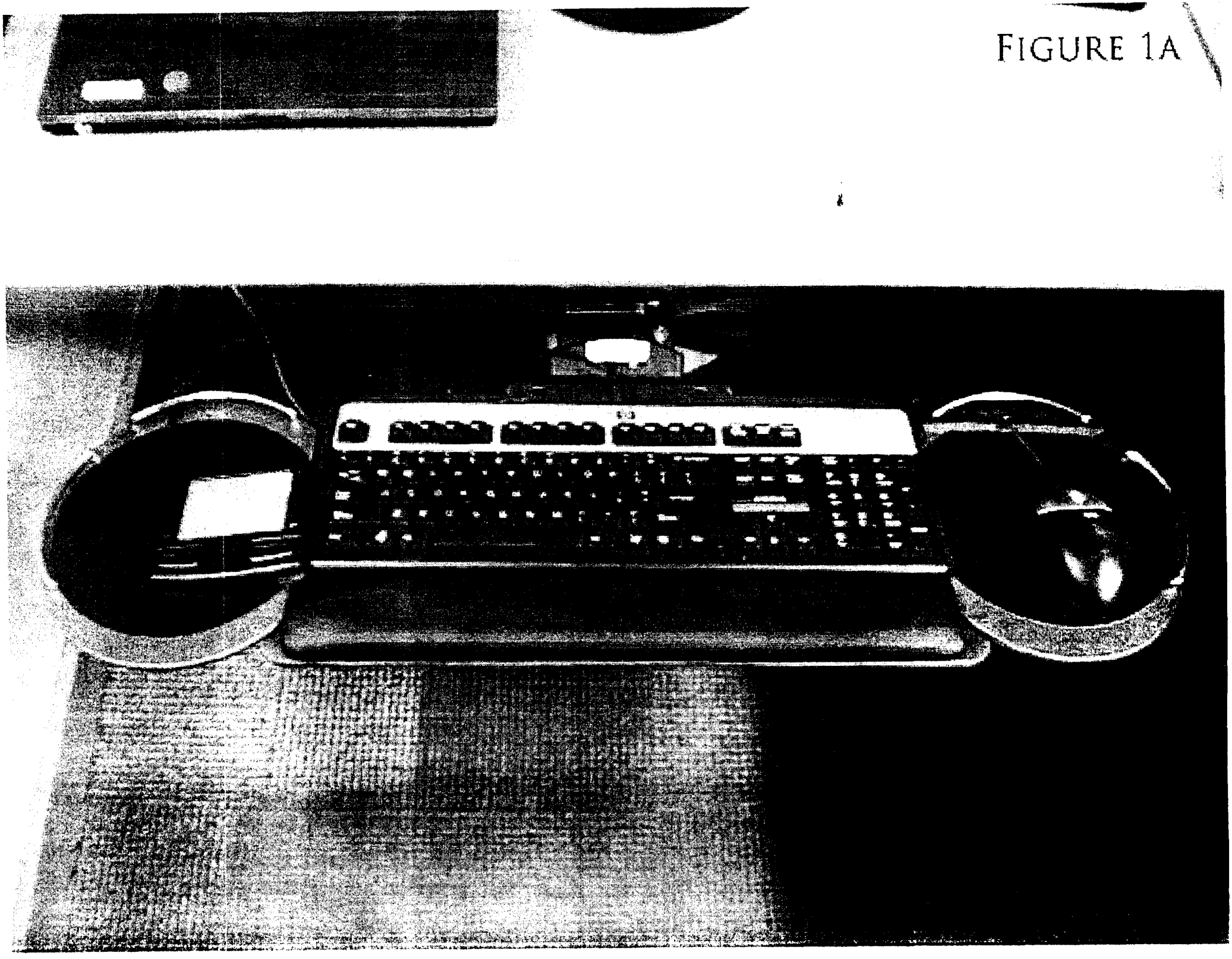


Figure 1b

Glide point has 11 features: 10 listed below, plus dragging an icon with a finger.

- Figure depicts left sided used.
- For dragging application: Double tap using left click button and drag.

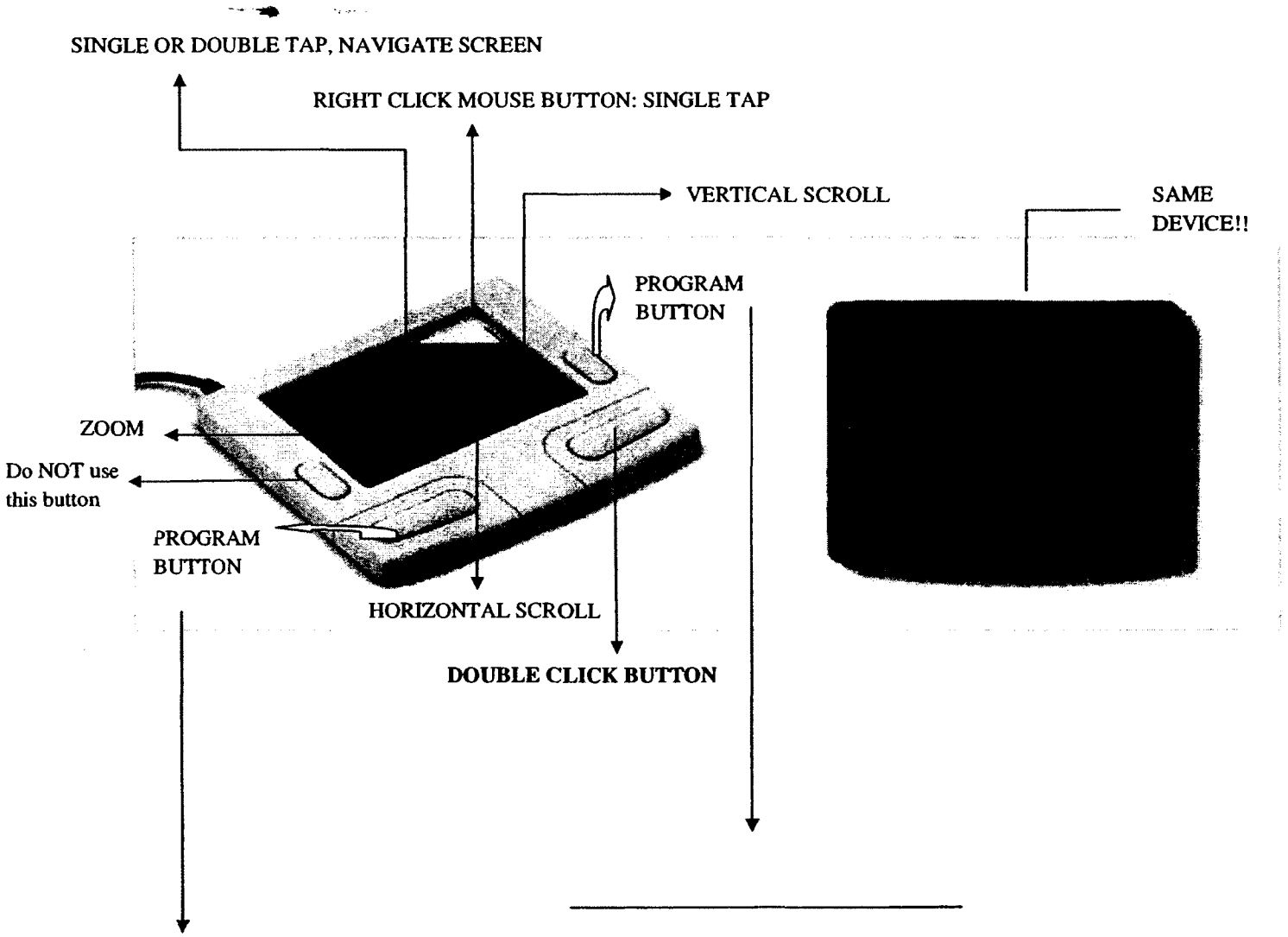
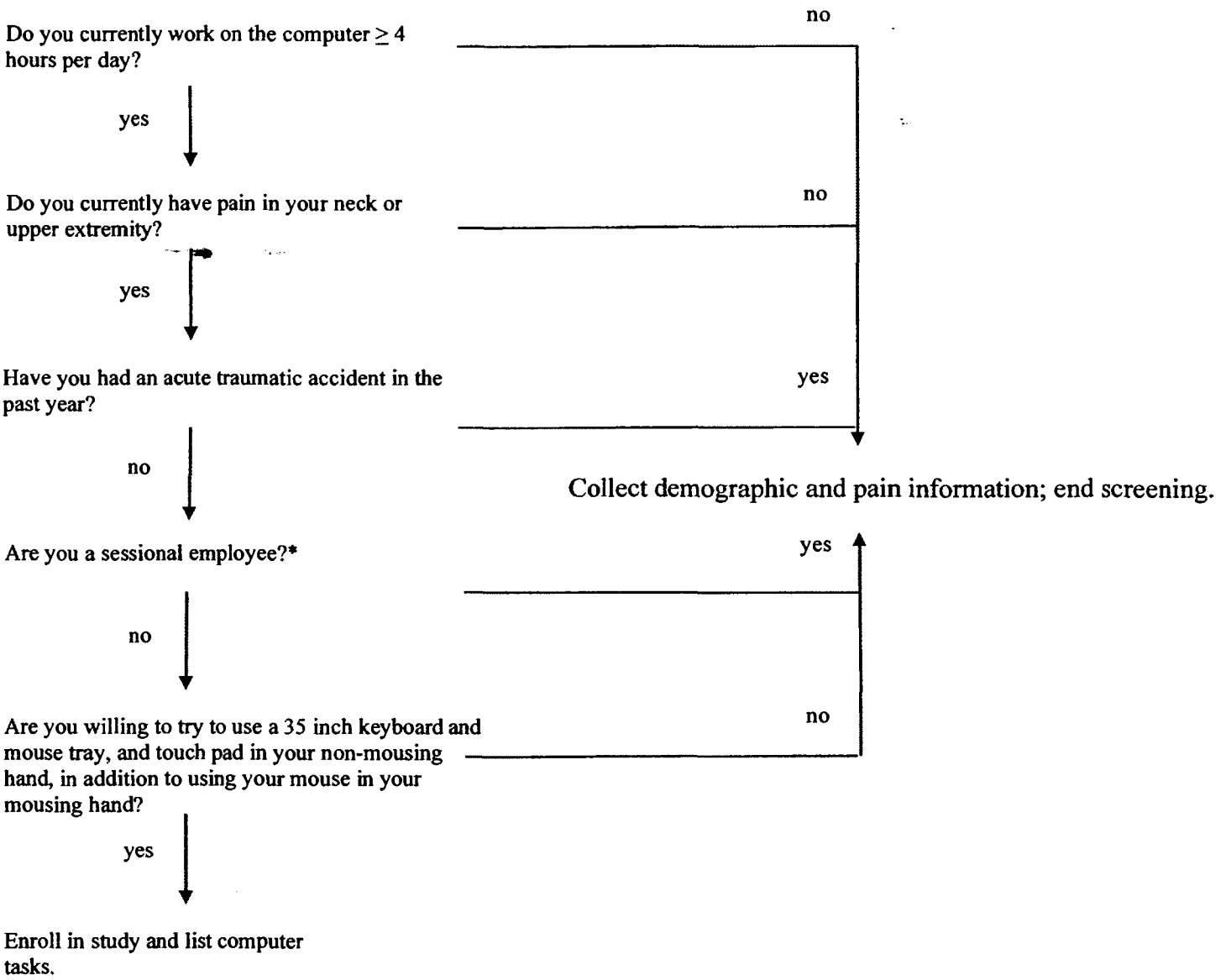
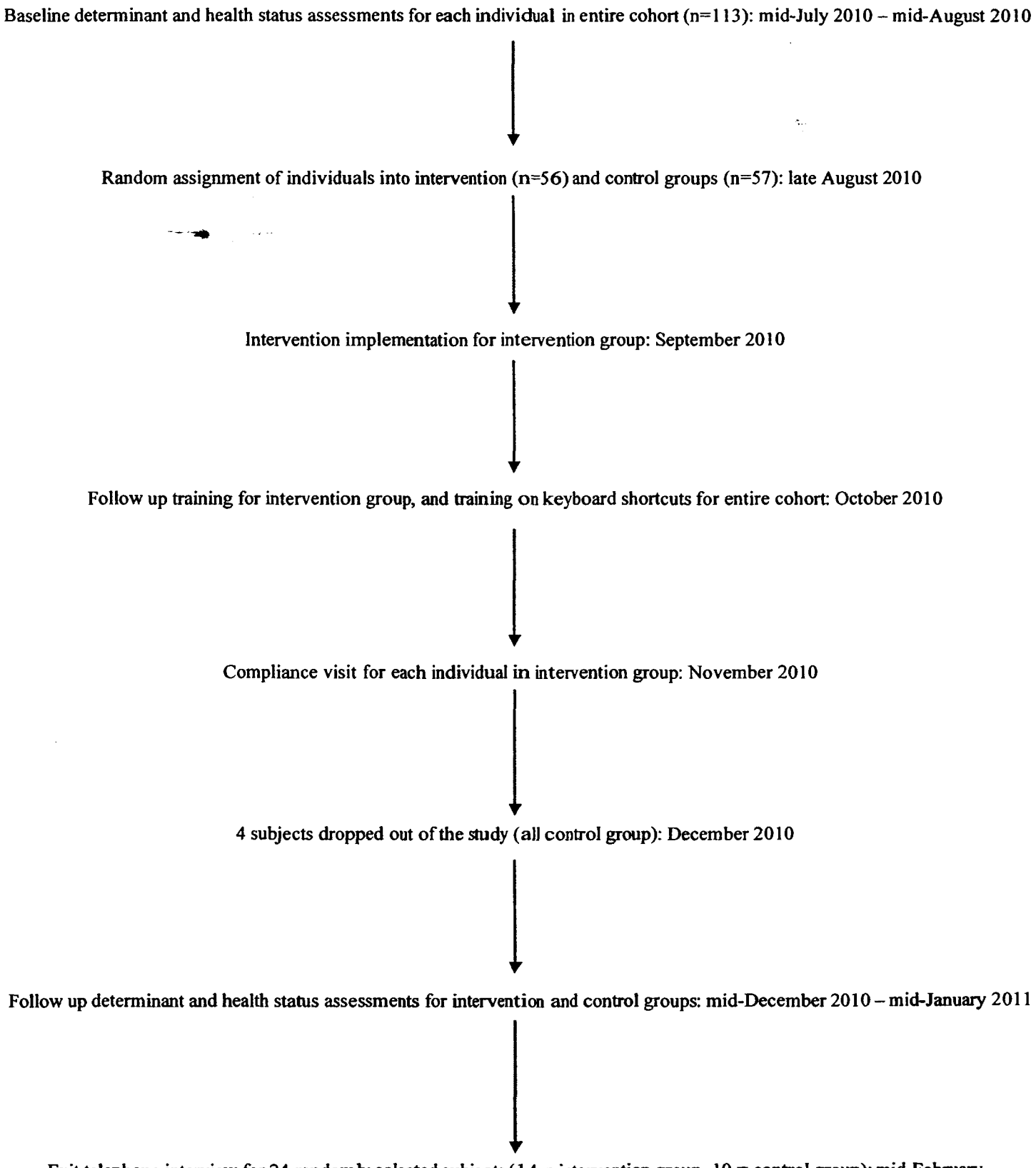


Figure2. Telephone screening survey and inclusion criteria




*A sessional employee is only employed during the legislative session, which lasts either 4 or 6 months per calendar year. A non-sessional employee works all year. The non-session part of the year is called the interim.

Figure3.Timeline and flowchart



# Table 2: Data collection assessment tools

| | Recruitment | Baseline | Follow-up |
|---|---|---|---|
| **Survey screening assessment** | | | |
| Age | √ | | |
| Gender | √ | | |
| Department | √ | | |
| Job title | √ | | |
| Pain status (verbal rating scale 1-5) | √ | | |
| Acute traumatic injury | √ | | |
| Sessional employee | √ | | |
| **Observational exposure assessment** | | | |
| Modified Computer Rapid Upper Limb Assessment | | √ | √ |
| Modified Hand Activity Level | | √ | √ |
| Typical day with an average workload | | √ | √ |
| Task | | √ | √ |
| Equipment used | | √ | √ |
| Body Mass Index | | √ | |
| **Interviewer-administered surveys** | | | |
| Self-assessed physical and temporal exposures | | √ | √ |
| Individual determinants | | √ | √ |
| Musculoskeletal pain (verbal rating scale 1-5) | | √ | √ |
| **Self-administered surveys** | | | |
| Psychosocial determinants (Job Content Questionnaire, plus additional items) | | √ | √ |
| Additional individual determinants | | √ | √ |
| Ergonomic knowledge | | √ | √ |
| MOS SF36 | | √ | √ |
| Intervention satisfaction | | | √ |
| **Compliance surveys** | | | |
| Equipment in regular use | | | √ |
| Recommended adjustments and positions | | | √ |
| Alterations to recommended equipment or technique | | | √ |
| **Exit telephone interviews** | | | |
| Work demands pre- and post-intervention | | | √ |
| Subjective effects of intervention | | | √ |

This table lists general items obtained during each of the surveys.
Individual determinants included: socio-demographic factors, history of present illness, and past medical history.
MOS SF36= Medical Outcomes Study Short Form 36.

Table3: Study domains and number of items (or questions) used for each domain

| Domain | Number of items or composite scores |
|---|---|
| Intervention | 1 individual item |
| Physical and temporal loads | 25 individual items |
| Psychosocial exposures | 4 individual items and 4 composite scores |
| Sociodemographic factors | 16 individual items |
| History of present illness | 13 individual items |
| Past medical history | 4 individual items |
| Ergonomic knowledge | 4 individual items |
| Department and job categories | 2 individual items |

Composite psychosocial measures were obtained from Karasek et al. 1985 and Karasek et al. 1998.
Ergonomic knowledge items were adapted from Robertson et al. 2009 and Robertson and O'Neill 2003.

Table4. Individual determinants by study group at baseline

| Variable | Intervention group (n=56) | | Control group (n=53) | | p-value |
|---|---|---|---|---|---|
| Age | | | | | |
| <35years (n, %) | 17 | 30.4 | 18 | 31.6 | 0.97 |
| 35-50 years (n, %) | 21 | 37.5 | 20 | 36.0 | |
| >50 years (n, %) | 18 | 32.1 | 19 | 33.3 | |
| Age, years (mean, IQR) | 43.4 | 27-62 | 43.6 | 26-61 | 0.93 |
| Female (n, %) | 34 | 60.7 | 41 | 39.3 | 0.21 |
| Education | | | | | |
| <2 years college (n, %) | 7 | 12.5 | 11 | 20.8 | 0.25 |
| ≥2 year college or graduate degree (n, %) | 49 | 87.5 | 42 | 79.3 | |
| Race | | | | | |
| White, European decent (n, %) | 50 | 89.3 | 44 | 83.0 | 0.34 |
| Marital status | | | | | |
| Married (n, %) | 41 | 73.2 | 37 | 69.1 | 0.69 |
| Not married (n, %) | 15 | 26.8 | 16 | 30.1 | |
| Salary | | | | | |
| <$75,000.00 (n, %) | 30 | 53.6 | 33 | 62.3 | 0.36 |
| ≥$75,000.00 (n, %) | 26 | 46.4 | 20 | 37.7 | |
| House work or hobbies | | | | | |
| <3 hours/week (n, %) | 13 | 23.2 | 9 | 17.0 | 0.68 |
| 3-6 hours/week (n, %) | 19 | 33.9 | 21 | 39.6 | |
| >6 hours/week (n, %) | 24 | 42.9 | 23 | 43.4 | |
| Child care | | | | | |
| No children at home or share responsibility (n, %) | 35 | 62.5 | 39 | 73.6 | 0.54 |
| Primary responsibility (n, %) | 21 | 37.5 | 14 | 26.4 | |
| Elder care | | | | | |
| No (n, %) | 50 | 89.3 | 45 | 84.9 | 0.50 |
| Smoking status | | | | | |
| No (n, %) | 55 | 98.2 | 47 | 88.7 | † |
| Handedness | | | | | |
| Right (n, %) | 49 | 87.5 | 45 | 84.9 | 0.69 |
| Baseline mousing hand | | | | | |
| Right (n, %) | 55 | 98.2 | 50 | 94.3 | † |
| Systemic or metabolic morbidity | | | | | |
| No (n, %) | 48 | 85.7 | 50 | 94.3 | † |
| Work absence (# of days in past 2 months) (median, IQR) | 0.2 | 0.1-0.7 | 0.2 | 0.1-0.5 | 0.99 |
| Difficulty sleeping | | | | | |
| Severe difficulty (n, %) | 24 | 42.9 | 10 | 17.5 | **<0.01** |
| Musculoskeletal pain | | | | | |
| Length of time experiencing pain | | | | | |
| <1 year (n, %) | 16 | 28.6 | 19 | 33.3 | 0.75 |
| 1 year (n, %) | 12 | 21.4 | 9 | 15.8 | |
| 2 years (n, %) | 7 | 12.5 | 5 | 8.8 | |
| ≥ 3 years (n, %) | 21 | 37.5 | 24 | 42.1 | |
| Exacerbation of regional musculoskeletal pain in past 2 months | | | | | |
| No (n, %) | 52 | 92.9 | 52 | 98.1 | † |
| Herniated disc low back or neck | | | | | |
| No (n, %) | 52 | 92.9 | 49 | 92.5 | † |
| Workers' Compensation | | | | | |
| No (n, %) | 56 | 100.0 | 52 | 98.1 | † |
| Medical care or physical rehabilitation in past 2 months | | | | | |
| No (n, %) | 47 | 83.9 | 44 | 83.0 | † |
| Currently taking medication | | | | | |
| No (n, %) | 48 | 85.7 | 49 | 92.5 | † |
| Surgery in past 5 years | | | | | |
| No (n, %) | 50 | 89.3 | 52 | 98.1 | † |
| Modified work ability index | | | | | |
| Unlikely or not certain (n, %) | 7 | 12.5 | 4 | 7.0 | 0.33 |
| Relatively certain (n, %) | 49 | 87.5 | 53 | 93.0 | |
| Daily physical activity | | | | | |
| No (n, %) | 23 | 41.1 | 30 | 56.6 | 0.11 |
| Yes (n, %) | 33 | 58.9 | 23 | 43.4 | |

$X^2$ test was used for categorical measures; †=p-values were not calculated when there were less than 5 observations per cell. t-test was used for continuous variables with normal distributions. Wilcoxon rank-sum test was used for continuous variables with non-parametric distributions. IQR= inter-quartile range. Work Ability Index (Ilmarinen, J. 2007) is composed of 7 items. We used a modified version of 1 of the 7 items: Do you believe that, from the standpoint of your health, you will be able to do your job 2 years from now? Bold value=significant result.

Table5. Physical and temporal determinants by study group at baseline

| Variable | Intervention group (n=56) | | Control group (n=53) | | p-value |
|---|---|---|---|---|---|
| Typical day w/ average workload | | | | | |
| Yes (n, %) | 50 | 89.3 | 47 | 88.7 | 0.99 |
| Physical and temporal load | | | | | |
| Hours per week on keyboard (mean, IQR) | 20.8 | 8-35 | 22.8 | 5-35 | 0.26 |
| Hours per week on pointing device (mean, IQR) | 22.5 | 10-35 | 25.4 | 10-35 | *0.08* |
| Hours per week on job at agency (mean, IQR) | 40.7 | 40-45 | 39.6 | 35-43 | 0.13 |
| Hours on computer before taking break | | | | | |
| <1hour (n, %) | 6 | 10.7 | 12 | 21.1 | 0.27 |
| 1-3 hours (n, %) | 35 | 62.5 | 34 | 59.7 | |
| >3hours (n, %) | 15 | 26.8 | 11 | 19.3 | |
| Years worked in job title (mean, IQR) | 6.1 | 1-22 | 7.3 | 1-22 | 0.37 |
| Years worked at agency (mean, IQR) | 9.8 | 2-23 | 10.1 | 1-23 | 0.85 |
| UE support | | | | | |
| No (n, %) | 15 | 26.8 | 18 | 34.0 | 0.42 |
| Yes (n, %) | 41 | 73.2 | 35 | 66.0 | |
| Work in pronation or wrist extended, flexed, or deviated | | | | | |
| No (n, %) | 14 | 25.0 | 11 | 20.8 | 0.60 |
| Yes (n, %) | 42 | 75.0 | 42 | 79.3 | |
| High finger effort at work | | | | | |
| No (n, %) | 16 | 28.6 | 12 | 22.6 | 0.48 |
| Yes (n, %) | 40 | 71.4 | 41 | 77.4 | |
| Hold neck and UE in static posture | | | | | |
| No (n, %) | 6 | 10.7 | 5 | 9.4 | 0.82 |
| Yes (n, %) | 50 | 89.3 | 48 | 90.6 | |
| Deadlines | | | | | |
| No (n, %) | 6 | 10.7 | 2 | 3.8 | † |
| Yes (n, %) | 50 | 89.3 | 51 | 96.2 | |
| Overtime | | | | | |
| No (n, %) | 24 | 42.9 | 28 | 52.8 | 0.30 |
| Yes (n, %) | 32 | 57.1 | 25 | 47.2 | |
| Daily hours telephone use (mean, IQR) | 1.9 | 1.3-2.4 | 1.8 | 1.5-2.2 | 0.87 |
| Other than computer work, repetitive work w/ motions ≤15 seconds | | | | | |
| No (n, %) | 38 | 67.9 | 33 | 62.3 | 0.54 |
| Yes (n, %) | 18 | 32.1 | 20 | 37.7 | |
| Hold object by pinching | | | | | |
| No (n, %) | 21 | 37.5 | 25 | 47.2 | 0.31 |
| Yes (n, %) | 35 | 62.5 | 28 | 52.8 | |
| Daily break time | | | | | |
| <I hour (n, %) | 47 | 83.9 | 43 | 81.1 | 0.70 |
| ≥1 hour (n, %) | 9 | 16.1 | 10 | 18.9 | |
| Work more than I job in which use computer | | | | | |
| No (n, %) | 46 | 82.1 | 45 | 84.9 | 0.70 |
| Yes (n, %) | 10 | 17.9 | 8 | 15.1 | |
| Number years of computer use over lifetime (mean, IQR) | 21.8 | 16-25 | 20.6 | 17-25 | 0.31 |
| Weekly time spent on home computer use | | | | | |
| 0-3 hours (n, %) | 23 | 41.1 | 27 | 47.4 | 0.77 |
| 3-6 hours (n, %) | 10 | 17.9 | 10 | 17.5 | |
| >6hours (n, %) | 23 | 41.1 | 20 | 35.1 | |
| Weekly time spent on PDA or cell phone | | | | | |
| 0-3 hours (n, %) | 37 | 66.1 | 40 | 70.2 | † |
| 3-6 hours (n, %) | 8 | 14.3 | 4 | 7.0 | |
| >6hours (n, %) | 11 | 19.6 | 13 | 22.8 | |

$X^2$ test was used for categorical measures; † = p-values were not calculated when there were less than 5 observations per cell.
t-test was used for continuous variables with normal distributions. IQR= inter-quartile range. UE = upper extremity. PDA = personal digital assistant.
Italics=borderline significant result.

## Table6. Psychosocial determinants by study group at baseline

| Variable | Intervention group (n=56) | | Control group (n=53) | | p-value |
|---|---|---|---|---|---|
| JCQ | | | | | |
| Quadrant term for job strain | | | | | |
| Low (n, %) | 15 | 26.8 | 10 | 17.5 | 0.50 |
| Moderate (n, %) | 27 | 48.2 | 31 | 54.4 | |
| High (n, %) | 14 | 25.0 | 16 | 28.1 | |
| Linear function term for job strain | | | | | |
| Low (n, %) | 18 | 32.1 | 19 | 33.3 | 0.18 |
| Moderate (n, %) | 25 | 44.6 | 17 | 29.8 | |
| High (n, %) | 13 | 23.2 | 21 | 36.8 | |
| Supervisor support | | | | | |
| Low (n, %) | 40 | 17.7 | 11 | 19.3 | 0.88 |
| High (n, %) | 16 | 82.1 | 46 | 80.7 | |
| Skill use (mean, IQR) | 17.8 | 17.0-19.0 | 17.5 | 16-19 | 0.49 |
| Decision making authority (mean, IQR) | 16.7 | 14.0-18.0 | 16.8 | 16-18 | 0.90 |
| Decision latitude (mean, IQR) | 34.5 | 30.5-38.0 | 34.3 | 31-37 | 0.82 |
| Psychological job demand (mean, IQR) | 33.9 | 31.0-36.0 | 33.2 | 30-36 | 0.46 |
| Linear function term for job strain (mean, IQR) | -0.3 | -3.3+1.8 | -0.5 | -2.5+1.5 | 0.71 |
| Supervisor support (mean, IQR) | 12.3 | 11.0-14.0 | 12.0 | 11.0-12.0 | 0.54 |
| How satisfied are you w/ your job | | | | | |
| Very dissatisfied, somewhat dissatisfied or neither (n, %) | 10 | 17.7 | 11 | 19.3 | 0.84 |
| Somewhat satisfied or very satisfied (n, %) | 46 | 82.1 | 46 | 80.7 | |
| Leave work in next 2 years b/c you are dissatisfied | | | | | |
| No (n, %) | 46 | 82.1 | 43 | 81.1 | 0.89 |
| Yes (n, %) | 10 | 17.9 | 10 | 18.9 | |
| Obligated to turn away from computer to do non-computer tasks | | | | | |
| No (n, %) | 15 | 26.8 | 14 | 26.4 | 0.97 |
| Yes (n, %) | 41 | 73.2 | 39 | 73.6 | |
| Adequate supplies and materials to perform job | | | | | |
| No (n, %) | 8 | 14.3 | 9 | 17.0 | 0.70 |
| Yes (n, %) | 48 | 85.7 | 44 | 83.0 | |

$X^2$ test was used for categorical measures; t-test was used for continuous variables with normal distributions. IQR= inter-quartile range.
Job content questionnaire (JCQ) *Quadrant term* was formed by dichotomizing demands and decision latitude scores at the medians of the current sample; "high job strain" was defined as the combination of demands scores above the median and decision latitude scores below the median, which defined approximately 25% of the cohort. Participants with demands and decision latitude scores both below the median or both above the median were defined as "moderate strain" (approximately 50% of the cohort). Subjects with demands scores below the median and decision latitude scores above the median were defined as "low strain" (approximately 25% of the cohort).
JCQ *Linear function term* is a continuous variable. Job strain was defined as y= (0.5) demands – (0.5) decision latitude. We used tertiles for this continuous variable so that it could be more easily interpreted. We then compared the top (high job strain) and middle tertiles with the bottom tertile (low strain).

## Table7. Department and job categories by study group at baseline

| Variable | Intervention group (n=56) | | Control group (n=53) | | |
|---|---|---|---|---|---|
| | n | % | n | % | p-value |
| Department | | | | | |
| Caucuses (Democratic and Republican parties) | 30 | 53.6 | 33 | 62.3 | 0.66 |
| Technical branches (IT, Fiscal Analysis, Legislative Research, Program Review) | 13 | 23.2 | 10 | 18.9 | |
| Management (Commissions, Management, Administration) | 13 | 23.2 | 10 | 18.9 | |
| Job title | | | | | |
| Assistants (assistants, press, aides, secretaries) | 36 | 64.3 | 34 | 64.2 | 0.90 |
| Directors (attorneys, directors, administrators, coordinators) | 14 | 25.0 | 12 | 22.6 | |
| Analysts (IT analysts, researchers) | 6 | 10.7 | 7 | 13.2 | |

$X^2$ test was used for categorical measures.
IT= information technology.

## Table8. Ergonomic knowledge by study group at baseline

| Variable | Intervention group (n=56) | | Control group (n=53) | | |
|---|---|---|---|---|---|
| Ergonomic knowledge | n | % | n | % | p-value |
| Overall ergonomic knowledge | | | | | |
| No or little knowledge | 46 | 82.1 | 45 | 84.9 | 0.70 |
| Moderate or expert knowledge | 10 | 17.9 | 8 | 15.1 | |
| Risk factors | | | | | |
| No or little knowledge | 50 | 89.3 | 46 | 86.8 | 0.69 |
| Moderate or expert knowledge | 6 | 10.7 | 7 | 13.2 | |
| Ergonomically correct posture | | | | | |
| No or little knowledge | 48 | 85.7 | 44 | 83.0 | 0.70 |
| Moderate or expert knowledge | 8 | 14.3 | 9 | 17.0 | |
| Ergonomically correct workspace | | | | | |
| No or little knowledge | 51 | 91.2 | 45 | 84.9 | 0.32 |
| Moderate or expert knowledge | 5 | 8.9 | 8 | 15.1 | |

Ergonomic knowledge items were adapted from Robertson et al. 2009. and Robertson and O'Neill 2003.
$X^2$ test was used for categorical measures.

## Table9. Posture and hand activity exposures by study group at baseline

| Variable | Intervention group (n=56) | | Control group (n=53) | | |
|---|---|---|---|---|---|
| RULA posture | mean | IQR | mean | IQR | p-value |
| Preferred limb† | 19.5 | 16.0-22.0 | 18.8 | 16.0-22.0 | 0.50 |
| Non-preferred limb‡ | 16.3 | 14.0-19.0 | 16.2 | 13.0-18.5 | 0.94 |
| Spine and leg | 7.7 | 5.0-11.0 | 7.2 | 5.0-10.0 | 0.44 |
| Spine, leg, preferred limb | 20.6 | 10.5-28.0 | 22.7 | 21.0-29.0 | 0.39 |
| Spine, leg, non-preferred limb | 18.4 | 9.5-25.0 | 20.1 | 19.0-26.0 | 0.44 |
| UE hand activity (HAL) | | | | | |
| Preferred limb | 5.5 | 4.0-7.2 | 5.5 | 4.0-6.6 | 0.85 |
| Non-preferred limb | 2.9 | 1.6-3.9 | 2.6 | 1.6-3.7 | 0.30 |

t-test was used for continuous variables with normal distributions. IQR= inter-quartile range.
RULA = rapid upper limb assessment.
Preferred limb= upper extremity using mouse; Non-preferred limb= upper extremity using either touch pad (Intervention Group) or no pointing device (Control Group).
UE= upper extremity.
Spine=neck, upper back, and trunk.
†RULA Preferred limb= mousing upper extremity comprised the mousing shoulder, elbow, forearm, and wrist.
‡RULA Non-preferred limb = non-mousing upper extremity comprised the non-mousing shoulder, elbow, forearm, and wrist.
HAL=hand activity level.
Time weighted average (TWA) for posture and hand activity were computed for up to 5 computer tasks (data entry, data acquisition, word processing, interactive communication, programming/graphics) in both the morning and afternoon.
In total, data were collected for 4 hours of an 8 hour workday.
Not all subjects performed all 5 tasks over the workday.

Table10. Musculoskeletal pain severity by anatomical region and quality of life by study group at baseline

| Variable | Intervention group (n=56) | | Control group(n=53) | | |
|---|---|---|---|---|---|
| Musculoskeletal pain in past 4 weeks by anatomical region | n | % | n | % | p-value |
| Preferred limb neck/UB | | | | | |
| <Mild pain | 36 | 64.3 | 29 | 54.7 | 0.21 |
| ≥Uncomfortable | 20 | 35.7 | 23 | 43.3 | |
| Non-preferred limb neck/UB | | | | | |
| <Mild pain | 34 | 69.7 | 32 | 60.4 | 0.97 |
| ≥Uncomfortable | 22 | 39.3 | 21 | 39.6 | |
| Preferred limb shoulder | | | | | |
| <Mild pain | 34 | 60.7 | 29 | 54.7 | 0.53 |
| ≥Uncomfortable | 22 | 39.3 | 24 | 45.3 | |
| Non-preferred limb shoulder | | | | | |
| <Mild pain | 36 | 64.3 | 37 | 69.8 | 0.54 |
| ≥Uncomfortable | 20 | 35.7 | 16 | 30.2 | |
| Preferred limb elbow | | | | | |
| <Mild pain | 50 | 89.3 | 46 | 86.8 | 0.69 |
| ≥Uncomfortable | 6 | 10.7 | 7 | 13.2 | |
| Non-preferred limb elbow | | | | | |
| <Mild pain | 52 | 92.9 | 50 | 94.3 | † |
| ≥Uncomfortable | 4 | 7.1 | 3 | 5.7 | |
| Preferred limb forearm | | | | | |
| <Mild pain | 44 | 78.6 | 44 | 83.0 | 0.56 |
| ≥Uncomfortable | 12 | 21.4 | 9 | 17.0 | |
| Non-preferred limb forearm | | | | | |
| <Mild pain | 50 | 89.3 | 51 | 96.2 | † |
| ≥Uncomfortable | 6 | 10.7 | 2 | 3.8 | |
| Preferred limb wrist | | | | | |
| <Mild pain | 44 | 78.6 | 36 | 67.9 | 0.21 |
| ≥Uncomfortable | 12 | 21.4 | 17 | 32.1 | |
| Non-preferred limb wrist | | | | | |
| <Mild pain | 52 | 92.9 | 49 | 92.5 | † |
| ≥Uncomfortable | 4 | 7.1 | 4 | 7.6 | |
| Preferred limb digits | | | | | |
| <Mild pain | 49 | 87.5 | 43 | 81.1 | 0.36 |
| ≥Uncomfortable | 7 | 12.5 | 10 | 18.9 | |
| Non-preferred limb digits | | | | | |
| <Mild pain | 52 | 92.9 | 50 | 94.3 | † |
| ≥Uncomfortable | 4 | 7.1 | 3 | 5.7 | |
| Quality of life | | | | | |
| MOS PCS | | | | | |
| <50 | 21 | 37.5 | 20 | 37.7 | 0.96 |
| ≥50 | 35 | 62.5 | 33 | 62.3 | |
| MOS MCS | | | | | |
| <50 | 25 | 44.6 | 20 | 37.7 | 0.46 |
| ≥50 | 31 | 55.4 | 33 | 62.3 | |

Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
All subjects (n=109) were symptomatic in at least 1 anatomical region.
Preferred limb= upper extremity using mouse. Non-preferred limb= upper extremity using either touch pad (Intervention Group) or no pointing device (Control Group).
UB= upper back.
Quality of life was measured by the Medical Outcomes Study Short Form 36v2 (MOS), which computes 2 outcome scores: PCS, or physical component summary and MCS, or mental component summary. The MOS compares the present study sample to the median MOS from the general US population in 1998. Values ≥ 50 represent better quality of life, while values below 50 represent poorer quality of life.
$X^2$ test was used for categorical measures. † = p-values were not calculated when there were less than 5 observations per cell.

Table11. Individual determinants by study group at follow-up

| Variable | Intervention group (n=56) | | Control group (n=53) | | p-value |
|---|---|---|---|---|---|
| House work or hobbies | | | | | |
| <3 hours/week (n, %) | 18 | 32.1 | 17 | 32.1 | 0.63 |
| 3-6 hours/week (n, %) | 19 | 33.9 | 14 | 26.4 | |
| >6 hours/week (n, %) | 19 | 33.9 | 22 | 41.5 | |
| Systemic or metabolic morbidity | | | | | |
| No (n, %) | 51 | 91.1 | 47 | 88.7 | 0.68 |
| Work absence (# of days in past 2 months) (median, IQR) | 0.1 | 0.0-0.1 | 0.1 | 0.0-0.1 | 0.52 |
| Difficulty sleeping | | | | | |
| Severe difficulty (n, %) | 8 | 14.3 | 9 | 17.0 | 0.70 |
| Exacerbation of regional musculoskeletal pain in past 2 months | | | | | |
| No (n, %) | 44 | 78.6 | 45 | 79.0 | 0.96 |
| Herniated disc low back or neck | | | | | |
| No (n, %) | 53 | 94.6 | 47 | 88.7 | † |
| Workers' compensation | | | | | |
| No (n, %) | 52 | 92.9 | 47 | 88.7 | † |
| Medical care or physical rehabilitation in past 2 months | | | | | |
| No (n, %) | 52 | 92.9 | 47 | 88.7 | † |
| Currently taking medication | | | | | |
| No (n, %) | 51 | 91.1 | 49 | 92.5 | † |
| Modified work ability index | | | | | |
| Unlikely or not certain (n, %) | 8 | 14.3 | 3 | 5.7 | 0.33 |
| Relatively certain (n, %) | 48 | 85.7 | 50 | 94.3 | |
| Daily physical activity | | | | | |
| No (n, %) | 27 | 48.2 | 30 | 56.6 | 0.38 |
| Yes (n, %) | 29 | 51.8 | 23 | 43.4 | |

$X^2$ test was used for categorical measures; † = p-values were not calculated when there were less than 5 observations per cell.
Wilcoxon rank-sum test was used for continuous variables with non-parametric distributions. IQR= inter-quartile range.
Work ability Index ( Ilmarinen, J. 2007) is composed of 7 items. We used a modified version of 1 of the 7 items: Do you believe that, from the standpoint of your health, you will be able to do your job 2 years from now?

## Table12. Physical and temporal determinants by study group at follow-up

| Variable | Intervention group (n=56) | | Control group (n=53) | | p-value |
|---|---|---|---|---|---|
| Typical day w/ average workload | | | | | |
| Yes (n, %) | 48 | 85.7 | 51 | 96.2 | 0.68 |
| Physical and temporal load | | | | | |
| Hours per week on keyboard (mean, IQR) | 25.6 | 20-30 | 27.8 | 25-35 | 0.27 |
| Hours per week on pointing device (mean, IQR) | 24.4 | 20-30 | 26.5 | 24-35 | 0.27 |
| Hours per week on job at GA (mean, IQR) | 41.8 | 40-42 | 40.8 | 40-41 | 0.40 |
| Hours on computer before taking break | | | | | |
| <1hour (n, %) | 10 | 17.9 | 9 | 17.0 | 0.16 |
| 1-3 hours (n, %) | 32 | 57.1 | 38 | 71.7 | |
| >3hours (n, %) | 14 | 25.0 | 6 | 11.3 | |
| UE support | | | | | |
| No (n, %) | 34 | 60.7 | 16 | 30.2 | **<0.01** |
| Yes (n, %) | 22 | 39.3 | 37 | 69.8 | |
| Work in pronation or wrist extended, flexed, or deviated | | | | | |
| No (n, %) | 15 | 26.8 | 9 | 17.0 | 0.21 |
| Yes (n, %) | 41 | 73.2 | 44 | 83.0 | |
| Finger effort at work | | | | | |
| No (n, %) | 12 | 21.4 | 14 | 26.4 | 0.54 |
| Yes (n, %) | 44 | 78.6 | 39 | 73.6 | |
| Hold neck and UE in static posture | | | | | |
| No (n, %) | 10 | 17.9 | 5 | 9.4 | 0.20 |
| Yes (n, %) | 46 | 82.1 | 48 | 90.6 | |
| Deadlines | | | | | |
| No (n, %) | 2 | 3.6 | 1 | 2.0 | † |
| Yes (n, %) | 54 | 96.4 | 52 | 98.0 | |
| Overtime | | | | | |
| No (n, %) | 14 | 25.0 | 20 | 37.7 | 0.15 |
| Yes (n, %) | 42 | 75.0 | 33 | 66.3 | |
| Daily hours telephone use (mean, IQR) | 2.1 | 1.0-3.0 | 1.7 | 1.0-2.0 | 0.17 |
| Other than computer work, repetitive work w/ motions ≤15 seconds | | | | | |
| No (n, %) | 34 | 60.7 | 31 | 58.5 | 0.81 |
| Yes (n, %) | 22 | 39.3 | 22 | 41.5 | |
| Hold object by pinching | | | | | |
| No (n, %) | 24 | 42.9 | 33 | 62.3 | **0.04** |
| Yes (n, %) | 32 | 57.1 | 20 | 37.7 | |
| Daily break time | | | | | |
| <1 hour (n, %) | 25 | 44.6 | 24 | 45.3 | 0.95 |
| ≥1 hour (n, %) | 31 | 55.4 | 29 | 54.7 | |
| Work more than 1 job in which use computer | | | | | |
| No (n, %) | 46 | 82.1 | 45 | 84.9 | 0.70 |
| Yes (n, %) | 10 | 17.9 | 8 | 15.1 | |
| Weekly time spent on home computer use | | | | | |
| 0-3 hours (n, %) | 25 | 44.6 | 26 | 49.1 | 0.72 |
| 3-6 hours (n, %) | 10 | 17.9 | 11 | 20.8 | |
| >6hours (n, %) | 21 | 37.5 | 16 | 30.2 | |
| Weekly time spent on PDA or cell phone | | | | | |
| 0-3 hours (n, %) | 32 | 57.1 | 37 | 69.8 | 0.31 |
| 3-6 hours (n, %) | 10 | 17.9 | 5 | 9.4 | |
| >6hours (n, %) | 14 | 25.0 | 11 | 20.8 | |

$X^2$ test was used for categorical measures. † = p-values were not calculated when there were less than 5 observations per cell.
t-test was used for continuous variables with normal distributions. IQR= inter-quartile range.
UE= upper extremity.
PDA = personal digital assistant.
Bold value=significant result.

## Table13. Psychosocial determinants by study group at follow-up

| Variable | Intervention group (n=56) | | Control group (n=53) | | p-value |
|---|---|---|---|---|---|
| JCQ | | | | | |
| Quadrant term for job strain | | | | | |
| Low (n, %) | 9 | 16.1 | 4 | 7.0 | † |
| Moderate (n, %) | 30 | 53.6 | 37 | 64.9 | |
| High (n, %) | 17 | 30.4 | 16 | 28.1 | |
| Linear function term for job strain | | | | | |
| Low (n, %) | 12 | 21.4 | 9 | 15.8 | **0.01** |
| Moderate (n, %) | 29 | 51.8 | 17 | 29.8 | |
| High (n, %) | 15 | 26.8 | 31 | 54.4 | |
| Supervisor support | | | | | |
| Low (n, %) | 41 | 73.2 | 40 | 70.2 | 0.72 |
| High (n, %) | 15 | 26.8 | 17 | 29.8 | |
| Skill use (mean, IQR) | 18.0 | 17.0-19.5 | 17.2 | 16-19 | *0.09* |
| Decision making authority (mean, IQR) | 16.8 | 16.0-18.0 | 16.8 | 14-18 | 0.99 |
| Decision latitude (mean, IQR) | 34.8 | 33.0-38.0 | 34.0 | 30-37 | 0.43 |
| Psychological job demand (mean, IQR) | 35.4 | 32.0-39.0 | 35.4 | 32-38 | 0.96 |
| Linear function term for job strain (mean, IQR) | 0.3 | -1.8+2.5 | 0.7 | -1.5+3.0 | 0.62 |
| Supervisor support (mean, IQR) | 12.5 | 11.0-14.0 | 11.9 | 10.0-13.0 | 0.21 |
| How satisfied are you w/ your job | | | | | |
| Very dissatisfied or somewhat dissatisfied or neither (n, %) | 13 | 23.2 | 9 | 17.0 | 0.42 |
| Somewhat satisfied or very satisfied (n, %) | 43 | 76.8 | 44 | 83.0 | |
| Leave work in next 2 years b/c you are dissatisfied | | | | | |
| No (n, %) | 48 | 85.7 | 46 | 86.8 | 0.87 |
| Yes (n, %) | 8 | 14.3 | 7 | 13.2 | |
| Obligated to turn away from computer to do non-computer tasks | | | | | |
| No (n, %) | 14 | 25.0 | 12 | 22.6 | 0.77 |
| Yes (n, %) | 42 | 75.0 | 41 | 77.4 | |
| Adequate supplies and materials to perform job | | | | | |
| No (n, %) | 7 | 12.5 | 4 | 7.5 | † |
| Yes (n, %) | 49 | 87.5 | 49 | 92.5 | |

$X^2$ test was used for categorical measures; † = p-values were not calculated when there were less than 5 observations per cell.
t-test was used for continuous variables with normal distributions. IQR= inter-quartile range.
Job content questionnaire (JCQ) *Quadrant term* was formed by dichotomizing demands and decision latitude scores at the medians of the current sample; "high job strain" was defined as the combination of demands scores above the median and decision latitude scores below the median, which defined approximately 25% of the cohort. Participants with demands and decision latitude scores both below the median or both above the median were defined as "moderate strain" (approximately 50% of the cohort). Subjects with demands scores below the median and decision latitude scores above the median were defined as "low strain" (approximately 25% of the cohort).
JCQ *Linear function term* is a continuous variable. Job strain was defined as y= (0.5) demands – (0.5) decision latitude. We used tertiles for this continuous variable so that it could be more easily interpreted. We then compared the top (high job strain) and middle tertiles with the bottom tertile (low strain)
Bold value=significant result, where $p \leq 0.05$.
Italics= borderline significant result, where $p \leq 0.10$ to $p > 0.05$.

Table14. Ergonomic knowledge by study group at follow-up

| Variable | Intervention group (n=56) | | Control group (n=53) | | |
|---|---|---|---|---|---|
| Ergonomic knowledge | n | % | n | % | p-value |
| Overall ergonomic knowledge | | | | | |
| No or little knowledge | 53 | 94.6 | 52 | 98.0 | 0.97 |
| Moderate or expert knowledge | 3 | 5.4 | 1 | 2.0 | |
| Risk factors | | | | | |
| No or little knowledge | 51 | 91.1 | 53 | 100.0 | 0.84 |
| Moderate or expert knowledge | 5 | 8.9 | 0 | 0.0 | |
| Ergonomically correct posture | | | | | |
| No or little knowledge | 0 | 0.0 | 52 | 98.1 | **<0.01** |
| Moderate or expert knowledge | 56 | 100.0 | 1 | 1.9 | |
| Ergonomically correct workspace | | | | | |
| No or little knowledge | 1 | 1.8 | 53 | 100.0 | **<0.01** |
| Moderate or expert knowledge | 55 | 98.2 | 0 | 0.0 | |

Ergonomic knowledge items were adapted from Robertson et al. (The effects of an office ergonomics training and chair intervention on worker knowledge, behavior and musculoskeletal risk. 2009.) and Robertson and O'Neill (Reducing musculoskeletal discomfort: effects of an office ergonomics workplace and training intervention. 2003.)
$X^2$ test was used for categorical measures.
Bold value=significant result.

Table15. Improvement or reduction in ergonomic knowledge by study group over study

| Ergonomic knowledge | Intervention group (n=56) | | Control group (n=53) | |
|---|---|---|---|---|
| | n | % | n | % |
| Overall ergonomic knowledge | | | | |
| Moderate or expert knowledge | 7 | 12.5 reduction | 7 | 13.2 reduction |
| Risk factors | | | | |
| Moderate or expert knowledge | 1 | 1.8 reduction | 7 | 13.2 reduction |
| Ergonomically correct posture | | | | |
| Moderate or expert knowledge | 48 | 85.7 improvement | 8 | 15.1 reduction |
| Ergonomically correct workspace | | | | |
| Moderate or expert knowledge | 50 | 89.3 improvement | 0 | 15.1 reduction |

Ergonomic knowledge items were adapted from Robertson et al. (The effects of an office ergonomics training and chair intervention on worker knowledge, behavior and musculoskeletal risk. 2009.) and Robertson and O'Neill (Reducing musculoskeletal discomfort: effects of an office ergonomics workplace and training intervention. 2003.)

## Table16. Posture and hand activity exposures by study group at follow-up

| Variable | Intervention group (n=56) | | Control group (n=53) | | |
|---|---|---|---|---|---|
| Modified RULA posture | mean | IQR | mean | IQR | p-value |
| Preferred limb† | 16.8 | 15.0-18.0 | 19.6 | 19.0-23.0 | **<0.01** |
| Non-preferred limb‡ | 13.4 | 11.0-15.0 | 19.0 | 16.0-22.0 | **<0.01** |
| Spine and LE | 8.2 | 6.0-9.5 | 9.1 | 8.0-11.0 | 0.16 |
| Spine, LE, preferred limb | 18.5 | 17.0-25.0 | 21.0 | 9.0-31.0 | 0.24 |
| Spine, LE, non-preferred limb | 16.6 | 14.0-22.0 | 19.3 | 10.0-29.0 | 0.22 |
| UE hand activity (HAL)/movement | | | | | |
| Preferred limb | 6.0 | 4.8-7.1 | 6.9 | 6.0-8.1 | **0.01** |
| Non-preferred limb | 4.0 | 2.6-5.5 | 2.6 | 0.3-4.2 | **<0.01** |

t-test was used for continuous variables with normal distributions. IQR= inter-quartile range.
RULA = rapid upper limb assessment.
Preferred limb= upper extremity using mouse; Non-preferred limb= upper extremity using either touch pad (Intervention Group) or no pointing device (Control Group).
UE= upper extremity. LE= lower extremity. Spine=neck, upper back, trunk.
†RULA Preferred limb= mousing upper extremity comprised the mousing shoulder, elbow, forearm, and wrist.
‡RULA Non-preferred limb = non-mousing upper extremity comprised the non-mousing shoulder, elbow, forearm, and wrist.
HAL=hand activity level.
Time weighted average (TWA) for posture and hand activity were computed for up to 5 computer tasks (data entry, data acquisition, word processing, interactive communication, programming/graphics) in both the morning and afternoon. Not all subjects performed all 5 tasks over the workday.
In total, data were collected for 4 hours of an 8 hour workday.
Bold value=significant result.

Table17. Musculoskeletal pain severity by anatomical region and quality of life by study group at follow-up

| Variable | Intervention group (n=56) | | Control group (n=53) | | |
|---|---|---|---|---|---|
| Musculoskeletal pain in past 4 weeks by anatomical region | n | % | n | % | p-value |
| Preferred limb neck/UB | | | | | |
| <Mild pain | 48 | 85.7 | 41 | 77.3 | 0.57 |
| ≥Uncomfortable | 8 | 14.3 | 12 | 22.6 | |
| Non-preferred limb neck/UB | | | | | |
| <Mild pain | 48 | 85.7 | 46 | 86.8 | 0.87 |
| ≥Uncomfortable | 8 | 14.3 | 7 | 13.2 | |
| Preferred limb shoulder | | | | | |
| <Mild pain | 50 | 89.3 | 43 | 81.1 | 0.23 |
| ≥Uncomfortable | 6 | 10.7 | 10 | 18.9 | |
| Non-preferred limb shoulder | | | | | |
| <Mild pain | 47 | 83.9 | 47 | 88.7 | 0.47 |
| ≥Uncomfortable | 9 | 16.1 | 6 | 11.3 | |
| Preferred limb elbow | | | | | |
| <Mild pain | 52 | 92.9 | 49 | 92.5 | † |
| ≥Uncomfortable | 4 | 7.1 | 4 | 7.6 | |
| Non-preferred limb elbow | | | | | |
| <Mild pain | 53 | 94.6 | 50 | 94.3 | † |
| ≥Uncomfortable | 3 | 5.4 | 3 | 6.7 | |
| Preferred limb forearm | | | | | |
| <Mild pain | 54 | 96.4 | 48 | 90.6 | † |
| ≥Uncomfortable | 2 | 3.6 | 5 | 9.4 | |
| Non-preferred limb forearm | | | | | |
| <Mild pain | 55 | 98.2 | 52 | 98.1 | † |
| ≥Uncomfortable | 1 | 1.8 | 1 | 1.9 | |
| Preferred limb wrist | | | | | |
| <Mild pain | 52 | 92.9 | 42 | 79.3 | † |
| ≥Uncomfortable | 4 | 7.1 | 11 | 20.8 | |
| Non-preferred limb wrist | | | | | |
| <Mild pain | 54 | 96.4 | 49 | 92.5 | † |
| ≥Uncomfortable | 2 | 3.6 | 4 | 7.6 | |
| Preferred limb digits | | | | | |
| <Mild pain | 53 | 94.6 | 48 | 90.6 | † |
| ≥Uncomfortable | 3 | 5.4 | 5 | 9.4 | |
| Non-preferred limb digits | | | | | |
| <Mild pain | 52 | 92.9 | 50 | 94.3 | † |
| ≥Uncomfortable | 4 | 7.1 | 3 | 6.7 | |
| Quality of life | | | | | |
| MOS SF 36v2 PCS | | | | | |
| <50 | 17 | 30.4 | 16 | 30.2 | 0.87 |
| ≥50 | 39 | 69.6 | 37 | 69.8 | |
| MOS SF 36v2 MCS | | | | | |
| <50 | 29 | 51.8 | 23 | 43.3 | 0.38 |
| ≥50 | 27 | 48.2 | 30 | 56.6 | |

Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized at the median of all anatomical regions combined.
All subjects (n=109) were symptomatic in at least 1 region.
Preferred limb= upper extremity using mouse; Non-preferred limb= upper extremity using either touch pad (Intervention Group) or no pointing device (Control Group).
UB=upper back.
Quality of life was measured by Medical Outcomes Study Short Form 36v2 (MOS), which computes 2 outcome scores: PCS, or physical component summary and MCS, or mental component summary. The MOS compares the present study sample to the median MOS from the general US population in 1998. Values ≥ 50 represent better quality of life, while values below 50 represent poorer quality of life.
$X^2$ test was used for categorical measures. † = p-values were not calculated when there were less than 5 observations per cell.

Table18. Absolute and proportional changes between intervention and control groups by physical exposure

| Variable | Follow-up – baseline | Absolute change in physical exposure = follow-up – baseline | Proportional change in physical exposure † | p-value |
|---|---|---|---|---|
| RULA posture | mean (IQR) | mean | % | |
| IG Preferred limb | 16.8 (15.0-18.0) – 19.5 (16.0-22.0) | -2.7 | 13.8% decrease | **<0.01** |
| CG Preferred limb | 19.6 (16.0-22.0) – 18.8 (16.0-22.0 | 0.8 | 4.3% increase | |
| IG Non-preferred limb | 13.4 (11.0-15.0) – 16.3 (14.0-19.0) | -2.9 | 17.8% decrease | **<0.01** |
| CG Non-preferred limb | 19.0 (16.0-22.0) – 16.2 (13.0-18.5) | 2.8 | 17.3% increase | |
| IG spine and LE | 8.2 (6.0-9.5) – 7.7 (5.0-11.0) | 0.5 | 6.5% increase | **0.03** |
| CG spine and LE | 9.1 (8.0-11.0) – 7.2 (5.0-10.0) | 1.9 | 26.4% increase | |
| IG spine, LE, preferred limb | 18.5 (17.0-25.0) – 20.6 (10.5-28.0) | -2.1 | 10.2% decrease | 0.12 |
| CG spine, LE, preferred limb | 21.0 (9.0-31.0) – 22.7 (21.0-29.0) | -1.7 | 7.5% decrease | |
| IG spine, LE, non-preferred limb | 16.6 (14.0-22.0) – 18.4 (9.5-25.0) | -1.8 | 9.8% decrease | *0.06* |
| CG spine, LE, non-preferred limb | 19.3 (10.0-29.0) – 20.1 (19.0-26.0) | -0.8 | 4.0% decrease | |
| Hand activity (HAL) | | | | |
| IG Preferred limb | 6.0 (4.8-7.1) – 5.5 (4.0-7.2) | 0.5 | 9.1% increase | **0.04** |
| CG Preferred limb | 6.9 (6.0-8.1) – 5.5 (4.0-6.6) | 1.4 | 25.1% increase | |
| IG Non-preferred limb | 4.0 (2.6-5.5) – 2.9 (1.6-3.9) | 1.1 | 37.9% increase | **<0.01** |
| CG Non-preferred limb | 2.6 (0.3-4.2) – 2.6 (1.6-3.7) | 0.0 | 0% change | |

IG= intervention group, where n=56. CG= control group, where n=53.
RULA = rapid upper limb assessment
Preferred limb= upper extremity using mouse.
Non-preferred limb= upper extremity using either touch pad (Intervention Group) or no pointing device (Control Group).
RULA Preferred limb= mousing upper extremity comprised the mousing shoulder, elbow, forearm, and wrist.
RULA Non-preferred limb = non-mousing upper extremity comprised the non-mousing shoulder, elbow, forearm, and wrist.
Spine=neck, upper back, trunk. LE=lower extremity.
Hand activity was measured by HAL (hand activity level).
Absolute physical exposure change = IG f/u-IG baseline physical exposure score or CG f/u-CG baseline, where f/u=follow-up.
Higher absolute negative change values represent a greater reduction in physical exposure; higher absolute positive change values represent a greater increase physical exposure.
†Proportional change in physical exposure IG = ((IG f/u-IG baseline)/IG baseline)*100
†Proportional change in physical exposure CG = ((CG f/u-CG baseline)/CG baseline)*100
†A "decrease" represents a reduction of physical exposure and an "increase" represents greater physical exposure.
p-values were calculated for proportional changes in physical exposure using the 2 sample proportional test.
Bold=significant value. *Italics*=borderline significant value.

## Table19. Absolute and proportional changes between intervention and control groups by health status

| Variable | ≥ Uncomfortable pain (scale score ≥3) | Absolute change in health outcome‡ | Proportional change in health outcome† |
|---|---|---|---|
| Musculoskeletal pain severity by anatomical region | Follow-up – baseline | Follow-up – baseline = | |
| IG Preferred limb neck/upper back | 14.3% – 35.7% | -21.4% | 59.9% decrease |
| CG Preferred limb neck/upper back | 22.6% – 43.3% | -20.7% | 47.7% decrease |
| IG Preferred limb shoulder | 10.7% – 39.3% | -28.6% | 72.8% decrease |
| CG Preferred limb shoulder | 18.9% – 45.3% | -26.4% | 58.3% decrease |
| IG Preferred limb elbow/forearm | 3.6% – 10.7% | -7.1% | 66.4% decrease |
| CG Preferred limb elbow/forearm | 9.4% – 13.2% | -3.8% | 28.8% decrease |
| IG Preferred limb wrist/hand/digits | 7.1% – 21.4% | -14.3% | 66.8% decrease |
| CG Preferred limb wrist/hand/digits | 20.8% – 32.1% | -11.3% | 35.2% decrease |
| IG Non-preferred limb neck/upper back | 14.3% – 39.3% | -25.0% | 63.6% decrease |
| CG Non-preferred limb neck/upper back | 13.2% – 39.6% | -26.4% | 66.7% decrease |
| IG Non-preferred limb shoulder | 17.1% – 35.7% | -18.6% | 52.1% decrease |
| CG Non-preferred limb shoulder | 13.4% – 30.2% | -16.8% | 55.6% decrease |
| IG Non-preferred limb elbow/forearm | 1.8% – 7.1% | -5.3% | 74.6% decrease |
| CG Non-preferred limb elbow/forearm | 1.9% – 5.7% | -3.8% | 66.7% decrease |
| IG Non-preferred limb wrist/hand/digits | 3.6% – 7.1% | -3.5% | 49.3% decrease |
| CG Non-preferred limb wrist/hand/digits | 7.6% – 7.6% | 0.0% | 0% change |
| Quality of life | ≥50 (better quality of life) | | |
| IG PCS | 69.6% – 62.5% | 7.1% | 11.4% improvement |
| CG PCS | 69.8% – 62.3% | 7.5% | 12.1% improvement |
| IG MCS | 48.2% – 55.4% | -7.2% | 13.0% decrement |
| CG MCS | 56.6% – 62.3% | -5.7% | 9.1% decrement |

Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
IG = intervention group, where n=56. CG = control group, where n=53. Follow up = f/u.
Preferred limb= upper extremity using mouse.
Non-preferred limb= upper extremity using either touch pad (Intervention Group) or no pointing device (Control Group).
Medical Outcomes Study Short Form 36v2 (MOS), which computes 2 outcome scores: PCS, or physical component summary and MCS, or mental component summary. The MOS compares the present study sample to the median MOS from the general US population in 1998. Values ≥ 50 represent better quality of life, while values below 50 represent poorer quality of life.
Absolute and proportional pain values represent % change in uncomfortable, miserable or intense pain.
Absolute change score = IG f/u-IG baseline or CG f/u-CG baseline.
‡Greater negative absolute change values in pain represent greater reductions of pain.
‡Greater positive absolute change values in Quality of life represent improved health. Higher negative absolute change values in Quality of life represent greater health decrements.
†Proportional change in health outcome IG= ((IG f/u-IG baseline)/IG baseline)*100.
†Proportional change in health outcome CG= ((CG f/u-CG baseline)/CG baseline)*100.
†A "decrease" represents a proportional reduction of musculoskeletal pain. An improvement represents improved quality of life. A decrement represents poorer quality of life.

## Table20. Summary table of unadjusted and adjusted multivariable linear regression models examining the association between change in ß coefficient of intervention and modified physical exposure (n=109)

| Variable | Unadjusted ß coefficient | 95% CI | | Adjusted ß coefficient | 95% CI | |
|---|---|---|---|---|---|---|
| Modified RULA posture | | | | | | |
| Intervention effect on spine and lower extremity | -0.52 | -1.38 | 0.33 | -0.80 | -1.64 | 0.05 |
| Intervention effect on preferred limb | -1.82 | -3.06 | -0.58 | **-1.89** | -3.10 | -0.68 |
| Intervention effect on non-preferred limb | -2.73 | -3.99 | -1.47 | **-2.64** | -3.92 | -1.37 |
| Intervention effect on spine, LE, preferred limb | -2.75 | -6.03 | 0.54 | -3.16 | -6.44 | 0.13 |
| Intervention effect on spine, LE, non-preferred limb | -2.93 | -5.94 | 0.08 | **-3.45** | -6.44 | -0.46 |
| Modified HAL (hand activity/upper extremity movement) | | | | | | |
| Intervention effect on preferred limb | -0.48 | -0.93 | -0.02 | -0.40 | -0.85 | 0.04 |
| Intervention effect on non-preferred limb | 0.87 | 0.37 | 1.38 | **0.86** | 0.36 | 1.37 |

Regression models were fit using the Generalized Estimating Equation model for normal distributions: $Y = B_0 + B_1X_1 + B_2X_2 + \ldots B_kX_k + E$
A negative ß coefficient indicates the intervention had a protective effect against non-neutral posture or increased hand activity/upper extremity movement at follow up.
RULA = rapid upper limb assessment.
HAL= hand activity level/upper extremity movement.
LE=lower extremity
CI = confidence interval.
Bold=significant value.

## Table21. Final Poisson multivariable regression model estimating effect of intervention on dichotomized regional musculoskeletal pain severity and quality of life (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Regional musculoskeletal pain severity | | | | | | |
| Intervention effect on preferred limb neck and upper back region | 0.93 | 0.91 | 0.95 | **0.95** | 0.93 | 0.98 |
| Intervention effect on non-preferred limb neck and upper back region | 1.03 | 0.90 | 1.18 | 0.99 | 0.98 | 1.01 |
| Intervention effect on preferred limb shoulder region | 0.97 | 0.87 | 1.09 | **0.96** | 0.92 | 1.00 |
| Intervention effect on non-preferred limb shoulder region | 1.00 | 0.94 | 1.06 | 0.97 | 0.92 | 1.01 |
| Intervention effect on preferred limb elbow region | 1.02 | 0.91 | 1.15 | **0.94** | 0.90 | 0.99 |
| Intervention effect on non-preferred limb elbow region | 1.02 | 0.91 | 1.15 | 1.00 | 0.95 | 1.04 |
| Intervention effect on preferred limb forearm region | 0.98 | 0.92 | 1.05 | 0.98 | 0.88 | 1.09 |
| Intervention effect on non-preferred limb forearm region | 1.05 | 1.02 | 1.10 | **1.03** | 1.02 | 1.05 |
| Intervention effect on preferred limb wrist region | 0.89 | 0.80 | 0.98 | **0.86** | 0.79 | 0.95 |
| Intervention effect on non-preferred limb wrist region | 1.01 | 0.98 | 1.05 | **0.98** | 0.97 | 0.98 |
| Intervention effect on preferred limb digits | 0.88 | 0.83 | 0.93 | **0.85** | 0.77 | 0.93 |
| Intervention effect on non-preferred limb digits | 1.01 | 0.91 | 1.11 | 1.00 | 0.95 | 1.04 |
| Quality of life | | | | | | |
| Physical component summary | 1.03 | 0.99 | 1.08 | 1.01 | 0.83 | 1.20 |
| Mental component summary | 0.99 | 0.90 | 1.10 | 1.01 | 0.91 | 1.11 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0 + \beta_1$*intervention $+\sum_{i=2}^{n}\beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
A value below 1.0 indicates the intervention had a protective effect on an anatomical region.
Quality of life=Medical Outcomes Study Short Form 36.
Bold=significant value.

Table22. Participant ratings of effect of engineering controls and training on pain, preference, ease of use, and productivity

| | Yes (%) |
|---|---|
| Decreased pain: KBT* | 73.0 |
| Decreased pain: TP† | 42.9 |
| Increased pain: KBT | 7.1 |
| Increased pain: TP | 8.9 |
| Neither increased nor decreased pain: KBT | 19.9 |
| Neither increased nor decreased pain: TP | 48.2 |
| Liked using KBT | 87.5 |
| Liked using TP | 50.0 |
| Disliked using KBT | 9.1 |
| Disliked using TP | 38.3 |
| Not difficult to use: KBT | 91.1 |
| Not difficult to use: TP | 50.0 |
| Improved productivity: KBT | 46.4 |
| Improved productivity: TP | 12.5 |
| Reduced productivity or no effect: KBT | 53.6 |
| Reduced productivity or no effect: TP | 87.5 |

*KBT = keyboard and mouse tray
†TP = touch pad

## Table23. Response characteristics between participants and non-participants

| Variable | Participants (n=113) | | Non-participants (n=305) | | p-value |
|---|---|---|---|---|---|
| Age (mean, IQR) | 43.6 | 33.0-55.0 | 43.1 | 35.0-53.0 | 0.70 |
| Female gender (n, %) | 75 | 66.4 | 150 | 49.2 | **<0.01** |
| Job title (n, %) | | | | | |
| Assistants (assistants, press, aides, secretaries) | 74 | 65.5 | 175 | 57.4 | 0.16 |
| Directors (attorneys, directors, administrators, coordinators) | 26 | 23.0 | 72 | 23.6 | |
| Analysts (IT analysts, researchers) | 13 | 11.5 | 58 | 19.0 | |
| Department (n, %) | | | | | |
| Caucuses (Democratic and Republican parties) | 67 | 59.3 | 143 | 46.9 | **0.05** |
| Technical branches (IT, Fiscal Analysis, Legislative Research, Program Review) | 23 | 20.3 | 95 | 31.2 | |
| Management (Commissions, Management, Administration) | 23 | 20.5 | 67 | 22.0 | |
| Years working at agency (mean, IQR) | 9.5 | 3.0-14.0 | 10.7 | 4.0-14.0 | 0.17 |
| Income (n, %) | | | | | |
| $≤35,000 | 6 | 5.3 | 6 | 2.0 | 0.17 |
| $>35,000-$75,000 | 59 | 52.2 | 173 | 57.1 | |
| $>$75,000 | 48 | 42.5 | 124 | 40.9 | |

$X^2$ test was used for categorical measures; t-test was used for continuous variables with normal distributions. IQR=inter quartile range
Non-participants= refused, ineligible employees, and non-respondents.
Participants=study cohort.
IT=information technology.
Bold=significant value

# EFFECT MODIFICATION BY AGE

## Table24. Individual characteristics of intervention group by age at baseline (n=56)

| Variable | <44 years old (n=26) | | ≥44 years old (n=30) | | p-value |
|---|---|---|---|---|---|
| Age (n, %) | 26 | 46.3 | 30 | 53.6 | 0.27 |
| Female (n, %) | 18 | 52.9 | 16 | 47.1 | 0.22 |
| Education | | | | | |
| <2 year college (n, %) | 1 | 3.9 | 6 | 20.0 | *0.07* |
| ≥2 college degree or graduate degree (n, %) | 25 | 96.2 | 24 | 80.0 | |
| Race | | | | | |
| White, European decent (n, %) | 23 | 88.5 | 27 | 90.0 | 0.85 |
| Marital status | | | | | |
| Married (n, %) | 17 | 65.4 | 24 | 80.0 | 0.22 |
| Not married (n, %) | 9 | 34.6 | 6 | 20.0 | |
| Salary | | | | | |
| <$75,000.00 (n, %) | 16 | 61.5 | 14 | 46.8 | 0.27 |
| ≥$75,000.00 (n, %) | 10 | 38.5 | 16 | 53.3 | |
| House work or hobbies | | | | | |
| <3 hours/week (n, %) | 4 | 15.4 | 9 | 30.0 | † |
| 3-6 hours/week (n, %) | 9 | 34.6 | 10 | 33.3 | |
| >6 hours/week (n, %) | 13 | 50.0 | 11 | 36.7 | |
| Child care | | | | | |
| No children at home or share responsibility (n, %) | 17 | 65.4 | 19 | 63.3 | 0.87 |
| Primary responsibility (n, %) | 9 | 34.6 | 11 | 36.8 | |
| Elder care | | | | | |
| No (n, %) | 26 | 100.0 | 24 | 80.0 | **0.02** |
| Smoking status | | | | | |
| No (n, %) | 26 | 100.0 | 29 | 96.7 | 0.35 |
| Handedness | | | | | |
| Right (n, %) | 23 | 88.5 | 26 | 86.7 | 0.84 |
| Baseline mousing hand | | | | | |
| Right (n, %) | 26 | 100.0 | 29 | 96.7 | 0.35 |
| Daily physical activity | | | | | |
| No (n, %) | 9 | 34.6 | 14 | 46.7 | 0.36 |
| Yes (n, %) | 17 | 65.4 | 16 | 53.3 | |
| Body mass index, kg/m$^2$ (mean, IQR) | 26.9 | 22.2-28.3 | 26.3 | 23.7-29.1 | 0.72 |
| Systemic or metabolic morbidity | | | | | |
| No (n, %) | 22 | 84.6 | 26 | 86.7 | † |
| Work absence from MSDs (# of days in past 2 months) (median, IQR) | 0.0 | 0.0-0.0 | 0.0 | 0.0-0.0 | 0.51 |
| Musculoskeletal pain | | | | | |
| Length of time experiencing pain | | | | | |
| <1 year (n, %) | 9 | 34.6 | 7 | 23.3 | † |
| 1 year (n, %) | 8 | 30.8 | 4 | 13.3 | |
| 2 years (n, %) | 5 | 19.2 | 2 | 6.7 | |
| ≥ 3 years (n, %) | 4 | 15.4 | 17 | 56.7 | |
| Exacerbation of quadrant musculoskeletal pain in past 2 months | | | | | |
| No (n, %) | 23 | 88.5 | 29 | 96.7 | † |
| Yes (n, %) | 3 | 11.5 | 1 | 3.3 | |
| Current herniated disc low back or neck | | | | | |
| No (n, %) | 25 | 96.2 | 27 | 90.0 | † |
| Medical care or physical rehab in past 2 months | | | | | |
| No (n, %) | 24 | 92.3 | 24 | 80.0 | † |
| Currently taking medication | | | | | |
| No (n, %) | 24 | 92.3 | 24 | 80.0 | † |
| Surgery in past 5 years | | | | | |
| No (n, %) | 23 | 88.5 | 27 | 90.0 | † |
| Difficulty sleeping | | | | | |
| No trouble or mild difficulty to moderate difficulty (n, %) | 14 | 53.8 | 18 | 60.0 | 0.64 |
| Severe difficulty to so much difficulty can't sleep (n, %) | 12 | 46.2 | 12 | 40.0 | |
| Work ability | | | | | |
| Unlikely or not certain (n, %) | 1 | 3.8 | 6 | 25.0 | † |
| Relatively certain (n, %) | 25 | 96.2 | 24 | 75.0 | |

$X^2$ test was used for categorical measures; † = p-values were not calculated when there were less than 5 observations per cell.
Wilcoxon rank-sum test used for continuous variables with non-parametric distributions. IQR= inter-quartile range.
Work ability = Ilmarinen, J., Work Ability Index (WAI). Occupational Medicine, 2007. The WAI is composed of 7 items. We used a modified version of 1 of the 7 items: Do you believe that, from the standpoint of your health, you will be able to do your job 2 years from now?
Bold=significant @ $p \leq 0.05$. Italics=borderline significant between $p \leq 0.10$ and $p > 0.05$.

Table25. Physical and temporal load determinants of intervention group by age at baseline (n=56)

| Variable | <44 years old (n=26) | | ≥44 years old (n=30) | | p-value |
|---|---|---|---|---|---|
| Typical day w/ average workload | | | | | |
| Yes (n, %) | 24 | 92.3 | 26 | 86.7 | † |
| Temporal load at work | | | | | |
| Hours per week on keyboard (mean, IQR) | 23.4 | 15.0-30.0 | 18.6 | 12.0-25.0 | **0.05** |
| Hours per week on pointing device (mean, IQR) | 26.2 | 20.0-30.0 | 19.3 | 10.0-25.0 | **<0.01** |
| Hours per week on job at agency (mean, IQR) | 40.8 | 40.0-40.0 | 40.6 | 40.0-40.0 | 0.80 |
| Hours on computer before taking break | | | | | |
| <1hour (n, %) | 2 | 7.7 | 4 | 13.3 | † |
| 1-3 hours (n, %) | 16 | 61.5 | 19 | 63.3 | |
| >3hours (n, %) | 8 | 30.8 | 7 | 23.3 | |
| Years worked in job title (median, IQR) | 4.0 | 2.0-5.0 | 8.0 | 2.0-12.0 | *0.06* |
| Years worked at agency (mean, IQR) | 5.3 | 2.0-6.0 | 13.7 | 5.0-22.0 | **<0.01** |
| UE support | | | | | |
| No (n, %) | 9 | 34.6 | 6 | 20.0 | 0.22 |
| Yes (n, %) | 17 | 65.4 | 24 | 80.0 | |
| Work in forearm pronation or wrist extended, flexed, or deviated | | | | | |
| No (n, %) | 7 | 26.9 | 7 | 23.3 | 0.76 |
| Yes (n, %) | 19 | 73.1 | 23 | 76.7 | |
| Finger effort at work | | | | | |
| No (n, %) | 4 | 15.4 | 12 | 40.0 | † |
| Yes (n, %) | 22 | 84.6 | 18 | 60.0 | |
| Hold neck and UE in static posture | | | | | |
| No (n, %) | 1 | 3.9 | 5 | 16.7 | † |
| Yes (n, %) | 25 | 96.2 | 25 | 83.3 | |
| Deadlines | | | | | |
| No (n, %) | 1 | 3.9 | 5 | 16.7 | † |
| Yes (n, %) | 25 | 96.2 | 25 | 83.3 | |
| Overtime | | | | | |
| No (n, %) | 11 | 42.3 | 13 | 43.3 | 0.94 |
| Yes (n, %) | 15 | 57.7 | 17 | 56.7 | |
| Daily hours telephone use (mean, IQR) | 2.1 | 1.0-3.0 | 2.1 | 1.0-2.0 | 0.97 |
| Other than computer work, repetitive work w/ motions ≤15 seconds | | | | | |
| No (n, %) | 18 | 69.2 | 20 | 66.7 | 0.84 |
| Yes (n, %) | 8 | 30.8 | 10 | 33.3 | |
| Hold object by pinching w/ fingers | | | | | |
| No (n, %) | 8 | 30.8 | 13 | 43.3 | 0.33 |
| Yes (n, %) | 18 | 69.2 | 17 | 56.7 | |
| Daily break time (lunch, rest periods) | | | | | |
| <1 hour (n, %) | 18 | 69.2 | 23 | 76.6 | 0.70 |
| ≥1 hour (n, %) | 8 | 30.8 | 7 | 23.3 | |
| Work more than 1 job in which use computer | | | | | |
| No (n, %) | 19 | 73.1 | 26 | 86.7 | † |
| Yes (n, %) | 7 | 26.9 | 4 | 13.3 | |
| Number years of computer use over lifetime (mean, IQR) | 18.5 | 16.0-20.0 | 25.5 | 20.0-30.0 | **<0.01** |
| Weekly time spent on home computer use | | | | | |
| 0-3 hours (n, %) | 8 | 30.8 | 15 | 50.0 | † |
| 3-6 hours (n, %) | 6 | 23.1 | 4 | 13.3 | |
| >6 hours (n, %) | 12 | 46.2 | 11 | 36.7 | |
| Weekly time spent on PDA or cell phone | | | | | |
| 0-3 hours (n, %) | 15 | 57.7 | 22 | 73.3 | † |
| 3-6 hours (n, %) | 3 | 11.5 | 5 | 16.7 | |
| >6 hours (n, %) | 8 | 30.8 | 3 | 10.0 | |

$X^2$ test was used for categorical measures. † = p-values were not calculated when there were less than 5 observations per cell.
t-test was used for continuous variables with normal distributions. Wilcoxon rank-sum test used for continuous variables with non-parametric distributions.
IQR= inter-quartile range.
UE = upper extremity.
PDA = personal digital assistant.
Bold=significant @ p≤0.05. Italics=borderline significant between p≤0.10 and p>0.05.

## Table26. Psychosocial determinants of intervention group by age at baseline (n=56)

| Variable | <44 years old (n=26) | | ≥44 years old (n=30) | | p-value |
|---|---|---|---|---|---|
| JCQ | | | | | |
| Quadrant term for job strain | | | | | |
| Low (n, %) | 5 | 19.2 | 10 | 33.3 | 0.43 |
| Moderate (n, %) | 13 | 50.0 | 14 | 46.7 | |
| High (n, %) | 8 | 30.8 | 6 | 20.0 | |
| Linear function term for job strain | | | | | |
| Low (n, %) | 6 | 23.1 | 12 | 40.0 | 0.40 |
| Moderate (n, %) | 13 | 50.0 | 12 | 40.0 | |
| High (n, %) | 7 | 26.9 | 6 | 20.0 | |
| Supervisor support | | | | | |
| Low (n, %) | 17 | 65.4 | 23 | 76.7 | 0.35 |
| High (n, %) | 9 | 34.6 | 7 | 23.3 | |
| Skill use (mean, IQR) | 17.8 | 17.0-19.0 | 18.1 | 17.0-20.0 | 0.50 |
| Decision authority (mean, IQR) | 16.2 | 14.0-18.0 | 17.1 | 14.0-20.0 | 0.39 |
| Decision latitude (mean, IQR) | 33.6 | 32.0-37.0 | 35.7 | 33.0-40.0 | *0.10* |
| Psychological job demand (mean, IQR) | 34.9 | 32.0-37.0 | 35.8 | 33.0-40.0 | 0.54 |
| Linear function term for job strain (median, IQR) | 0.5 | -1.5+2.5 | 0.3 | -2.5-+2.5 | 0.76 |
| Supervisor support (mean, IQR) | 12.4 | 11.0-13.0 | 12.5 | 11.0-14.0 | 0.80 |
| How satisfied are you w/ your job | | | | | |
| Very dissatisfied or somewhat dissatisfied or neither (n, %) | 4 | 15.3 | 6 | 20.0 | † |
| Somewhat satisfied or very satisfied (n, %) | 22 | 84.6 | 24 | 80.0 | |
| Leave work in next 2 years b/c you are dissatisfied | | | | | |
| No (n, %) | 23 | 88.5 | 26 | 86.7 | † |
| Yes (n, %) | 3 | 11.5 | 4 | 13.3 | |
| Obligated to turn away from computer to do non-computer tasks | | | | | |
| No (n, %) | 8 | 30.8 | 7 | 23.3 | 0.53 |
| Yes (n, %) | 18 | 69.2 | 23 | 76.7 | |
| Adequate supplies and materials to perform job | | | | | |
| No (n, %) | 5 | 19.2 | 3 | 10.0 | † |
| Yes (n, %) | 21 | 80.8 | 27 | 90.0 | |

$X^2$ test was used for categorical measures; † = p-values were not calculated when there were less than 5 observations per cell.
t-test was used for continuous variables with normal distributions. Wilcoxon rank-sum test used for continuous variables with non-parametric distributions
IQR= inter-quartile range.
Job content questionnaire (JCQ) *Quadrant term* was formed by dichotomizing demands and decision latitude scores at the medians of the current sample; "high job strain" was defined as the combination of demands scores above the median and decision latitude scores below the median, which defined approximately 25% of the cohort. Participants with demands and decision latitude scores both below the median or both above the median were defined as "moderate strain" (approximately 50% of the cohort). Subjects with demands scores below the median and decision latitude scores above the median were defined as "low strain" (approximately 25% of the cohort).
JCQ *Linear function term* is a continuous variable. Job strain was defined as y= (0.5) demands – (0.5) decision latitude. We used tertiles (33.3%) for this continuous variable so that it could more easily interpreted. We then compared the top (high job strain) and middle tertiles with the bottom tertile (low strain).
Italics=borderline significant between $p \leq 0.10$ and $p > 0.05$.

Table27. Departments and job categories of intervention group by age at baseline (n=56)

| Variable | <44 years old (n=26) | | ≥44 years old (n=30) | | p-value |
|---|---|---|---|---|---|
| Department | | | | | |
| Caucus (democratic and republican parties) (n, %) | 16 | 61.5 | 14 | 46.7 | † |
| Technical branch (IT, fiscal analysis, legislative research, program review) (n, %) | 7 | 26.9 | 6 | 20.0 | |
| Management (commissions, management, administration) (n, %) | 3 | 11.5 | 10 | 33.3 | |
| Job title | | | | | |
| Assistant (assistants, press, aides, secretaries) (n, %) | 19 | 73.1 | 17 | 56.7 | † |
| Director (attorneys, directors, administrators, coordinators) (n, %) | 4 | 15.4 | 10 | 33.3 | |
| Analyst (IT analysts, researchers) (n, %) | 3 | 11.5 | 3 | 10.0 | |

† = p-values were not calculated when there were less than 5 observations per cell.
IT= information technology.

## Table28. Ergonomic knowledge of intervention group by age at baseline (n=56)

| Variable | <44 years old (n=26) | | ≥44 years old (n=30) | | |
|---|---|---|---|---|---|
| Ergonomic knowledge | n | % | n | % | p-value |
| Overall ergonomic knowledge | | | | | |
| No or little knowledge | 22 | 84.6 | 24 | 80.0 | † |
| Moderate or expert knowledge | 4 | 15.4 | 6 | 20.0 | |
| Risk factors | | | | | |
| No or little knowledge | 25 | 96.2 | 25 | 83.3 | † |
| Moderate or expert knowledge | 1 | 3.9 | 5 | 16.7 | |
| Ergonomically correct posture | | | | | |
| No or little knowledge | 24 | 92.3 | 24 | 80.0 | † |
| Moderate or expert knowledge | 2 | 7.7 | 6 | 20.0 | |
| Ergonomically correct workspace | | | | | |
| No or little knowledge | 25 | 96.2 | 26 | 86.7 | † |
| Moderate or expert knowledge | 1 | 3.9 | 4 | 13.3 | |

Ergonomic knowledge items were adapted from Robertson et al. (The effects of an office ergonomics training and chair intervention on worker knowledge, behavior and musculoskeletal risk. 2009.) and Robertson and O'Neill (Reducing musculoskeletal discomfort: effects of an office ergonomics workplace and training intervention. 2003.)

† = p-values were not calculated when there were less than 5 observations per cell

# Table29. Posture and hand activity/upper extremity movement of intervention group by age at baseline (n=56)

| Variable | <44 years old (n=26) | | ≥44 years old (n=30) | | |
|---|---|---|---|---|---|
| Modified RULA posture elements | mean | IQR | mean | IQR | p-value |
| Spine, LE | 9.4 | 8.4-10.6 | 9.5 | 8.6-11.5 | 0.33 |
| Preferred limb | 19.2 | 17.2-20.5 | 18.2 | 16.3-23.9 | 0.90 |
| Non-preferred limb | 16.7 | 13.1-19.9 | 15.2 | 14.6-18.1 | 0.89 |
| Spine, LE, Preferred limb | 25.1 | 2.3-28.8 | 26.1 | 22.0-28.2 | 0.46 |
| Spine, LE, Non-preferred limb | 21.5 | 4.7-25.3 | 21.7 | 20.1-26.5 | 0.49 |
| UE Hand activity (HAL)/movement | | | | | |
| Preferred limb | 5.2 | 3.1-6.3 | 4.3 | 2.8-6.2 | 0.36 |
| Non-preferred limb | 2.6 | 1.6-3.9 | 1.8 | 1.4-4.2 | 0.71 |

RULA = rapid upper limb assessment. Higher RULA scores reflect greater exposure.
UE=upper extremity. Hand activity level measured by HAL. Higher hand activity scores reflect greater exposure.
Preferred limb= mouse use; Non-preferred limb= touch pad.
Preferred limb comprised the shoulder, elbow, forearm, and wrist using the mouse.
Non-preferred limb comprised the shoulder, elbow, forearm, and wrist using the touch pad.
Spine=neck, upper back, trunk.
LE=lower extremity.
Time weighted average (TWA) for posture and hand activity were computed for up to 5 computer tasks (data entry, data acquisition, word processing, interactive communication, programming/graphics) in both the morning and afternoon. However, not all subjects performed all 5 tasks over the workday. In total, data were collected for 4 hours of an 8 hour workday.
t-test used for continuous variables with normal distributions. IQR= inter-quartile range.

Table30. Musculoskeletal pain severity by anatomical quadrant of intervention group by age at baseline (n=56)

| Outcome variable | <44 years old (n=26) | | ≥44 years old (n=30) | | |
|---|---|---|---|---|---|
| Musculoskeletal pain severity in past 4 weeks by quadrant | n | % | n | % | p-value |
| Preferred proximal limb | | | | | |
| ≤Mild pain | 16 | 61.5 | 18 | 60.0 | 0.91 |
| ≥Uncomfortable | 10 | 38.5 | 12 | 40.0 | |
| Non-preferred proximal limb | | | | | |
| ≤Mild pain | 16 | 61.5 | 19 | 63.3 | 0.89 |
| ≥Uncomfortable | 10 | 38.5 | 11 | 36.7 | |
| Preferred distal limb | | | | | |
| ≤Mild pain | 24 | 92.3 | 21 | 70.0 | † |
| ≥Uncomfortable | 3 | 7.7 | 9 | 30.0 | |
| Non-preferred distal limb | | | | | |
| ≤Mild pain | 22 | 84.6 | 27 | 90.0 | † |
| ≥Uncomfortable | 4 | 15.4 | 3 | 10.0 | |

Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the average of the median pain severity value in all 4 quadrants.
All subjects (n=109) were symptomatic in at least 1 region.
Preferred limb= mouse use; Non-preferred limb= touch pad.
Proximal quadrant = neck, upper back, shoulder; distal quadrant = elbow, forearm, wrist, digits.
$X^2$ test was used for categorical measures. p-values were not calculated when there were less than 5 observations per cell.

## Table31. Individual characteristics of intervention group by age at follow-up (n=56)

| Variable | <44 years old (n=26) | | ≥44 years old (n=30) | | p-value |
|---|---|---|---|---|---|
| House work or hobbies | | | | | |
| <3 hours/week (n, %) | 7 | 26.9 | 11 | 36.7 | 0.46 |
| 3-6 hours/week (n, %) | 11 | 42.3 | 8 | 26.7 | |
| >6 hours/week (n, %) | 8 | 30.7 | 11 | 36.7 | |
| Child care | | | | | |
| No children at home or share responsibility (n, %) | 17 | 65.4 | 19 | 63.3 | 0.87 |
| Primary responsibility (n, %) | 9 | 34.6 | 11 | 36.8 | |
| Elder care | | | | | |
| No (n, %) | 26 | 100.0 | 24 | 80.0 | **0.02** |
| Daily physical activity | | | | | |
| No (n, %) | 12 | 46.2 | 15 | 50.0 | 0.77 |
| Yes (n, %) | 14 | 53.9 | 15 | 50.0 | |
| Systemic or metabolic morbidity | | | | | |
| No (n, %) | 24 | 92.3 | 27 | 90.0 | † |
| Work absence from MSDs (# of days in past 2 months) (median, IQR) | 0.0 | 0.0-0.0 | 0.0 | 0.0-0.0 | 0.50 |
| Exacerbation of quadrant musculoskeletal pain in past 2 months | | | | | |
| No (n, %) | 22 | 84.6 | 22 | 73.3 | † |
| Yes (n, %) | 4 | 15.4 | 8 | 26.7 | |
| Current herniated disc low back or neck | | | | | |
| No (n, %) | 26 | 100.0 | 27 | 90.0 | † |
| Medical care or physical rehab in past 2 months | | | | | |
| No (n, %) | 21 | 80.8 | 27 | 90.0 | † |
| Currently taking medication | | | | | |
| No (n, %) | 24 | 92.3 | 27 | 90.0 | † |
| Surgery in past 5 years | | | | | |
| No (n, %) | 23 | 88.5 | 26 | 86.7 | † |
| Difficulty sleeping | | | | | |
| No trouble or mild difficulty to moderate difficulty (n, %) | 23 | 88.5 | 25 | 83.3 | † |
| Severe difficulty to so much difficulty can't sleep (n, %) | 3 | 11.5 | 5 | 16.7 | |
| Work ability | | | | | |
| Unlikely or not certain (n, %) | 2 | 7.7 | 6 | 25.0 | † |
| Relatively certain (n, %) | 24 | 92.3 | 24 | 75.0 | |

$X^2$ test was used for categorical measures; † = p-values were not calculated when there were less than 5 observations per cell.
Wilcoxon rank-sum test used for continuous variables with non-parametric distributions. IQR= inter-quartile range.
Work ability = Ilmarinen, J., Work Ability Index (WAI). Occupational Medicine, 2007. The WAI is composed of 7 items. We used a modified version of 1 of the 7 items: Do you believe that, from the standpoint of your health, you will be able to do your job 2 years from now?
Bold=significant @ $p \leq 0.05$.

Table32. Physical and temporal load determinants of intervention group by age at follow-up (n=56)

| Variable | <44 years old (n=26) | | ≥44 years old (n=30) | | p-value |
|---|---|---|---|---|---|
| Typical day w/ average workload | | | | | |
| Yes (n, %) | 21 | 80.8 | 26 | 86.7 | † |
| Temporal load at work | | | | | |
| Hours per week on keyboard (mean, IQR) | 27.3 | 20.0-35.0 | 24.2 | 20.0-30.0 | 0.25 |
| Hours per week on pointing device (mean, IQR) | 27.1 | 20.0-30.0 | 22.1 | 15.0-30.0 | **0.05** |
| Hours per week on job at agency (mean, IQR) | 40.2 | 40.0-40.0 | 43.3 | 40.0-45.0 | 0.11 |
| Hours on computer before taking break | | | | | |
| <1hour (n, %) | 2 | 7.7 | 8 | 26.7 | † |
| 1-3 hours (n, %) | 17 | 65.4 | 15 | 50.0 | |
| >3hours (n, %) | 8 | 26.9 | 7 | 23.3 | |
| UE support | | | | | |
| No (n, %) | 18 | 69.2 | 16 | 53.3 | 0.22 |
| Yes (n, %) | 8 | 30.8 | 14 | 46.7 | |
| Work in forearm pronation, or wrist extended, flexed, or deviated | | | | | |
| No (n, %) | 8 | 30.8 | 7 | 23.3 | 0.53 |
| Yes (n, %) | 18 | 69.2 | 23 | 76.7 | |
| Finger effort at work | | | | | |
| No (n, %) | 5 | 19.2 | 7 | 23.3 | 0.71 |
| Yes (n, %) | 21 | 80.8 | 23 | 76.7 | |
| Hold neck and UE in static posture | | | | | |
| No (n, %) | 2 | 7.7 | 8 | 26.7 | † |
| Yes (n, %) | 24 | 92.3 | 22 | 73.3 | |
| Deadlines | | | | | |
| No (n, %) | 0 | 0.0 | 2 | 6.7 | † |
| Yes (n, %) | 26 | 100.0 | 28 | 93.3 | |
| Overtime | | | | | |
| No (n, %) | 8 | 30.8 | 6 | 25.0 | 0.35 |
| Yes (n, %) | 18 | 69.2 | 24 | 75.0 | |
| Daily hours telephone use (mean, IQR) | 1.9 | 1.0-2.0 | 1.9 | 1.0-2.0 | 0.97 |
| Other than computer work, repetitive work w/ motions ≤15 seconds | | | | | |
| No (n, %) | 16 | 61.5 | 18 | 60.0 | 0.91 |
| Yes (n, %) | 10 | 38.5 | 12 | 40.0 | |
| Hold object by pinching w/ fingers | | | | | |
| No (n, %) | 12 | 46.2 | 12 | 40.0 | 0.64 |
| Yes (n, %) | 14 | 53.9 | 18 | 60.0 | |
| Daily break time (lunch, rest periods) | | | | | |
| <1 hour (n, %) | 19 | 73.1 | 23 | 76.7 | 0.78 |
| ≥1 hour (n, %) | 7 | 26.9 | 7 | 23.3 | |
| Work more than 1 job in which use computer | | | | | |
| No (n, %) | 19 | 73.1 | 27 | 90.0 | † |
| Yes (n, %) | 7 | 26.9 | 3 | 10.0 | |
| Weekly time spent on home computer use | | | | | |
| 0-3 hours (n, %) | 10 | 38.5 | 15 | 50.0 | † |
| 3-6 hours (n, %) | 4 | 15.4 | 6 | 20.0 | |
| >6 hours (n, %) | 12 | 46.2 | 9 | 30.0 | |
| Weekly time spent on PDA or cell phone | | | | | |
| 0-3 hours (n, %) | 12 | 46.2 | 20 | 66.7 | † |
| 3-6 hours (n, %) | 3 | 11.5 | 7 | 23.3 | |
| >6 hours (n, %) | 11 | 42.3 | 3 | 10.0 | |

$X^2$ test was used for categorical measures. † = p-values were not calculated when there were less than 5 observations per cell.
t-test was used for continuous variables with normal distributions. IQR= inter-quartile range.
UE = upper extremity.
PDA = personal digital assistant.
Bold=significant @ p≤0.05.

## Table33. Psychosocial determinants of intervention group by age at follow-up (n=56)

| Variable | <44 years old (n=26) | | ≥44 years old (n=30) | | p-value |
|---|---|---|---|---|---|
| JCQ | | | | | |
| Quadrant term for job strain | | | | | |
| Low (n, %) | 4 | 15.4 | 5 | 16.7 | † |
| Moderate (n, %) | 13 | 50.0 | 17 | 56.7 | |
| High (n, %) | 9 | 34.6 | 8 | 26.7 | |
| Linear function term for job strain | | | | | |
| Low (n, %) | 4 | 15.4 | 8 | 26.7 | 0.56 |
| Moderate (n, %) | 15 | 57.7 | 14 | 46.7 | |
| High (n, %) | 7 | 26.9 | 8 | 26.7 | |
| Supervisor support | | | | | |
| Low (n, %) | 19 | 73.1 | 22 | 73.3 | 0.98 |
| High (n, %) | 7 | 26.9 | 8 | 26.7 | |
| Skill use (mean, IQR) | 17.8 | 15.0-19.0 | 17.7 | 16.0-20.0 | 0.89 |
| Decision making authority (mean, IQR) | 16.2 | 14.0-18.0 | 17.1 | 14.0-20.0 | 0.39 |
| Decision latitude (mean, IQR) | 34.0 | 31.0-37.0 | 34.9 | 30.0-40.0 | 0.56 |
| Psychological job demand (mean, IQR) | 34.5 | 32.0-36.0 | 33.5 | 31.0-36.0 | 0.49 |
| Linear function term for job strain (median, IQR) | 0.3 | -1.5+2.5 | 0.5 | -2.5+2.5 | 0.69 |
| Supervisor support (mean, IQR) | 11.8 | 11.0-14.0 | 12.6 | 12.0-15.0 | 0.19 |
| How satisfied are you w/ your job | | | | | |
| Very dissatisfied or somewhat dissatisfied or neither (n, %) | 6 | 23.1 | 7 | 23.3 | 0.98 |
| Somewhat satisfied or very satisfied (n, %) | 20 | 76.9 | 23 | 76.7 | |
| Leave work in next 2 years b/c you are dissatisfied | | | | | |
| No (n, %) | 22 | 84.6 | 26 | 86.7 | † |
| Yes (n, %) | 4 | 15.4 | 4 | 13.3 | |
| Obligated to turn away from computer to do non-computer tasks | | | | | |
| No (n, %) | 7 | 26.9 | 7 | 23.3 | 0.78 |
| Yes (n, %) | 19 | 73.1 | 23 | 76.7 | |
| Adequate supplies and materials to perform job | | | | | |
| No (n, %) | 2 | 7.7 | 5 | 16.7 | † |
| Yes (n, %) | 24 | 92.3 | 25 | 83.3 | |

$X^2$ test was used for categorical measures; † = p-values were not calculated when there were less than 5 observations per cell.
t-test was used for continuous variables with normal distributions. Wilcoxon rank-sum test used for continuous variables with non-parametric distributions
IQR= inter-quartile range.
Job content questionnaire (JCQ) *Quadrant term* was formed by dichotomizing demands and decision latitude scores at the medians of the current sample; "high job strain" was defined as the combination of demands scores above the median and decision latitude scores below the median, which defined approximately 25% of the cohort. Participants with demands and decision latitude scores both below the median or both above the median were defined as "moderate strain" (approximately 50% of the cohort). Subjects with demands scores below the median and decision latitude scores above the median were defined as "low strain" (approximately 25% of the cohort).
JCQ *Linear function term* is a continuous variable. Job strain was defined as y= (0.5) demands – (0.5) decision latitude. We used tertiles (33.3%) for this continuous variable so that it could more easily interpreted. We then compared the top (high job strain) and middle tertiles with the bottom tertile (low strain).

## Table34. Ergonomic knowledge of intervention group by age at follow-up (n=56)

| Variable | <44 years old (n=26) | | ≥44 years old (n=30) | | |
|---|---|---|---|---|---|
| Ergonomic knowledge | n | % | n | % | p-value |
| Overall ergonomic knowledge | | | | | |
| No or little knowledge | 25 | 96.6 | 28 | 93.3 | † |
| Moderate or expert knowledge | 1 | 3.9 | 2 | 6.7 | |
| Risk factors | | | | | |
| No or little knowledge | 25 | 96.2 | 26 | 86.7 | † |
| Moderate or expert knowledge | 1 | 3.9 | 4 | 13.3 | |
| Ergonomically correct posture | | | | | |
| No or little knowledge | 0 | 0.0 | 0 | 0.0 | † |
| Moderate or expert knowledge | 26 | 100.0 | 30 | 100.0 | |
| Ergonomically correct workspace | | | | | |
| No or little knowledge | 0 | 0.0 | 1 | 3.3 | † |
| Moderate or expert knowledge | 26 | 100.0 | 29 | 96.7 | |

Ergonomic knowledge items were adapted from Robertson et al. (The effects of an office ergonomics training and chair intervention on worker knowledge, behavior and musculoskeletal risk. 2009.) and Robertson and O'Neill (Reducing musculoskeletal discomfort: effects of an office ergonomics workplace and training intervention. 2003.)

$X^2$ test was used for categorical measures. † = p-values were not calculated when there were less than 5 observations per cell

## Table35. Posture and hand activity of intervention group by age at follow-up (n=56)

| Exposure | <44 years old (n=26) | | ≥44 years old (n=30) | | |
|---|---|---|---|---|---|
| Modified RULA posture elements | mean | IQR | mean | IQR | p-value |
| Spine, LE | 7.7 | 6.3-9.5 | 8.1 | 7.5-10.7 | 0.14 |
| Preferred limb | 16.3 | 15.1-18.6 | 16.4 | 15.9-18.0 | 0.72 |
| Non-preferred limb | 13.1 | 12.3-15.7 | 13.9 | 11.2-15.1 | 0.80 |
| Spine, LE, Preferred limb | 23.9 | 21.6-26.9 | 23.4 | 20.2-26.8 | 0.77 |
| Spine, LE, Non-preferred limb | 20.8 | 14.1-22.4 | 20.3 | 13.9-23.3 | 0.85 |
| UE hand activity (HAL) | | | | | |
| Preferred limb | 5.4 | 4.5-6.8 | 4.8 | 3.2-6.0 | **0.05** |
| Non-preferred limb | 4.0 | 2.3-5.4 | 4.5 | 3.0-5.6 | 0.43 |

RULA = rapid upper limb assessment. Higher RULA scores reflect greater exposure.
UE=upper extremity. Hand activity level measured by HAL. Higher hand activity scores reflect greater exposure.
Preferred limb= mouse use; Non-preferred limb= touch pad.
Preferred limb comprised the shoulder, elbow, forearm, and wrist using the mouse.
Non-preferred limb comprised the shoulder, elbow, forearm, and wrist using the touch pad.
Spine=neck, upper back, trunk.
LE=lower extremity.
Time weighted average (TWA) for posture and hand activity were computed for up to 5 computer tasks (data entry, data acquisition, word processing, interactive communication, programming/graphics) in both the morning and afternoon. However, not all subjects performed all 5 tasks over the workday. In total, data were collected for 4 hours of an 8 hour workday.
t-test used for continuous variables with normal distributions. IQR= inter-quartile range.
Bold=significant @ $p \leq 0.05$.

## Table36. Musculoskeletal pain severity by anatomical quadrant of intervention group by age at follow-up (n=56)

| Outcome variable | <44 years old (n=26) | | ≥44 years old (n=30) | | |
|---|---|---|---|---|---|
| Musculoskeletal pain severity in past 4 weeks by quadrant | n | % | n | % | p-value |
| Preferred proximal limb | | | | | |
| ≤Mild pain | 19 | 73.1 | 29 | 96.7 | † |
| ≥Uncomfortable | 7 | 26.9 | 1 | 3.3 | |
| Non-preferred proximal limb | | | | | |
| ≤Mild pain | 22 | 84.6 | 25 | 83.3 | † |
| ≥Uncomfortable | 4 | 15.4 | 5 | 16.7 | |
| Preferred distal limb | | | | | |
| ≤Mild pain | 25 | 96.2 | 26 | 86.7 | † |
| ≥Uncomfortable | 1 | 3.9 | 4 | 13.3 | |
| Non-preferred distal limb | | | | | |
| ≤Mild pain | 25 | 96.2 | 27 | 90.0 | † |
| ≥Uncomfortable | 1 | 3.9 | 3 | 10.0 | |

Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the average of the median pain severity value in all 4 quadrants.
All subjects (n=109) were symptomatic in at least 1 region.
Preferred limb= mouse use; Non-preferred limb= touch pad.
Proximal quadrant = neck, upper back, shoulder; distal quadrant = elbow, forearm, wrist, digits.
$X^2$ test was used for categorical measures. p-values were not calculated when there were less than 5 observations per cell.

## Table37. Absolute % change in musculoskeletal pain severity by anatomical quadrant and age over time (n=56)

| Outcome variable | <44 years old (n=26) | ≥44 years old (n=30) |
|---|---|---|
| Musculoskeletal pain severity | Follow-up-baseline (%) | Follow-up-baseline (%) |
| Preferred proximal limb ≥Uncomfortable | 11.6% reduction | 36.7% reduction |
| Non-preferred proximal limb ≥Uncomfortable | 23.1% reduction | 20.0% reduction |
| Preferred distal limb ≥Uncomfortable | 3.8% reduction | 16.7% reduction |
| Non-preferred distal limb ≥Uncomfortable | 11.5% reduction | 0.0% reduction |

Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the average of the median pain severity values in all 4 quadrants.
All subjects (n=109) were symptomatic in at least 1 region.
Preferred limb= mouse use; Non-preferred limb= touch pad.
Proximal quadrant = neck, upper back, shoulder; distal quadrant = elbow, forearm, wrist, digits.

## Table 38. Relation between physical exposure and age over time

| | Baseline (B) | | | | Follow-up (FU) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <44 years old (n=26) | | ≥44 years old (n=30) | | <44 years old (n=26) | | ≥44 years old (n=30) | | <44 years old | ≥44 years old | $R^2$ | |
| Modified Computer RULA | Exposure range on absolute scale | Mean | Exposure range on absolute scale | Mean | Exposure range on absolute scale | Mean | Exposure range on absolute scale | Mean | Absolute mean change in physical exposure | | B | FU |
| Spine and LE | 8-9 | 8.5 | 9-11 | 10.0 | 7-8 | 7.5 | 8-9 | 8.5 | -1.0 | -1.5 | .03 | .02 |
| Preferred limb | 16-17 | 16.5 | 15-16 | 15.5 | 16-17 | 16.5 | 16-16 | 16.0 | 0.0 | +0.5 | .09 | .02 |
| Non-preferred limb | 15-15 | 15.0 | 15-15 | 15.0 | 13-14 | 13.5 | 12-13 | 12.5 | -1.5 | -2.5 | .01 | .01 |
| Spine, LE, preferred limb | 26-27 | 26.5 | 25-26 | 25.5 | 23-24 | 23.5 | 24-26 | 25.0 | -3.0 | -0.5 | .08 | .03 |
| Spine, LE, non-preferred limb | 24-24 | 24.0 | 24-24 | 24.0 | 21-22 | 21.5 | 22-23 | 22.5 | -2.5 | -1.5 | .00 | .00 |
| Hand activity/UE movement | | | | | | | | | | | | |
| Preferred limb | 4.5-5.5 | 5.0 | 3.5-4.5 | 4.0 | 5.0-5.8 | 5.4 | 4.0-5.0 | 4.5 | +0.4 | +0.5 | .09 | .08 |
| Non-preferred limb | 3.0-3.5 | 3.3 | 2.5-3.0 | 2.7 | 3.9-4.0 | 4.0 | 4.0-4.1 | 4.1 | +0.7 | +1.4 | .01 | .00 |

Values based on Appendix A1, Figures 1-7. Exposure values are approximate estimates.
RULA = rapid upper limb assessment. Higher RULA scores reflect greater exposure.
Hand activity level measured by modified HAL. Higher hand activity scores reflect greater exposure.
Preferred limb= mouse use; Non-preferred limb= touch pad.
Preferred limb comprised the shoulder, elbow, forearm, and wrist using the mouse.
Non-preferred limb comprised the shoulder, elbow, forearm, and wrist using the touch pad.
Spine=neck, upper back, trunk.
UE=upper extremity. LE=lower extremity.
Absolute mean change in physical exposure: positive values represent increases in exposure; negative values represent reductions in exposure.
$R^2$ = goodness of fit (% variation of the data explained by the fitted line; the closer the points to the line, the better the fit).

Table39. Intervention compliance by age at follow-up (n=56)

| Variable | <44 years old (n=26) | | ≥44 years old (n=30) | |
|---|---|---|---|---|
| Compliance | n | % | n | % |
| Is equipment used regularly (yes) | | | | |
| Keyboard/mouse tray | 23 | 88.5 | 30 | 100.0 |
| Touch pad | 14 | 53.8 | 28 | 93.3 |
| Adherence to recommended adjustments (yes) | | | | |
| Keyboard/mouse tray | 20 | 66.7 | 30 | 100.0 |
| Touch pad | 15 | 56.7 | 27 | 90.0 |
| Alterations to recommended equipment (no) | | | | |
| Keyboard/mouse tray | 26 | 100.0 | 30 | 100.0 |
| Touch pad | 23 | 88.5 | 29 | 96.7 |
| Alterations to recommended technique (no) | | | | |
| Keyboard/mouse tray | 26 | 100.0 | 30 | 100.0 |
| Touch pad | 24 | 92.3 | 30 | 100.0 |

Table 40. Regression models estimating association between dichotomous musculoskeletal pain severity in upper extremity quadrant and interaction between modified RULA posture*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| Preferred proximal upper extremity quadrant | | | |
| RULA spine, LE (high) | 1.01 | 0.93 | 1.11 |
| Age (≥44 years) | 1.02 | 0.73 | 1.42 |
| RULA spine, LE (high)*Age (≥44 years) | 0.89 | 0.74 | 1.08 |
| RULA preferred limb (high) | 1.13 | 1.09 | 1.17 |
| Age (≥44 years) | 0.94 | 0.86 | 1.04 |
| RULA preferred limb (high)*Age (≥44 years) | 1.04 | 0.89 | 1.21 |
| RULA non-preferred limb (high) | 0.83 | 0.71 | 0.96 |
| Age (≥44 years) | 0.84 | 0.86 | 0.94 |
| RULA non-preferred limb (high)*Age (≥44 years) | **1.22** | 1.06 | 1.40 |
| RULA spine, LE, preferred limb (high) | 0.89 | 0.70 | 1.12 |
| Age (≥44 years) | 0.85 | 0.76 | 0.96 |
| RULA spine, LE, preferred limb (high)*Age (≥44 years) | **1.18** | 1.06 | 1.32 |
| RULA spine, LE, non-preferred limb (high) | 0.84 | 0.78 | 0.90 |
| Age (≥44 years) | 0.92 | 0.66 | 1.32 |
| RULA spine, LE, non-preferred limb (high)*Age (≥44 years) | 1.08 | 0.91 | 1.30 |
| Non-preferred proximal upper extremity quadrant | | | |
| RULA spine, LE (high) | 1.09 | 1.00 | 1.19 |
| Age (≥44 years) | 1.16 | 0.92 | 1.46 |
| RULA spine and LE (high)*Age (≥44 years) | 0.85 | 0.65 | 1.12 |
| RULA preferred limb (high) | 1.13 | 1.07 | 1.19 |
| Age (≥44 years) | 1.06 | 0.92 | 1.22 |
| RULA preferred limb (high)*Age (≥44 years) | 0.99 | 0.75 | 1.31 |
| RULA non-preferred limb (high) | 1.02 | 0.69 | 1.49 |
| Age (≥44 years) | 0.84 | 0.91 | 1.39 |
| RULA non-preferred limb (high)*Age (≥44 years) | 0.90 | 0.59 | 1.37 |
| RULA spine, LE, preferred limb (high) | 1.00 | 0.79 | 1.28 |
| Age (≥44 years) | 0.85 | 0.85 | 1.16 |
| RULA spine, LE, preferred limb (high)*Age (≥44 years) | 1.12 | 0.88 | 1.42 |
| RULA spine, LE, non-preferred limb (high) | 0.95 | 0.74 | 1.23 |
| Age (≥44 years) | 0.99 | 0.88 | 1.12 |
| RULA spine, LE, non-preferred limb (high)*Age (≥44 years) | 1.11 | 0.94 | 1.31 |
| Preferred distal upper extremity quadrant | | | |
| RULA preferred limb (high) | 1.11 | 1.03 | 1.19 |
| Age (≥44 years) | 1.19 | 1.17 | 1.21 |
| RULA preferred limb (high)*Age (≥44 years) | 0.99 | 0.75 | 1.30 |
| RULA spine, LE, preferred limb (high) | 1.07 | 0.96 | 1.20 |
| Age (≥44 years) | 1.26 | 1.08 | 1.46 |
| RULA spine, LE, preferred limb (high)*Age (≥44 years) | **0.88** | 0.86 | 0.90 |
| Non-preferred distal upper extremity quadrant | | | |
| RULA non-preferred limb (high) | 1.05 | 1.03 | 1.07 |
| Age (≥44 years) | 0.93 | 0.92 | 0.95 |
| RULA non-preferred limb (high)*Age (≥44 years) | **0.83** | 0.82 | 0.84 |
| RULA spine, LE, non-preferred limb (high) | 0.99 | 0.84 | 1.16 |
| Age (≥44 years) | 1.00 | 0.89 | 1.12 |
| RULA spine, LE, non-preferred limb (high)*Age (≥44 years) | 0.96 | 0.87 | 1.06 |

See Appendix A2, Tables 1-28 for final main effects and interaction models.
Posture was measured by modified RULA=rapid limb upper assessment. "High" refers to high physical exposure.
RR=relative risk. CI=confidence interval.
Preferred limb= mouse use; Non-preferred limb= touch pad.
Spine=neck, upper back, trunk. LE=lower extremity.
Bold=significant findings.

Table 41. Regression models estimating association between dichotomous musculoskeletal pain severity in upper extremity quadrant and interaction between modified hand activity/upper extremity movement*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| Preferred proximal upper extremity quadrant | | | |
| Hand activity preferred limb (high) | 1.06 | 0.99 | 1.14 |
| Age (≥44 years) | 0.96 | 0.79 | 1.18 |
| Hand activity preferred limb (high)*Age (≥44 years) | *0.99* | 0.99 | 1.00 |
| Hand activity non-preferred limb (high) | 0.97 | 0.94 | 1.00 |
| Age (≥44 years) | 0.96 | 0.79 | 1.18 |
| Hand activity non-preferred limb (high)*Age (≥44 years) | **0.99** | 0.98 | 0.99 |
| Non-preferred proximal upper extremity quadrant | | | |
| Hand activity preferred limb (high) | 1.04 | 1.03 | 1.06 |
| Age (≥44 years) | 1.06 | 1.03 | 1.09 |
| Hand activity, preferred limb (high)*Age (≥44 years) | 1.04 | 0.93 | 1.18 |
| Hand activity non-preferred limb (high) | 1.03 | 0.66 | 1.60 |
| Age (≥44 years) | 1.09 | 0.94 | 1.26 |
| Hand activity, non-preferred limb (high)*Age (≥44 years) | 0.92 | 0.44 | 1.89 |
| Preferred distal upper extremity quadrant | | | |
| Hand activity preferred limb (high) | 1.01 | 0.89 | 1.15 |
| Age (≥44 years) | 1.15 | 1.06 | 1.26 |
| Hand activity preferred limb (high)*Age (≥44 years) | 0.97 | 0.84 | 1.13 |
| Non-preferred distal upper extremity quadrant | | | |
| Hand activity non-preferred limb (high) | 0.84 | 0.73 | 0.96 |
| Age (≥44 years) | 0.79 | 0.72 | 0.87 |
| Hand activity non-preferred limb (high)*Age (≥44 years) | *1.10* | 1.00 | 1.21 |

See Appendix A2, Tables 29-40 for final main effects and interaction models.
Hand activity level measured by modified HAL. "High" refers to high physical exposure.
Preferred limb= mouse use; Non-preferred limb= touch pad.
Bold=significant findings.
Italics=borderline significant findings.

Table 42. Overall change in range and frequency of postural movements at baseline in workers performing 1 task (interactive communication or word processing) over the day (n=68)

| Physical exposure<br>Range | AM | PM | Δ |
|---|---|---|---|
| RULA postural elements (n, %), high exposure | | | |
| Spine | 16(23.5) | 20(29.4) | +4 |
| Preferred limb, upper arm | 39(57.4) | 37(54.4) | -2 |
| Preferred limb, lower arm | 37(54.4) | 45(66.2) | +8 |
| Preferred limb, wrist | 66(97.1) | 67(98.5) | +1 |
| Non-preferred limb, upper arm | 20(29.4) | 16(23.5) | -4 |
| Non-preferred limb, lower arm | 23(33.8) | 29(42.7) | +6 |
| Non-preferred limb, wrist | 67(98.5) | 68(100.0) | +1 |
| Upper body RULA posture (mean, sd) | | | |
| Spine, preferred & non-preferred limb | 19.9(6.2) | 20.3(6.2) | +0.4 |
| Frequency | | | |
| Hand activity/UE movement (mean, sd) | | | |
| Preferred limb | 4.7(2.0) | 4.4(2.0) | -0.3 |
| Non-preferred limb | 2.8(1.9) | 2.7(1.8) | -0.1 |

Spine=neck, upper back, trunk. UE= upper extremity
Preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, wrist, digits.
Non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, wrist, digits.
Posture was measured by rapid upper limb assessment (RULA). RULA elements=body regions. Upper body RULA comprised the sum total of all RULA elements.
Continuous measures for RULA elements were dichotomized at their sample medians.
Hand activity/upper extremity movement was measured by hand activity level (HAL).
Higher physical exposure values for continuous variables=higher physical exposure.

Table 43. Changes in range and frequency of postural movements at baseline in workers performing 1 task (interactive communication or word processing) over the day, by chronicity (n=68)

| | Chronicity ≤ 1year (n=22) | | | Chronicity > 1 year (n=46) | | |
|---|---|---|---|---|---|---|
| Physical exposure Range | AM | PM | Δ | AM | PM | Δ |
| RULA postural elements (n, %), high exposure | | | | | | |
| Spine | 8(36.4) | 9(40.9) | +1 | 8(17.4) | 11(23.9) | +3 |
| Preferred limb, upper arm | 14(63.6) | 15(68.2) | +1 | 25(54.3) | 22(47.8) | -3 |
| Preferred limb, lower arm | 13(59.1) | 18(81.8) | +5 | 24(52.2) | 27(58.7) | +3 |
| Preferred limb, wrist | 21(95.4) | 21(95.4) | 0 | 45(97.8) | 46(100.0) | +1 |
| Non-preferred limb, upper arm | 7(31.8) | 9(40.9) | +2 | 13(28.3) | 7(15.2) | -8 |
| Non-preferred limb, lower arm | 10(45.5) | 9(40.9) | -1 | 13(28.3) | 20(43.5) | +7 |
| Non-preferred limb, wrist | 22(100.0) | 22(100.0) | 0 | 45(97.8) | 46(100) | +1 |
| Upper body RULA posture (mean, sd) | | | | | | |
| Spine, preferred & non-preferred limb | 18.7(5.8) | 21.0(6.3) | +2.3 | 19.2(5.5) | 20.9(5.9) | +1.7 |
| Frequency | | | | | | |
| Hand activity/UE movement (mean, sd) | | | | | | |
| Preferred limb | 5.3(2.2) | 4.6(2.5) | -0.7 | 4.5(1.9) | 4.2(1.5) | -0.3 |
| Non-preferred limb | 3.0(1.2) | 2.5(1.7) | -0.5 | 2.5(1.2) | 2.1(1.3) | -0.4 |

Spine=neck, upper back, trunk. UE= upper extremity
Preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, wrist, digits.
Non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, wrist, digits.
Posture was measured by rapid upper limb assessment (RULA). RULA elements=body regions. Upper body RULA comprised the sum total of all RULA elements.
Continuous measures for RULA elements were dichotomized at their sample medians.
Hand activity/upper extremity movement was measured by hand activity level (HAL).
Higher physical exposure values for continuous variables=higher physical exposure.

Table 44. Changes in range and frequency of postural movements at baseline in workers performing 1 task (interactive communication or word processing) over the day, by pain severity (n=68)

| Physical exposure | Severity ≤ 2 | | | Severity ≥ 3 | | |
|---|---|---|---|---|---|---|
| Range | AM | PM | Δ | AM | PM | Δ |
| RULA postural elements (n, %), high exposure, by pain | | | | | | |
| Preferred proximal UE quadrant pain | | | | | | |
| Spine | 11(29.0) | 13(34.2) | +2 | 5(16.7) | 7(23.3) | +2 |
| Preferred limb, upper arm | 20(52.6) | 18(47.4) | -2 | 19(63.3) | 19(63.3) | 0 |
| Preferred distal UE quadrant pain | | | | | | |
| Preferred limb, lower arm | 28(53.9) | 31(59.6) | +3 | 9(56/3) | 14(87.5) | +5 |
| Preferred limb, wrist | 50(96.2) | 51(98.1) | +1 | 16(100.0) | 16(100.0) | 0 |
| Non-preferred proximal UE quadrant pain | | | | | | |
| Spine | 12(27.3) | 14(31.8) | +2 | 4(16.7) | 6(25.0) | +2 |
| Non-preferred limb, upper arm | 15(34.1) | 12(27.3) | -3 | 5(20.8) | 4(16.7) | -1 |
| Non-preferred distal UE quadrant pain | | | | | | |
| Non-preferred limb, lower arm | 22(33.3) | 28(42.2) | +6 | 1(50.0) | 1(50.0) | 0 |
| Non-preferred limb, wrist | 65(98.5) | 66(100.0) | +1 | 2(100.0) | 2(100.0) | 0 |
| Upper body RULA posture (mean, sd) | | | | | | |
| Preferred proximal UE quadrant pain | | | | | | |
| Spine, preferred & non-preferred limb | 22.2(6.4) | 23.2(6.0) | +1.0 | 21.1(6.1) | 23.2(5.9) | +1.9 |
| Preferred distal UE quadrant pain | | | | | | |
| Spine, preferred & non-preferred limb | 19.2(6.1) | 20.9(6.4) | +1.7 | 21.9(6.0) | 22.5(6.2) | +0.6 |
| Non-preferred proximal UE quadrant pain | | | | | | |
| Spine, preferred & non-preferred limb | 18.3(5.5) | 21.0(6.6) | +2.7 | 19.9(5.3) | 22.8(6.4) | +2.9 |
| Non-preferred distal UE quadrant pain | | | | | | |
| Spine, preferred & non-preferred limb | 22.7(6.2) | 23.2(6.3) | +0.5 | 21.1(5.3) | 21.9(6.0) | +0.8 |
| Frequency | | | | | | |
| Hand Activity/UE movement (mean, sd) | | | | | | |
| Preferred proximal UE quadrant pain | | | | | | |
| Preferred limb | 5.1(2.0) | 4.9(2.1) | -0.2 | 5.0(2.0) | 4.3(2.2) | -0.7 |
| Preferred distal UE quadrant pain | | | | | | |
| Preferred limb | 5.4(2.5) | 4.8(2.5) | -0.6 | 5.1(2.0) | 4.4(2.0) | -0.7 |
| Non-preferred proximal UE quadrant pain | | | | | | |
| Non-preferred limb | 3.3(1.6) | 2.7(1.9) | -0.6 | 3.3(1.2) | 2.6(2.0) | -0.7 |
| Non-preferred distal UE quadrant pain | | | | | | |
| Non-preferred limb | 3.6(1.9) | 2.7(1.9) | -0.9 | 3.0(1.0) | 2.5(1.9) | -0.5 |

Spine=neck, upper back, trunk. UE= upper extremity. Preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, wrist, digits. Non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, wrist, digits.
Posture was measured by rapid upper limb assessment (RULA). RULA elements=body regions. Upper body RULA comprised the sum total of all RULA elements. Continuous measures for RULA elements were dichotomized at their sample medians.
Hand activity/upper extremity movement was measured by hand activity level (HAL).Higher physical exposure values for continuous variables=higher physical exposure.

Table 45. Changes in range and frequency of postural movements at baseline in workers performing 1 task (interactive communication or word processing) over the day, by age (n=68)

| Physical exposure | Age ≤ 44years (n=26) | | | Age > 44years (n=42) | | |
|---|---|---|---|---|---|---|
| Range | AM | PM | Δ | AM | PM | Δ |
| RULA postural elements (n, %), high exposure | | | | | | |
| Spine | 8(30.8) | 8(30.8) | 0 | 8(19.1) | 12(28.7) | +4 |
| Preferred limb, upper arm | 19(73.1) | 18(69.2) | -1 | 20(47.6) | 19(45.2) | -1 |
| Preferred limb, lower arm | 15(57.7) | 20(76.9) | +5 | 22(52.4) | 25(59.5) | +3 |
| Preferred limb, wrist | 25(96.2) | 25(96.2) | 0 | 41(97.6) | 42(100.0) | +1 |
| Non-preferred limb, upper arm | 8(30.8) | 5(19.2) | -3 | 12(28.6) | 11(26.2) | -1 |
| Non-preferred limb, lower arm | 11(42.3) | 10(38.5) | -1 | 12(28.6) | 19(45.2) | +7 |
| Non-preferred limb, wrist | 26(100.0) | 26(100.0) | 0 | 41(97.6) | 42(100.0) | +2 |
| Upper body RULA posture (mean, sd) | | | | | | |
| Spine, LE, preferred & non-preferred limb | 21.1(6.0) | 23.1(6.1) | +2.0 | 22.0(6.9) | 23.7(5.8) | +1.7 |
| Frequency | | | | | | |
| Hand Activity/UE movement (mean, sd) | | | | | | |
| Preferred limb | 5.5(2.4) | 4.7(2.1) | -0.7 | 5.1(2.8) | 4.3(2.1) | -0.8 |
| Non-preferred limb | 3.8(1.9) | 3.0(2.0) | -0.8 | 3.5(2.1) | 2.7(1.3) | -0.8 |

Spine=neck, upper back, trunk. UE= upper extremity
Preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, wrist, digits.
Non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, wrist, digits.
Posture was measured by rapid upper limb assessment (RULA). RULA elements=body regions. Upper body RULA comprised the sum total of all RULA elements.
Continuous measures for RULA elements were dichotomized at their sample medians.
Hand activity/upper extremity movement was measured by hand activity level (HAL).
Higher physical exposure values for continuous variables=higher physical exposure.

Appendix A

# RECRUITMENT LETTER

Dear

My name is Jon Dropkin. I am a very experienced ergonomist who has been working as an ergonomist since 1994. I will be conducting an **ergonomic intervention study** at the Legislative Office Buildings.

The purpose of the study is to examine what effect a new, fully adjustable keyboard/mouse tray and a touch pad mouse have on posture, repetitive motion, overall health and pain.

- The study will start sometime between June 15th and July 15th.
- It will last 7 months, ending in approximately mid-January.
- It will involve between 8 to 9 hours of your time over the 7 months.
- The new equipment should not interfere or inhibit your work flow or job demands, as this is commonly used equipment in many office environments.
- We will not be removing the mouse that you are currently using. The touch pad mouse, which will be used in your non-mousing hand, will only supplement your traditional mouse or other mouse (pointing device).

If you are:

1. **Interested** in participating in the study and willing to answer some questions to determine whether you are **eligible** for the study, or
2. **Not interested** in participating in the study, but **would be willing** to answer some questions,

I would like to contact you by telephone to ask you questions having to do with this study. The questions will take about **15 minutes** to answer. I will send you the questions prior to our telephone conversation.

If you have agreed to either participate in the study or answer the questions only, please email me at jonathan.dropkin@mssm.edu to submit a contact telephone number and time of day in which to call.

Thank you for your time and consideration.

Your help is greatly appreciated.

Sincerely,
Jon Dropkin, MS, PT
University of Massachusetts Lowell

# Appendix B

## Observational exposure assessment

Change to PDF Scan

# OBSERVATIONAL ASSESSMENT

**Date:**

Month

☐ January ☐ July

☐ February ☐ August

☐ March ☐ September

☐ April ☐ October

☐ May ☐ November

☐ June ☐ December

Day

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Year: 2010 ☐ 2011 ☐

Time: Baseline O Post Intervention Assessment O

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Baseline BMI: (height_____weight_____) =_____

1st AM

| 1. 30 Seconds: R UE, Head, Neck | | 2. 30 Seconds: L UE, Trunk, LE | | 3. 30 Seconds: R HAL | | | 4. 30 Seconds: L HAL | | | 5. 30 Seconds: Equipment in use | Y | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neck√ 0-10$^0$ (+1) | O | Trunk / √ 0-10$^0$ (+1) | O | Hands idle most of time; no regular movement | 0 | O | Hands idle most of time; no regular movement | 0 | O | 35" tray | O | O |
| Neck√ 11-20$^0$ (+2) | O | Trunk√ 11-20$^0$ (+2) | O | | | | | | | 24" tray/ drawer | O | O |
| Neck√ >20$^0$ (+3) | O | Trunk√ 21-60$^0$ (+3) | O | | | | | | | 19" tray/ drawer | O | O |
| Neck / (+4) | O | Trunk√ >60$^0$ (+4) | O | | | | | | | Corded mouse | O | O |
| Neck rotation (+1) | O | Trunk rotation (+1) | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Cordless mouse | O | O |
| Neck SB (+1) | O | Trunk sidebending (+1) | O | | | | | | | Trackball | O | O |
| Forward head (+1) | O | Upper arm -20+20$^0$ (+1) | O | | | | | | | Touch pad | O | O |
| Upper arm -20+20$^0$ (+1) | O | Upper arm / >21$^0$ (+2) | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Tablet/ stylus | O | O |
| Upper arm / >21$^0$ (+2) | O | Upper arm√ 21-45$^0$(+2) | O | | | | | | | 3M joystick | O | O |
| Upper arm√ 21-45$^0$(+2) | O | Upper arm√ 46-90$^0$(+3) | O | | | | | | | Rollermouse | O | O |
| | | | | | | | | | | Forearm support | O | O |
| Upper arm√ 46-90$^0$(+3) | O | Upper arm√ >90$^0$(+4) | O | Steady motion/exertion; infrequent pauses | 6 | O | Steady motion/exertion; infrequent pauses | 6 | O | Eyeglasses/ contacts | O | O |
| Upper arm√ >90$^0$(+4) | O | Upper arm ABD (+1) | O | | | | | | | Document holder(s) | O | O |
| Upper arm ABD (+1) | O | Upper arm supported (0) | O | | | | | | | Headset | O | O |
| Upper arm supported (0) | O | Shoulders elevated (+1) | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Monitor arm or riser | O | O |
| Shoulders elevated (+1) | O | Phone use (+1) | O | | | | | | | Glare screen | O | O |
| Phone use (+1) | O | Phone scrunch (+1) | O | | | | | | | Alternative KB | O | O |
| Phone scrunch (+1) | O | Elbow 90$^0$(0) | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Adherence to TP technique | O | O |
| Elbow 90$^0$(0) | O | Elbow 80-110$^0$(+1), excluding 90$^0$ | O | **5. (continued) Task:** | | | | | | Adherence to KBT technique | O | O |
| Elbow 80-110$^0$(+1), excluding 90$^0$ | O | Elbow hoz ABD/ADD(+1) | O | **Adherence or alteration to recommended equipment adjustments or positions: ONLY 1X AM & PM** | | | | | | **EQUIPMENT PRESENT: ONLY 1X AM or PM** | | |
| Elbow hoz ABD/ADD(+1) | O | Low KB + neg slope (0) | O | 1. | | | | | | Alternative KB | O | O |
| | | RULA elbow 110$^0$-120$^0$ (+2) | O | 2. | | | | | | KB tray/drawer | O | O |
| RULA elbow 110$^0$-120$^0$ (+2) | O | JD elbow >120$^0$ (0) | O | 3. | | | | | | Corded mouse | O | O |
| JD elbow >120$^0$ (0) | O | RULA forearm midrange (+1) | O | 4. | | | | | | Cordless mouse | O | O |
| RULA forearm midrange (+1) | O | RULA forearm full prona (+2) | O | 5. | | | | | | Trackball | O | O |
| | | JD forearm neutrl (0) | O | | | | | | | | | |
| RULA forearm full prona (+2) | O | Wrist 0$^0$ (+1) | O | 6. | | | | | | Touch pad | O | O |
| JD forearm neutrl (0) | O | | | | | | | | | | | |
| Wrist 0$^0$ (+1) | O | Wrist / <15$^0$ (+2) | O | **Alterations to recommended equipment: ONLY 1X AM & PM** | | | | | | Tablet/ stylus | O | O |
| Wrist / <15$^0$ (+2) | O | Wrist / >15$^0$ (+3) | O | | | | | | | 3M joystick | O | O |
| Wrist / >15$^0$ (+3) | O | Wrist√ <15$^0$ (+2) | O | 1. | | | | | | Rollermouse | O | O |
| Wrist√ <15$^0$ (+2) | O | Wrist√ >15$^0$ (+3) | O | 2. | | | | | | Eyeglasses/ contacts | O | O |
| Wrist√ >15$^0$ (+3) | O | Wrist RD/UD (+1) | O | 3. | | | | | | Document holder(s) | O | O |
| Wrist RD/UD (+1) | O | Legs/feet supported (+1) | O | 4. | | | | | | Headset | O | O |
| | | Legs/feet unsupported (+2) | O | 5. | | | | | | Monitor arm or riser | O | O |
| | | | | 6. | | | | | | Glare screen | O | O |
| | | | | | | | | | | Forearm support | O | O |

2nd AM

| 1. 30 Seconds: R UE, Head, Neck | | 2. 30 Seconds: L UE, Trunk, LE | | 3. 30 Seconds: R HAL | | | 4. 30 Seconds: L HAL | | | 5. 30 Seconds: Equipment in use | Y | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neck√ 0-10$^0$ (+1) | O | Trunk / √ 0-10$^0$ (+1) | O | Hands idle most of time; no regular movement | 0 | O | Hands idle most of time; no regular movement | 0 | O | 35" tray | O | O |
| Neck√ 11-20$^0$ (+2) | O | Trunk√ 11-20$^0$ (+2) | O | | | | | | | 24" tray/ drawer | O | O |
| Neck√ >20$^0$ (+3) | O | Trunk√ 21-60$^0$ (+3) | O | | | | | | | 19" tray/ drawer | O | O |
| Neck / (+4) | O | Trunk√ >60$^0$ (+4) | O | | | | | | | Corded mouse | O | O |
| Neck rotation (+1) | O | Trunk rotation (+1) | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Cordless mouse | O | O |
| Neck SB (+1) | O | Trunk sidebending (+1) | O | | | | | | | Trackball | O | O |
| Forward head (+1) | O | Upper arm –20+20$^0$ (+1) | O | | | | | | | Touch pad | O | O |
| Upper arm –20+20$^0$ (+1) | O | Upper arm / >21$^0$ (+2) | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Tablet/ stylus | O | O |
| Upper arm / >21$^0$ (+2) | O | Upper arm√ 21-45$^0$ (+2) | O | | | | | | | 3M joystick | O | O |
| Upper arm√ 21-45$^0$ (+2) | O | Upper arm√ 46-90$^0$ (+3) | O | | | | | | | Rollermouse | O | O |
| | | | | | | | | | | Forearm support | O | O |
| Upper arm√ 46-90$^0$ (+3) | O | Upper arm√ >90$^0$ (+4) | O | Steady motion/exertion; infrequent pauses | 6 | O | Steady motion/exertion; infrequent pauses | 6 | O | Eyeglasses/ contacts | O | O |
| Upper arm√ >90$^0$ (+4) | O | Upper arm ABD (+1) | O | | | | | | | Document holder(s) | O | O |
| Upper arm ABD (+1) | O | Upper arm supported (0) | O | | | | | | | Headset | O | O |
| Upper arm supported (0) | O | Shoulders elevated (+1) | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Monitor arm or riser | O | O |
| Shoulders elevated (+1) | O | Phone use (+1) | O | | | | | | | Glare screen | O | O |
| Phone use (+1) | O | Phone scrunch (+1) | O | | | | | | | Alternative KB | O | O |
| Phone scrunch (+1) | O | Elbow 90$^0$(0) | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Adherence to TP technique | O | O |
| Elbow 90$^0$(0) | O | Elbow 80-110$^0$(+1), excluding 90$^0$ | O | **5. (continued) Task:** | | | | | | Adherence to KBT technique | O | O |
| Elbow 80-110$^0$(+1), excluding 90$^0$ | O | Elbow hoz ABD/ADD(+1) | O | **Adherence or alteration to recommended equipment adjustments or positions: ONLY 1X AM & PM** | | | | | | **EQUIPMENT PRESENT: ONLY 1X AM or PM** | | |
| Elbow hoz ABD/ADD(+1) | O | Low KB + neg slope (0) | O | 1. | | | | | | Alternative KB | O | O |
| | | RULA elbow 110$^0$-120$^0$ (+2) | O | 2. | | | | | | KB tray/drawer | O | O |
| RULA elbow 110$^0$-120$^0$ (+2) | O | JD elbow >120$^0$ (0) | O | 3. | | | | | | Corded mouse | O | O |
| JD elbow >120$^0$ (0) | O | RULA forearm midrange (+1) | O | 4. | | | | | | Cordless mouse | O | O |
| RULA forearm midrange (+1) | O | RULA forearm full prona (+2) | O | 5. | | | | | | Trackball | O | O |
| | | JD forearm neutrl (0) | O | | | | | | | | | |
| RULA forearm full prona (+2) | O | Wrist 0$^0$ (+1) | O | 6. | | | | | | Touch pad | O | O |
| JD forearm neutrl (0) | O | | | | | | | | | | | |
| Wrist 0$^0$ (+1) | O | Wrist / <15$^0$ (+2) | O | **Alterations to recommended equipment: ONLY 1X AM & PM** | | | | | | Tablet/ stylus | O | O |
| Wrist / <15$^0$ (+2) | O | Wrist / >15$^0$ (+3) | O | | | | | | | 3M joystick | O | O |
| Wrist / >15$^0$ (+3) | O | Wrist√ <15$^0$ (+2) | O | 1. | | | | | | Rollermouse | O | O |
| Wrist√ <15$^0$ (+2) | O | Wrist√ >15$^0$ (+3) | O | 2. | | | | | | Eyeglasses/ contacts | O | O |
| Wrist√ >15$^0$ (+3) | O | Wrist RD/UD (+1) | O | 3. | | | | | | Document holder(s) | O | O |
| Wrist RD/UD (+1) | O | Legs/feet supported (+1) | O | 4. | | | | | | Headset | O | O |
| | | Legs/feet unsupported (+2) | O | 5. | | | | | | Monitor arm or riser | O | O |
| | | | | 6. | | | | | | Glare screen | O | O |
| | | | | | | | | | | Forearm support | O | O |

3rd AM

| 1. 30 Seconds: R UE, Head, Neck | | 2. 30 Seconds: L UE, Trunk, LE | | 3. 30 Seconds: R HAL | | | 4. 30 Seconds: L HAL | | | 5. 30 Seconds: Equipment in use | Y | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neck√ 0-10$^0$ (+1) | O | Trunk / √ 0-10$^0$ (+1) | O | Hands idle most of time; no regular movement | 0 | O | Hands idle most of time; no regular movement | 0 | O | 35" tray | O | O |
| Neck√ 11-20$^0$ (+2) | O | Trunk√ 11-20$^0$ (+2) | O | | | | | | | 24" tray/ drawer | O | O |
| Neck√ >20$^0$ (+3) | O | Trunk√ 21-60$^0$ (+3) | O | | | | | | | 19" tray/ drawer | O | O |
| Neck / (+4) | O | Trunk√ >60$^0$ (+4) | O | | | | | | | *Corded mouse* | O | O |
| Neck rotation (+1) | O | Trunk rotation (+1) | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Cordless mouse | O | O |
| Neck SB (+1) | O | Trunk sidebending (+1) | O | | | | | | | Trackball | O | O |
| Forward head (+1) | O | Upper arm –20+20$^0$ (+1) | O | | | | | | | Touch pad | O | O |
| Upper arm –20+20$^0$ (+1) | O | Upper arm / >21$^0$ (+2) | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Tablet/ stylus | O | O |
| Upper arm / >21$^0$ (+2) | O | Upper arm√ 21-45$^0$(+2) | O | | | | | | | 3M joystick | O | O |
| Upper arm√ 21-45$^0$(+2) | O | Upper arm√ 46-90$^0$(+3) | O | | | | | | | Rollermouse | O | O |
| | | | | | | | | | | Forearm support | O | O |
| Upper arm√ 46-90$^0$(+3) | O | Upper arm√ >90$^0$(+4) | O | Steady motion/exertion; infrequent pauses | 6 | O | Steady motion/exertion; infrequent pauses | 6 | O | Eyeglasses/ contacts | O | O |
| Upper arm√ >90$^0$(+4) | O | Upper arm ABD (+1) | O | | | | | | | Document holder(s) | O | O |
| Upper arm ABD (+1) | O | Upper arm supported (0) | O | | | | | | | Headset | O | O |
| Upper arm supported (0) | O | Shoulders elevated (+1) | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Monitor arm or riser | O | O |
| Shoulders elevated (+1) | O | Phone use (+1) | O | | | | | | | Glare screen | O | O |
| Phone use (+1) | O | Phone scrunch (+1) | O | | | | | | | Alternative KB | O | O |
| Phone scrunch (+1) | O | Elbow 90$^0$(0) | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Adherence to TP technique | O | O |
| Elbow 90$^0$(0) | O | Elbow 80-110$^0$(+1), excluding 90$^0$ | O | **5. (continued) Task:** | | | | | | Adherence to KBT technique | O | O |
| Elbow 80-110$^0$(+1), excluding 90$^0$ | O | Elbow hoz ABD/ADD(+1) | O | **Adherence or alteration to recommended equipment adjustments or positions: ONLY 1X AM & PM** | | | | | | **EQUIPMENT PRESENT: ONLY 1X AM or PM** | | |
| Elbow hoz ABD/ADD(+1) | O | Low KB + neg slope (0) | O | 1. | | | | | | Alternative KB | O | O |
| | | RULA elbow 110$^0$-120$^0$ (+2) | O | 2. | | | | | | KB tray/drawer | O | O |
| RULA elbow 110$^0$-120$^0$ (+2) | O | JD elbow >120$^0$ (0) | O | 3. | | | | | | Corded mouse | O | O |
| JD elbow >120$^0$ (-1) | O | RULA forearm midrange (+1) | O | 4. | | | | | | Cordless mouse | O | O |
| RULA forearm midrange (+1) | O | RULA forearm full prona (+2) | O | 5. | | | | | | Trackball | O | O |
| | | JD forearm neutrl (0) | O | | | | | | | | | |
| RULA forearm full prona (+2) | O | Wrist 0$^0$ (+1) | O | 6. | | | | | | Touch pad | O | O |
| JD forearm neutrl (0) | O | | | | | | | | | | | |
| Wrist 0$^0$ (+1) | O | Wrist / <15$^0$ (+2) | O | **Alterations to recommended equipment: ONLY 1X AM & PM** | | | | | | Tablet/ stylus | O | O |
| Wrist / <15$^0$ (+2) | O | Wrist / >15$^0$ (+3) | O | | | | | | | 3M joystick | O | O |
| Wrist / >15$^0$ (+3) | O | Wrist√ <15$^0$ (+2) | O | 1. | | | | | | Rollermouse | O | O |
| Wrist√ <15$^0$ (+2) | O | Wrist√ >15$^0$ (+3) | O | 2. | | | | | | Eyeglasses/ contacts | O | O |
| Wrist√ >15$^0$ (+3) | O | Wrist RD/UD (+1) | O | 3. | | | | | | Document holder(s) | O | O |
| Wrist RD/UD (+1) | O | Legs/feet supported (+1) | O | 4. | | | | | | Headset | O | O |
| | | Legs/feet unsupported (+2) | O | 5. | | | | | | Monitor arm or riser | O | O |
| | | | | 6. | | | | | | Glare screen | O | O |
| | | | | | | | | | | Forearm support | O | O |

4th AM

| 1. 30 Seconds: R UE, Head, Neck | | 2. 30 Seconds: L UE, Trunk, LE | | 3. 30 Seconds: R HAL | | | 4. 30 Seconds: L HAL | | | 5. 30 Seconds: Equipment in use | Y | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neck√ 0-10$^0$ (+1) | O | Trunk / √ 0-10$^0$ (+1) | O | Hands idle most of time; no regular movement | 0 | O | Hands idle most of time; no regular movement | 0 | O | 35" tray | O | O |
| Neck√ 11-20$^0$ (+2) | O | Trunk√ 11-20$^0$ (+2) | O | | | | | | | 24" tray/ drawer | O | O |
| Neck√ >20$^0$ (+3) | O | Trunk√ 21-60$^0$ (+3) | O | | | | | | | 19" tray/ drawer | O | O |
| Neck / (+4) | O | Trunk√ >60$^0$ (+4) | O | | | | | | | Corded mouse | O | O |
| Neck rotation (+1) | O | Trunk rotation (+1) | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Cordless mouse | O | O |
| Neck SB (+1) | O | Trunk sidebending (+1) | O | | | | | | | Trackball | O | O |
| Forward head (+1) | O | Upper arm -20+20$^0$ (+1) | O | | | | | | | Touch pad | O | O |
| Upper arm -20+20$^0$ (+1) | O | Upper arm / >21$^0$ (+2) | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Tablet/ stylus | O | O |
| Upper arm / >21$^0$ (+2) | O | Upper arm√ 21-45$^0$ (+2) | O | | | | | | | 3M joystick | O | O |
| Upper arm√ 21-45$^0$ (+2) | O | Upper arm√ 46-90$^0$ (+3) | O | | | | | | | Rollermouse | O | O |
| | | | | | | | | | | Forearm support | O | O |
| Upper arm√ 46-90$^0$ (+3) | O | Upper arm√ >90$^0$ (+4) | O | Steady motion/exertion; infrequent pauses | 6 | O | Steady motion/exertion; infrequent pauses | 6 | O | Eyeglasses/ contacts | O | O |
| Upper arm√ >90$^0$ (+4) | O | Upper arm ABD (+1) | O | | | | | | | Document holder(s) | O | O |
| Upper arm ABD (+1) | O | Upper arm supported (0) | O | | | | | | | Headset | O | O |
| Upper arm supported (0) | O | Shoulders elevated (+1) | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Monitor arm or riser | O | O |
| Shoulders elevated (+1) | O | Phone use (+1) | O | | | | | | | Glare screen | O | O |
| Phone use (+1) | O | Phone scrunch (+1) | O | | | | | | | Alternative KB | O | O |
| Phone scrunch (+1) | O | Elbow 90$^0$(0) | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Adherence to TP technique | O | O |
| Elbow 90$^0$(0) | O | Elbow 80-110$^0$(+1), excluding 90$^0$ | O | **5. (continued) Task:** | | | | | | Adherence to KBT technique | O | O |
| Elbow 80-110$^0$(+1), excluding 90$^0$ | O | Elbow hoz ABD/ADD(+1) | O | **Adherence or alteration to recommended equipment adjustments or positions: ONLY 1X AM & PM** | | | | | | **EQUIPMENT PRESENT: ONLY 1X AM or PM** | | |
| Elbow hoz ABD/ADD(+1) | O | Low KB + neg slope (0) | O | 1. | | | | | | Alternative KB | O | O |
| Low KB + neg slope (-1) | O | RULA elbow 110$^0$-120$^0$ (+2) | O | 2. | | | | | | KB tray/drawer | O | O |
| RULA elbow 110$^0$-120$^0$ (+2) | O | JD elbow >120$^0$ (0) | O | 3. | | | | | | Corded mouse | O | O |
| JD elbow >120$^0$ (0) | O | RULA forearm midrange (+1) | O | 4. | | | | | | Cordless mouse | O | O |
| RULA forearm midrange (+1) | O | RULA forearm full prona (+2) | O | 5. | | | | | | Trackball | O | O |
| | | JD forearm neutrl (0) | O | | | | | | | | | |
| RULA forearm full prona (+2) | O | Wrist 0$^0$ (+1) | O | 6. | | | | | | Touch pad | O | O |
| JD forearm neutrl (0) | O | | | | | | | | | | | |
| Wrist 0$^0$ (+1) | O | Wrist / <15$^0$ (+2) | O | Alterations to recommended equipment: ONLY 1X AM & PM | | | | | | Tablet/ stylus | O | O |
| Wrist / <15$^0$ (+2) | O | Wrist / >15$^0$ (+3) | O | | | | | | | 3M joystick | O | O |
| Wrist / >15$^0$ (+3) | O | Wrist√ <15$^0$ (+2) | O | 1. | | | | | | Rollermouse | O | O |
| Wrist√ <15$^0$ (+2) | O | Wrist√ >15$^0$ (+3) | O | 2. | | | | | | Eyeglasses/ contacts | O | O |
| Wrist√ >15$^0$ (+3) | O | Wrist RD/UD (+1) | O | 3. | | | | | | Document holder(s) | O | O |
| Wrist RD/UD (+1) | O | Legs/feet supported (+1) | O | 4. | | | | | | Headset | O | O |
| | | Legs/feet unsupported (+2) | O | 5. | | | | | | Monitor arm or riser | O | O |
| | | | | 6. | | | | | | Glare screen | O | O |
| | | | | | | | | | | Forearm support | O | O |

5th AM

| 1. 30 Seconds: R UE, Head, Neck | | 2. 30 Seconds: L UE, Trunk, LE | | 3. 30 Seconds: R HAL | | | 4. 30 Seconds: L HAL | | | 5. 30 Seconds: Equipment In use | Y | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neck√ 0-10$^0$ (+1) | O | Trunk / √ 0-10$^0$ (+1) | O | Hands idle most of time; no regular movement | 0 | O | Hands idle most of time; no regular movement | 0 | O | 35" tray | O | O |
| Neck√ 11-20$^0$ (+2) | O | Trunk√ 11-20$^0$ (+2) | O | | | | | | | 24" tray/ drawer | O | O |
| Neck√ >20$^0$ (+3) | O | Trunk√ 21-60$^0$ (+3) | O | | | | | | | 19" tray/ drawer | O | O |
| Neck / (+4) | O | Trunk√ >60$^0$ (+4) | O | | | | | | | Corded mouse | O | O |
| Neck rotation (+1) | O | Trunk rotation (+1) | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Cordless mouse | O | O |
| Neck SB (+1) | O | Trunk sidebending (+1) | O | | | | | | | Trackball | O | O |
| Forward head (+1) | O | Upper arm –20+20$^0$ (+1) | O | | | | | | | Touch pad | O | O |
| Upper arm –20+20$^0$ (+1) | O | Upper arm / >21$^0$ (+2) | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Tablet/ stylus | O | O |
| Upper arm / >21$^0$ (+2) | O | Upper arm√ 21-45$^0$ (+2) | O | | | | | | | 3M joystick | O | O |
| Upper arm√ 21-45$^0$ (+2) | O | Upper arm√ 46-90$^0$ (+3) | O | | | | | | | Rollermouse | O | O |
| | | | | | | | | | | Forearm support | O | O |
| Upper arm√ 46-90$^0$ (+3) | O | Upper arm√ >90$^0$ (+4) | O | Steady motion/exertion; infrequent pauses | 6 | O | Steady motion/exertion; infrequent pauses | 6 | O | Eyeglasses/ contacts | O | O |
| Upper arm√ >90$^0$ (+4) | O | Upper arm ABD (+1) | O | | | | | | | Document holder(s) | O | O |
| Upper arm ABD (+1) | O | Upper arm supported (0) | O | | | | | | | Headset | O | O |
| Upper arm supported (0) | O | Shoulders elevated (+1) | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Monitor arm or riser | O | O |
| Shoulders elevated (+1) | O | Phone use (+1) | O | | | | | | | Glare screen | O | O |
| Phone use (+1) | O | Phone scrunch (+1) | O | | | | | | | Alternative KB | O | O |
| Phone scrunch (+1) | O | Elbow 90$^0$(0) | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Adherence to TP technique | O | O |
| Elbow 90$^0$(0) | O | Elbow 80-110$^0$(+1), excluding 90$^0$ | O | **5. (continued) Task:** | | | | | | Adherence to KBT technique | O | O |
| Elbow 80-110$^0$(+1), excluding 90$^0$ | O | Elbow hoz ABD/ADD(+1) | O | **Adherence or alteration to recommended equipment adjustments or positions: ONLY 1X AM & PM** | | | | | | **EQUIPMENT PRESENT: ONLY 1X AM or PM** | | |
| Elbow hoz ABD/ADD(+1) | O | Low KB + neg slope (0) | O | 1. | | | | | | Alternative KB | O | O |
| | | RULA elbow 110$^0$-120$^0$ (+2) | O | 2. | | | | | | KB tray/drawer | O | O |
| RULA elbow 110$^0$-120$^0$ (+2) | O | JD elbow >120$^0$ (0) | O | 3. | | | | | | Corded mouse | O | O |
| JD elbow >120$^0$ (0) | O | RULA forearm midrange (+1) | O | 4. | | | | | | Cordless mouse | O | O |
| RULA forearm midrange (+1) | O | RULA forearm full prona (+2) | O | 5. | | | | | | Trackball | O | O |
| | | JD forearm neutrl (0) | O | | | | | | | | | |
| RULA forearm full prona (+2) | O | Wrist 0$^0$ (+1) | O | 6. | | | | | | Touch pad | O | O |
| JD forearm neutrl (0) | O | | | | | | | | | | | |
| Wrist 0$^0$ (+1) | O | Wrist / <15$^0$ (+2) | O | **Alterations to recommended equipment: ONLY 1X AM & PM** | | | | | | Tablet/ stylus | O | O |
| Wrist / <15$^0$ (+2) | O | Wrist / >15$^0$ (+3) | O | | | | | | | 3M joystick | O | O |
| Wrist / >15$^0$ (+3) | O | Wrist√ <15$^0$ (+2) | O | 1. | | | | | | Rollermouse | O | O |
| Wrist√ <15$^0$ (+2) | O | Wrist√ >15$^0$ (+3) | O | 2. | | | | | | Eyeglasses/ contacts | O | O |
| Wrist√ >15$^0$ (+3) | O | Wrist RD/UD (+1) | O | 3. | | | | | | Document holder(s) | O | O |
| Wrist RD/UD (+1) | O | Legs/feet supported (+1) | O | 4. | | | | | | Headset | O | O |
| | | Legs/feet unsupported (+2) | O | 5. | | | | | | Monitor arm or riser | O | O |
| | | | | 6. | | | | | | Glare screen | O | O |
| | | | | | | | | | | Forearm support | O | O |

6th AM

| 1. 30 Seconds: R UE, Head, Neck | | 2. 30 Seconds: L UE, Trunk, LE | | 3. 30 Seconds: R HAL | | | 4. 30 Seconds: L HAL | | | 5. 30 Seconds: Equipment in use | Y | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neck√ 0-10$^0$ (+1) | O | Trunk / √ 0-10$^0$ (+1) | O | Hands idle most of time; no regular movement | 0 | O | Hands idle most of time; no regular movement | 0 | O | 35" tray | O | O |
| Neck√ 11-20$^0$ (+2) | O | Trunk√ 11-20$^0$ (+2) | O | | | | | | | 24" tray/ drawer | O | O |
| Neck√ >20$^0$ (+3) | O | Trunk√ 21-60$^0$ (+3) | O | | | | | | | 19" tray/ drawer | O | O |
| Neck / (+4) | O | Trunk√ >60$^0$ (+4) | O | | | | | | | Corded mouse | O | O |
| Neck rotation (+1) | O | Trunk rotation (+1) | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Cordless mouse | O | O |
| Neck SB (+1) | O | Trunk sidebending (+1) | O | | | | | | | Trackball | O | O |
| Forward head (+1) | O | Upper arm –20+20$^0$ (+1) | O | | | | | | | Touch pad | O | O |
| Upper arm –20+20$^0$ (+1) | O | Upper arm / >21$^0$ (+2) | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Tablet/ stylus | O | O |
| Upper arm / >21$^0$ (+2) | O | Upper arm√ 21-45$^0$ (+2) | O | | | | | | | 3M joystick | O | O |
| Upper arm√ 21-45$^0$ (+2) | O | Upper arm√ 46-90$^0$ (+3) | O | | | | | | | Rollermouse | O | O |
| | | | | | | | | | | Forearm support | O | O |
| Upper arm√ 46-90$^0$ (+3) | O | Upper arm√ >90$^0$ (+4) | O | Steady motion/exertion; infrequent pauses | 6 | O | Steady motion/exertion; infrequent pauses | 6 | O | Eyeglasses/ contacts | O | O |
| Upper arm√ >90$^0$ (+4) | O | Upper arm ABD (+1) | O | | | | | | | Document holder(s) | O | O |
| Upper arm ABD (+1) | O | Upper arm supported (0) | O | | | | | | | Headset | O | O |
| Upper arm supported (0) | O | Shoulders elevated (+1) | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Monitor arm or riser | O | O |
| Shoulders elevated (+1) | O | Phone use (+1) | O | | | | | | | Glare screen | O | O |
| Phone use (+1) | O | Phone scrunch (+1) | O | | | | | | | Alternative KB | O | O |
| Phone scrunch (+1) | O | Elbow 90$^0$(0) | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Adherence to TP technique | O | O |
| Elbow 90$^0$(0) | O | Elbow 80-110$^0$(+1), excluding 90$^0$ | O | **5. (continued) Task:** | | | | | | Adherence to KBT technique | O | O |
| Elbow 80-110$^0$(+1), excluding 90$^0$ | O | Elbow hoz ABD/ADD(+1) | O | **Adherence or alteration to recommended equipment adjustments or positions:** ONLY 1X AM & PM | | | | | | **EQUIPMENT PRESENT: ONLY 1X AM or PM** | | |
| Elbow hoz ABD/ADD(+1) | O | Low KB + neg slope (0) | O | 1. | | | | | | Alternative KB | O | O |
| | | RULA elbow 110$^0$-120$^0$ (+2) | O | 2. | | | | | | KB tray/drawer | O | O |
| RULA elbow 110$^0$-120$^0$ (+2) | O | JD elbow >120$^0$ (0) | O | 3. | | | | | | Corded mouse | O | O |
| JD elbow >120$^0$ (0) | O | RULA forearm midrange (+1) | O | 4. | | | | | | Cordless mouse | O | O |
| RULA forearm midrange (+1) | O | RULA forearm full prona (+2) | O | 5. | | | | | | Trackball | O | O |
| | | JD forearm neutrl (0) | O | | | | | | | | | |
| RULA forearm full prona (+2) | O | Wrist 0$^0$ (+1) | O | 6. | | | | | | Touch pad | O | O |
| JD forearm neutrl (0) | O | | | | | | | | | | | |
| Wrist 0$^0$ (+1) | O | Wrist / <15$^0$ (+2) | O | **Alterations to recommended equipment:** ONLY 1X AM & PM | | | | | | Tablet/ stylus | O | O |
| Wrist / <15$^0$ (+2) | O | Wrist / >15$^0$ (+3) | O | | | | | | | 3M joystick | O | O |
| Wrist / >15$^0$ (+3) | O | Wrist√ <15$^0$ (+2) | O | 1. | | | | | | Rollermouse | O | O |
| Wrist√ <15$^0$ (+2) | O | Wrist√ >15$^0$ (+3) | O | 2. | | | | | | Eyeglasses/ contacts | O | O |
| Wrist√ >15$^0$ (+3) | O | Wrist RD/UD (+1) | O | 3. | | | | | | Document holder(s) | O | O |
| Wrist RD/UD (+1) | O | Legs/feet supported (+1) | O | 4. | | | | | | Headset | O | O |
| | | Legs/feet unsupported (+2) | O | 5. | | | | | | Monitor arm or riser | O | O |
| | | | | 6. | | | | | | Glare screen | O | O |
| | | | | | | | | | | Forearm support | O | O |

1st PM

| 1. 30 Seconds: R UE, Head, Neck | | 2. 30 Seconds: L UE, Trunk, LE | | 3. 30 Seconds: R HAL | | | 4. 30 Seconds: L HAL | | | 5. 30 Seconds: Equipment in use | Y | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neck√ 0-10$^0$ (+1) | O | Trunk / √ 0-10$^0$ (+1) | O | Hands idle most of time; no regular movement | 0 | O | Hands idle most of time; no regular movement | 0 | O | 35" tray | O | O |
| Neck√ 11-20$^0$ (+2) | O | Trunk√ 11-20$^0$ (+2) | O | | | | | | | 24" tray/ drawer | O | O |
| Neck√ >20$^0$ (+3) | O | Trunk√ 21-60$^0$ (+3) | O | | | | | | | 19" tray/ drawer | O | O |
| Neck / (+4) | O | Trunk√ >60$^0$ (+4) | O | | | | | | | Corded mouse | O | O |
| Neck rotation (+1) | O | Trunk rotation (+1) | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Cordless mouse | O | O |
| Neck SB (+1) | O | Trunk sidebending (+1) | O | | | | | | | Trackball | O | O |
| Forward head (+1) | O | Upper arm –20+20$^0$ (+1) | O | | | | | | | Touch pad | O | O |
| Upper arm –20+20$^0$ (+1) | O | Upper arm / >21$^0$ (+2) | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Tablet/ stylus | O | O |
| Upper arm / >21$^0$ (+2) | O | Upper arm√ 21-45$^0$ (+2) | O | | | | | | | 3M joystick | O | O |
| Upper arm√ 21-45$^0$ (+2) | O | Upper arm√ 46-90$^0$ (+3) | O | | | | | | | Rollermouse | O | O |
| | | | | | | | | | | Forearm support | O | O |
| Upper arm√ 46-90$^0$ (+3) | O | Upper arm√ >90$^0$ (+4) | O | Steady motion/exertion; infrequent pauses | 6 | O | Steady motion/exertion; infrequent pauses | 6 | O | Eyeglasses/ contacts | O | O |
| Upper arm√ >90$^0$ (+4) | O | Upper arm ABD (+1) | O | | | | | | | Document holder(s) | O | O |
| Upper arm ABD (+1) | O | Upper arm supported (0) | O | | | | | | | Headset | O | O |
| Upper arm supported (0) | O | Shoulders elevated (+1) | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Monitor arm or riser | O | O |
| Shoulders elevated (+1) | O | Phone use (+1) | O | | | | | | | Glare screen | O | O |
| Phone use (+1) | O | Phone scrunch (+1) | O | | | | | | | Alternative KB | O | O |
| Phone scrunch (+1) | O | Elbow 90$^0$(0) | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Adherence to TP technique | O | O |
| Elbow 90$^0$(-1) | O | Elbow 80-110$^0$(+1), excluding 90$^0$ | O | **5. (continued) Task:** | | | | | | Adherence to KBT technique | O | O |
| Elbow 80-110$^0$(+1), excluding 90$^0$ | O | Elbow hoz ABD/ADD(+1) | O | **Adherence or alteration to recommended equipment adjustments or positions: ONLY 1X AM & PM** | | | | | | **EQUIPMENT PRESENT: ONLY 1X AM or PM** | | |
| Elbow hoz ABD/ADD(+1) | O | Low KB + neg slope (0) | O | 1. | | | | | | Alternative KB | O | O |
| | | RULA elbow 110$^0$-120$^0$ (+2) | O | 2. | | | | | | KB tray/drawer | O | O |
| RULA elbow 110$^0$-120$^0$ (+2) | O | JD elbow >120$^0$ (0) | O | 3. | | | | | | Corded mouse | O | O |
| JD elbow >120$^0$ (0) | O | RULA forearm midrange (+1) | O | 4. | | | | | | Cordless mouse | O | O |
| RULA forearm midrange (+1) | O | RULA forearm full prona (+2) | O | 5. | | | | | | Trackball | O | O |
| | | JD forearm neutrl (0) | O | | | | | | | | | |
| RULA forearm full prona (+2) | O | Wrist 0$^0$ (+1) | O | 6. | | | | | | Touch pad | O | O |
| JD forearm neutrl (0) | O | | | | | | | | | | | |
| Wrist 0$^0$ (+1) | O | Wrist / <15$^0$ (+2) | O | **Alterations to recommended equipment: ONLY 1X AM & PM** | | | | | | Tablet/ stylus | O | O |
| Wrist / <15$^0$ (+2) | O | Wrist / >15$^0$ (+3) | O | | | | | | | 3M joystick | O | O |
| Wrist / >15$^0$ (+3) | O | Wrist√ <15$^0$ (+2) | O | 1. | | | | | | Rollermouse | O | O |
| Wrist√ <15$^0$ (+2) | O | Wrist√ >15$^0$ (+3) | O | 2. | | | | | | Eyeglasses/ contacts | O | O |
| Wrist√ >15$^0$ (+3) | O | Wrist RD/UD (+1) | O | 3. | | | | | | Document holder(s) | O | O |
| Wrist RD/UD (+1) | O | Legs/feet supported (+1) | O | 4. | | | | | | Headset | O | O |
| | | Legs/feet unsupported (+2) | O | 5. | | | | | | Monitor arm or riser | O | O |
| | | | | 6. | | | | | | Glare screen | O | O |
| | | | | | | | | | | Forearm support | O | O |

2nd PM

| 1. 30 Seconds: R UE, Head, Neck | | 2. 30 Seconds: L UE, Trunk, LE | | 3. 30 Seconds: R HAL | | | 4. 30 Seconds: L HAL | | | 5. 30 Seconds: Equipment in use | Y | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neck√ 0-10$^0$ (+1) | O | Trunk / √ 0-10$^0$ (+1) | O | Hands idle most of time; no regular movement | 0 | O | Hands idle most of time; no regular movement | 0 | O | 35" tray | O | O |
| Neck√ 11-20$^0$ (+2) | O | Trunk√ 11-20$^0$ (+2) | O | | | | | | | 24" tray/ drawer | O | O |
| Neck√ >20$^0$ (+3) | O | Trunk√ 21-60$^0$ (+3) | O | | | | | | | 19" tray/ drawer | O | O |
| Neck / (+4) | O | Trunk√ >60$^0$ (+4) | O | | | | | | | Corded mouse | O | O |
| Neck rotation (+1) | O | Trunk rotation (+1) | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Cordless mouse | O | O |
| Neck SB (+1) | O | Trunk sidebending (+1) | O | | | | | | | Trackball | O | O |
| Forward head (+1) | O | Upper arm –20+20$^0$ (+1) | O | | | | | | | Touch pad | O | O |
| Upper arm –20+20$^0$ (+1) | O | Upper arm / >21$^0$ (+2) | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Tablet/ stylus | O | O |
| Upper arm / >21$^0$ (+2) | O | Upper arm√ 21-45$^0$ (+2) | O | | | | | | | 3M joystick | O | O |
| Upper arm√ 21-45$^0$ (+2) | O | Upper arm√ 46-90$^0$ (+3) | O | | | | | | | Rollermouse | O | O |
| | | | | | | | | | | Forearm support | O | O |
| Upper arm√ 46-90$^0$ (+3) | O | Upper arm√ >90$^0$ (+4) | O | Steady motion/exertion; infrequent pauses | 6 | O | Steady motion/exertion; infrequent pauses | 6 | O | Eyeglasses/ contacts | O | O |
| Upper arm√ >90$^0$ (+4) | O | Upper arm ABD (+1) | O | | | | | | | Document holder(s) | O | O |
| Upper arm ABD (+1) | O | Upper arm supported (0) | O | | | | | | | Headset | O | O |
| Upper arm supported (0) | O | Shoulders elevated (+1) | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Monitor arm or riser | O | O |
| Shoulders elevated (+1) | O | Phone use (+1) | O | | | | | | | Glare screen | O | O |
| Phone use (+1) | O | Phone scrunch (+1) | O | | | | | | | Alternative KB | O | O |
| Phone scrunch (+1) | O | Elbow 90$^0$(0) | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Adherence to TP technique | O | O |
| Elbow 90$^0$(0) | O | Elbow 80-110$^0$(+1), excluding 90$^0$ | O | **5. (continued) Task:** | | | | | | Adherence to KBT technique | O | O |
| Elbow 80-110$^0$(+1), excluding 90$^0$ | O | Elbow hoz ABD/ADD(+1) | O | **Adherence or alteration to recommended equipment adjustments or positions: ONLY 1X AM & PM** | | | | | | **EQUIPMENT PRESENT: ONLY 1X AM or PM** | | |
| Elbow hoz ABD/ADD(+1) | O | Low KB + neg slope (0) | O | 1. | | | | | | Alternative KB | O | O |
| | | RULA elbow 110$^0$-120$^0$ (+2) | O | 2. | | | | | | KB tray/drawer | O | O |
| RULA elbow 110$^0$-120$^0$ (+2) | O | JD elbow >120$^0$ (0) | O | 3. | | | | | | Corded mouse | O | O |
| JD elbow >90$^0$ (0) | O | RULA forearm midrange (+1) | O | 4. | | | | | | Cordless mouse | O | O |
| RULA forearm midrange (+1) | O | RULA forearm full prona (+2) | O | 5. | | | | | | Trackball | O | O |
| | | JD forearm neutrl (0) | O | | | | | | | | | |
| RULA forearm full prona (+2) | O | Wrist 0$^0$ (+1) | O | 6. | | | | | | Touch pad | O | O |
| JD forearm neutrl (0) | O | | | | | | | | | | | |
| Wrist 0$^0$ (+1) | O | Wrist / <15$^0$ (+2) | O | **Alterations to recommended equipment: ONLY 1X AM & PM** | | | | | | Tablet/ stylus | O | O |
| Wrist / <15$^0$ (+2) | O | Wrist / >15$^0$ (+3) | O | | | | | | | 3M joystick | O | O |
| Wrist / >15$^0$ (+3) | O | Wrist√ <15$^0$ (+2) | O | 1. | | | | | | Rollermouse | O | O |
| Wrist√ <15$^0$ (+2) | O | Wrist√ >15$^0$ (+3) | O | 2. | | | | | | Eyeglasses/ contacts | O | O |
| Wrist√ >15$^0$ (+3) | O | Wrist RD/UD (+1) | O | 3. | | | | | | Document holder(s) | O | O |
| Wrist RD/UD (+1) | O | Legs/feet supported (+1) | O | 4. | | | | | | Headset | O | O |
| | | Legs/feet unsupported (+2) | O | 5. | | | | | | Monitor arm or riser | O | O |
| | | | | 6. | | | | | | Glare screen | O | O |
| | | | | | | | | | | Forearm support | O | O |

3rd PM

| 1. 30 Seconds: R UE, Head, Neck | | 2. 30 Seconds: L UE, Trunk, LE | | 3. 30 Seconds: R HAL | | | 4. 30 Seconds: L HAL | | | 5. 30 Seconds: Equipment in use | Y | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neck√ 0-10⁰ (+1) | O | Trunk / √ 0-10⁰ (+1) | O | Hands idle most of time; no regular movement | 0 | O | Hands idle most of time; no regular movement | 0 | O | 35" tray | O | O |
| Neck√ 11-20⁰ (+2) | O | Trunk√ 11-20⁰ (+2) | O | | | | | | | 24" tray/ drawer | O | O |
| Neck√ >20⁰ (+3) | O | Trunk√ 21-60⁰ (+3) | O | | | | | | | 19" tray/ drawer | O | O |
| Neck / (+4) | O | Trunk√ >60⁰ (+4) | O | | | | | | | Corded mouse | O | O |
| Neck rotation (+1) | O | Trunk rotation (+1) | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Cordless mouse | O | O |
| Neck SB (+1) | O | Trunk sidebending (+1) | O | | | | | | | Trackball | O | O |
| Forward head (+1) | O | Upper arm –20+20⁰ (+1) | O | | | | | | | Touch pad | O | O |
| Upper arm –20+20⁰ (+1) | O | Upper arm / >21⁰ (+2) | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Tablet/ stylus | O | O |
| Upper arm / >21⁰ (+2) | O | Upper arm√ 21-45⁰(+2) | O | | | | | | | 3M joystick | O | O |
| Upper arm√ 21-45⁰(+2) | O | Upper arm√ 46-90⁰(+3) | O | | | | | | | Rollermouse | O | O |
| | | | | | | | | | | Forearm support | O | O |
| Upper arm√ 46-90⁰(+3) | O | Upper arm√ >90⁰(+4) | O | Steady motion/exertion; infrequent pauses | 6 | O | Steady motion/exertion; infrequent pauses | 6 | O | Eyeglasses/ contacts | O | O |
| Upper arm√ >90⁰(+4) | O | Upper arm ABD (+1) | O | | | | | | | Document holder(s) | O | O |
| Upper arm ABD (+1) | O | Upper arm supported (0) | O | | | | | | | Headset | O | O |
| Upper arm supported (0) | O | Shoulders elevated (+1) | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Monitor arm or riser | O | O |
| Shoulders elevated (+1) | O | Phone use (+1) | O | | | | | | | Glare screen | O | O |
| Phone use (+1) | O | Phone scrunch (+1) | O | | | | | | | Alternative KB | O | O |
| Phone scrunch (+1) | O | Elbow 90⁰(0) | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Adherence to TP technique | O | O |
| Elbow 90⁰(0) | O | Elbow 80-110⁰(+1), excluding 90⁰ | O | **5. (continued) Task:** | | | | | | Adherence to KBT technique | O | O |
| Elbow 80-110⁰(+1), excluding 90⁰ | O | Elbow hoz ABD/ADD(+1) | O | **Adherence or alteration to recommended equipment adjustments or positions: ONLY 1X AM & PM** | | | | | | **EQUIPMENT PRESENT: ONLY 1X AM or PM** | | |
| Elbow hoz ABD/ADD(+1) | O | Low KB + neg slope (0) | O | 1. | | | | | | Alternative KB | O | O |
| | | RULA elbow 110⁰-120⁰ (+2) | O | 2. | | | | | | KB tray/drawer | O | O |
| RULA elbow 110⁰-120⁰ (+2) | O | JD elbow >120⁰ (0) | O | 3. | | | | | | Corded mouse | O | O |
| JD elbow >120⁰ (0) | O | RULA forearm midrange (+1) | O | 4. | | | | | | Cordless mouse | O | O |
| RULA forearm midrange (+1) | O | RULA forearm full prona (+2) | O | 5. | | | | | | Trackball | O | O |
| | | JD forearm neutrl (0) | O | | | | | | | | | |
| RULA forearm full prona (+2) | O | Wrist 0⁰ (+1) | O | 6. | | | | | | Touch pad | O | O |
| JD forearm neutrl (0) | O | | | | | | | | | | | |
| Wrist 0⁰ (+1) | O | Wrist / <15⁰ (+2) | O | **Alterations to recommended equipment: ONLY 1X AM & PM** | | | | | | Tablet/ stylus | O | O |
| Wrist / <15⁰ (+2) | O | Wrist / >15⁰ (+3) | O | | | | | | | 3M joystick | O | O |
| Wrist / >15⁰ (+3) | O | Wrist√ <15⁰ (+2) | O | 1. | | | | | | Rollermouse | O | O |
| Wrist√ <15⁰ (+2) | O | Wrist√ >15⁰ (+3) | O | 2. | | | | | | Eyeglasses/ contacts | O | O |
| Wrist√ >15⁰ (+3) | O | Wrist RD/UD (+1) | O | 3. | | | | | | Document holder(s) | O | O |
| Wrist RD/UD (+1) | O | Legs/feet supported (+1) | O | 4. | | | | | | Headset | O | O |
| | | Legs/feet unsupported (+2) | O | 5. | | | | | | Monitor arm or riser | O | O |
| | | | | 6. | | | | | | Glare screen | O | O |
| | | | | | | | | | | Forearm support | O | O |

4th PM

| 1. 30 Seconds: R UE, Head, Neck | | 2. 30 Seconds: L UE, Trunk, LE | | 3. 30 Seconds: R HAL | | | 4. 30 Seconds: L HAL | | | 5. 30 Seconds: Equipment in use | Y | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neck√ 0-10⁰ (+1) | O | Trunk / √ 0-10⁰ (+1) | O | Hands idle most of time; no regular movement | 0 | O | Hands idle most of time; no regular movement | 0 | O | 35" tray | O | O |
| Neck√ 11-20⁰ (+2) | O | Trunk√ 11-20⁰ (+2) | O | | | | | | | 24" tray/ drawer | O | O |
| Neck√ >20⁰ (+3) | O | Trunk√ 21-60⁰ (+3) | O | | | | | | | 19" tray/ drawer | O | O |
| Neck / (+4) | O | Trunk√ >60⁰ (+4) | O | | | | | | | Corded mouse | O | O |
| Neck rotation (+1) | O | Trunk rotation (+1) | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Cordless mouse | O | O |
| Neck SB (+1) | O | Trunk sidebending (+1) | O | | | | | | | Trackball | O | O |
| Forward head (+1) | O | Upper arm –20+20⁰ (+1) | O | | | | | | | Touch pad | O | O |
| Upper arm –20+20⁰ (+1) | O | Upper arm / >21⁰ (+2) | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Tablet/ stylus | O | O |
| Upper arm / >21⁰ (+2) | O | Upper arm√ 21-45⁰ (+2) | O | | | | | | | 3M joystick | O | O |
| Upper arm√ 21-45⁰ (+2) | O | Upper arm√ 46-90⁰ (+3) | O | | | | | | | Rollermouse | O | O |
| | | | | | | | | | | Forearm support | O | O |
| Upper arm√ 46-90⁰ (+3) | O | Upper arm√ >90⁰ (+4) | O | Steady motion/exertion; infrequent pauses | 6 | O | Steady motion/exertion; infrequent pauses | 6 | O | Eyeglasses/ contacts | O | O |
| Upper arm√ >90⁰ (+4) | O | Upper arm ABD (+1) | O | | | | | | | Document holder(s) | O | O |
| Upper arm ABD (+1) | O | Upper arm supported (0) | O | | | | | | | Headset | O | O |
| Upper arm supported (0) | O | Shoulders elevated (+1) | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Monitor arm or riser | O | O |
| Shoulders elevated (+1) | O | Phone use (+1) | O | | | | | | | Glare screen | O | O |
| Phone use (+1) | O | Phone scrunch (+1) | O | | | | | | | Alternative KB | O | O |
| Phone scrunch (+1) | O | Elbow 90⁰(0) | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Adherence to TP technique | O | O |
| Elbow 90ᵘ(0) | O | Elbow 80-110ᵘ(+1), excluding 90ᵘ | O | **5. (continued) Task:** | | | | | | Adherence to KBT technique | O | O |
| Elbow 80-110ᵘ(+1), excluding 90ᵘ | O | Elbow hoz ABD/ADD(+1) | O | **Adherence or alteration to recommended equipment adjustments or positions: ONLY 1X AM & PM** | | | | | | **EQUIPMENT PRESENT: ONLY 1X AM or PM** | | |
| Elbow hoz ABD/ADD(+1) | O | Low KB + neg slope (0) | O | 1. | | | | | | Alternative KB | O | O |
| | | RULA elbow 110⁰-120⁰ (+2) | O | 2. | | | | | | KB tray/drawer | O | O |
| RULA elbow 110⁰-120⁰ (+2) | O | JD elbow >120⁰ (0) | O | 3. | | | | | | Corded mouse | O | O |
| JD elbow >120⁰ (0) | O | RULA forearm midrange (+1) | O | 4. | | | | | | Cordless mouse | O | O |
| RULA forearm midrange (+1) | O | RULA forearm full prona (+2) | O | 5. | | | | | | Trackball | O | O |
| | | JD forearm neutrl (0) | O | | | | | | | | | |
| RULA forearm full prona (+2) | O | Wrist 0⁰ (+1) | O | 6. | | | | | | Touch pad | O | O |
| JD forearm neutrl (0) | O | | | | | | | | | | | |
| Wrist 0⁰ (+1) | O | Wrist / <15⁰ (+2) | O | Alterations to recommended equipment: ONLY 1X AM & PM | | | | | | Tablet/ stylus | O | O |
| Wrist / <15⁰ (+2) | O | Wrist / >15⁰ (+3) | O | | | | | | | 3M joystick | O | O |
| Wrist / >15⁰ (+3) | O | Wrist√ <15⁰ (+2) | O | 1. | | | | | | Rollermouse | O | O |
| Wrist√ <15⁰ (+2) | O | Wrist√ >15⁰ (+3) | O | 2. | | | | | | Eyeglasses/ contacts | O | O |
| Wrist√ >15⁰ (+3) | O | Wrist RD/UD (+1) | O | 3. | | | | | | Document holder(s) | O | O |
| Wrist RD/UD (+1) | O | Legs/feet supported (+1) | O | 4. | | | | | | Headset | O | O |
| | | Legs/feet unsupported (+2) | O | 5. | | | | | | Monitor arm or riser | O | O |
| | | | | 6. | | | | | | Glare screen | O | O |
| | | | | | | | | | | Forearm support | O | O |

5th PM

| 1. 30 Seconds: R UE, Head, Neck | | 2. 30 Seconds: L UE, Trunk, LE | | 3. 30 Seconds: R HAL | | | 4. 30 Seconds: L HAL | | | 5. 30 Seconds: Equipment In use | Y | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neck√ 0-10$^0$ (+1) | O | Trunk / √ 0-10$^0$ (+1) | O | Hands idle most of time; no regular movement | 0 | O | Hands idle most of time; no regular movement | 0 | O | 35" tray | O | O |
| Neck√ 11-20$^0$ (+2) | O | Trunk√ 11-20$^0$ (+2) | O | | | | | | | 24" tray/ drawer | O | O |
| Neck√ >20$^0$ (+3) | O | Trunk√ 21-60$^0$ (+3) | O | | | | | | | 19" tray/ drawer | O | O |
| Neck / (+4) | O | Trunk√ >60$^0$ (+4) | O | | | | | | | Corded mouse | O | O |
| Neck rotation (+1) | O | Trunk rotation (+1) | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Cordless mouse | O | O |
| Neck SB (+1) | O | Trunk sidebending (+1) | O | | | | | | | Trackball | O | O |
| Forward head (+1) | O | Upper arm –20+20$^0$ (+1) | O | | | | | | | Touch pad | O | O |
| Upper arm –20+20$^0$ (+1) | O | Upper arm / >21$^0$ (+2) | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Tablet/ stylus | O | O |
| Upper arm / >21$^0$ (+2) | O | Upper arm√ 21-45$^0$ (+2) | O | | | | | | | 3M joystick | O | O |
| Upper arm√ 21-45$^0$ (+2) | O | Upper arm√ 46-90$^0$ (+3) | O | | | | | | | Rollermouse | O | O |
| | | | | | | | | | | Forearm support | O | O |
| Upper arm√ 46-90$^0$ (+3) | O | Upper arm√ >90$^0$ (+4) | O | Steady motion/exertion; infrequent pauses | 6 | O | Steady motion/exertion; infrequent pauses | 6 | O | Eyeglasses/ contacts | O | O |
| Upper arm√ >90$^0$ (+4) | O | Upper arm ABD (+1) | O | | | | | | | Document holder(s) | O | O |
| Upper arm ABD (+1) | O | Upper arm supported (0) | O | | | | | | | Headset | O | O |
| Upper arm supported (0) | O | Shoulders elevated (+1) | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Monitor arm or riser | O | O |
| Shoulders elevated (+1) | O | Phone use (+1) | O | | | | | | | Glare screen | O | O |
| Phone use (+1) | O | Phone scrunch (+1) | O | | | | | | | Alternative KB | O | O |
| Phone scrunch (+1) | O | Elbow 90$^0$(0) | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Adherence to TP technique | O | O |
| Elbow 90$^0$(0) | O | Elbow 80-110$^0$(+1), excluding 90$^0$ | O | **5. (continued) Task:** | | | | | | Adherence to KBT technique | O | O |
| Elbow 80-110$^0$(+1), excluding 90$^0$ | O | Elbow hoz ABD/ADD(+1) | O | **Adherence or alteration to recommended equipment adjustments or positions: ONLY 1X AM & PM** | | | | | | **EQUIPMENT PRESENT: ONLY 1X AM or PM** | | |
| Elbow hoz ABD/ADD(+1) | O | Low KB + neg slope (0) | O | 1. | | | | | | Alternative KB | O | O |
| | | RULA elbow 110$^0$-120$^0$ (+2) | O | 2. | | | | | | KB tray/drawer | O | O |
| RULA elbow 110$^0$-120$^0$ (+2) | O | JD elbow >120$^0$ (0) | O | 3. | | | | | | Corded mouse | O | O |
| JD elbow >120$^0$ (0) | O | RULA forearm midrange (+1) | O | 4. | | | | | | Cordless mouse | O | O |
| RULA forearm midrange (+1) | O | RULA forearm full prona (+2) | O | 5. | | | | | | Trackball | O | O |
| | | JD forearm neutrl (0) | O | | | | | | | | | |
| RULA forearm full prona (+2) | O | Wrist 0$^0$ (+1) | O | 6. | | | | | | Touch pad | O | O |
| JD forearm neutrl (0) | O | | | | | | | | | | | |
| Wrist 0$^0$ (+1) | O | Wrist / <15$^0$ (+2) | O | **Alterations to recommended equipment: ONLY 1X AM & PM** | | | | | | Tablet/ stylus | O | O |
| Wrist / <15$^0$ (+2) | O | Wrist / >15$^0$ (+3) | O | | | | | | | 3M joystick | O | O |
| Wrist / >15$^0$ (+3) | O | Wrist√ <15$^0$ (+2) | O | 1. | | | | | | Rollermouse | O | O |
| Wrist√ <15$^0$ (+2) | O | Wrist√ >15$^0$ (+3) | O | 2. | | | | | | Eyeglasses/ contacts | O | O |
| Wrist√ >15$^0$ (+3) | O | Wrist RD/UD (+1) | O | 3. | | | | | | Document holder(s) | O | O |
| Wrist RD/UD (+1) | O | Legs/feet supported (+1) | O | 4. | | | | | | Headset | O | O |
| | | Legs/feet unsupported (+2) | O | 5. | | | | | | Monitor arm or riser | O | O |
| | | | | 6. | | | | | | Glare screen | O | O |
| | | | | | | | | | | Forearm support | O | O |

6th PM

| 1. 30 Seconds: R UE, Head, Neck | | 2. 30 Seconds: L UE, Trunk, LE | | 3. 30 Seconds: R HAL | | | 4. 30 Seconds: L HAL | | | 5. 30 Seconds: Equipment in use | Y | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Neck√ 0-10⁰ (+1) | O | Trunk / √ 0-10⁰ (+1) | O | Hands idle most of time; no regular movement | 0 | O | Hands idle most of time; no regular movement | 0 | O | 35" tray | O | O |
| Neck√ 11-20⁰ (+2) | O | Trunk√ 11-20⁰ (+2) | O | | | | | | | 24" tray/ drawer | O | O |
| Neck√ >20⁰ (+3) | O | Trunk√ 21-60⁰ (+3) | O | | | | | | | 19" tray/ drawer | O | O |
| Neck / (+4) | O | Trunk√ >60⁰ (+4) | O | | | | | | | Corded mouse | O | O |
| Neck rotation (+1) | O | Trunk rotation (+1) | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Consistent, conspicuous long pauses; very slow motions | 2 | O | Cordless mouse | O | O |
| Neck SB (+1) | O | Trunk sidebending (+1) | O | | | | | | | Trackball | O | O |
| Forward head (+1) | O | Upper arm –20+20⁰ (+1) | O | | | | | | | Touch pad | O | O |
| Upper arm –20+20⁰ (+1) | O | Upper arm / >21⁰ (+2) | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Slow, steady motions/exertions; frequent brief pauses | 4 | O | Tablet/ stylus | O | O |
| Upper arm / >21⁰ (+2) | O | Upper arm√ 21-45⁰ (+2) | O | | | | | | | 3M joystick | O | O |
| Upper arm√ 21-45⁰ (+2) | O | Upper arm√ 46-90⁰ (+3) | O | | | | | | | Rollermouse | O | O |
| | | | | | | | | | | Forearm support | O | O |
| Upper arm√ 46-90⁰ (+3) | O | Upper arm√ >90⁰ (+4) | O | Steady motion/exertion; infrequent pauses | 6 | O | Steady motion/exertion; infrequent pauses | 6 | O | Eyeglasses/ contacts | O | O |
| Upper arm√ >90⁰ (+4) | O | Upper arm ABD (+1) | O | | | | | | | Document holder(s) | O | O |
| Upper arm ABD (+1) | O | Upper arm supported (0) | O | | | | | | | Headset | O | O |
| Upper arm supported (0) | O | Shoulders elevated (+1) | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Rapid steady motion/exertion; no regular pauses | 8 | O | Monitor arm or riser | O | O |
| Shoulders elevated (+1) | O | Phone use (+1) | O | | | | | | | Glare screen | O | O |
| Phone use (+1) | O | Phone scrunch (+1) | O | | | | | | | Alternative KB | O | O |
| Phone scrunch (+1) | O | Elbow 90⁰(0) | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Rapid steady motion/exertion; difficulty keeping up | 10 | O | Adherence to TP technique | O | O |
| Elbow 90⁰(0) | O | Elbow 80-110⁰(+1), excluding 90⁰ | O | **5. (continued) Task:** | | | | | | Adherence to KBT technique | O | O |
| Elbow 80-110⁰(+1), excluding 90⁰ | O | Elbow hoz ABD/ADD(+1) | O | **Adherence or alteration to recommended equipment adjustments or positions: ONLY 1X AM & PM** | | | | | | **EQUIPMENT PRESENT: ONLY 1X AM or PM** | | |
| Elbow hoz ABD/ADD(+1) | O | Low KB + neg slope (0) | O | 1. | | | | | | Alternative KB | O | O |
| | | RULA elbow 110⁰-120⁰ (+2) | O | 2. | | | | | | KB tray/drawer | O | O |
| RULA elbow 110⁰-120⁰ (+2) | O | JD elbow >120⁰ (0) | O | 3. | | | | | | Corded mouse | O | O |
| JD elbow >120⁰ (0) | O | RULA forearm midrange (+1) | O | 4. | | | | | | Cordless mouse | O | O |
| RULA forearm midrange (+1) | O | RULA forearm full prona (+2) | O | 5. | | | | | | Trackball | O | O |
| | | JD forearm neutrl (0) | O | | | | | | | | | |
| RULA forearm full prona (+2) | O | Wrist 0⁰ (+1) | O | 6. | | | | | | Touch pad | O | O |
| JD forearm neutrl (0) | O | | | | | | | | | | | |
| Wrist 0⁰ (+1) | O | Wrist / <15⁰ (+2) | O | **Alterations to recommended equipment: ONLY 1X AM & PM** | | | | | | Tablet/ stylus | O | O |
| Wrist / <15⁰ (+2) | O | Wrist / >15⁰ (+3) | O | | | | | | | 3M joystick | O | O |
| Wrist / >15⁰ (+3) | O | Wrist√ <15⁰ (+2) | O | 1. | | | | | | Rollermouse | O | O |
| Wrist√ <15⁰ (+2) | O | Wrist√ >15⁰ (+3) | O | 2. | | | | | | Eyeglasses/ contacts | O | O |
| Wrist√ >15⁰ (+3) | O | Wrist RD/UD (+1) | O | 3. | | | | | | Document holder(s) | O | O |
| Wrist RD/UD (+1) | O | Legs/feet supported (+1) | O | 4. | | | | | | Headset | O | O |
| | | Legs/feet unsupported (+2) | O | 5. | | | | | | Monitor arm or riser | O | O |
| | | | | 6. | | | | | | Glare screen | O | O |
| | | | | | | | | | | Forearm support | O | O |

Additional Notes:

## Appendix C. References for Screening Survey

| SCREENING SURVEY | REFERENCE |
|---|---|
| **Socio demographic items** | |
| Gender | |
| Age | |
| Race | [1] |
| Education | [1] |
| Current marital status | |
| Smoking status | |
| Yearly income | [2] |
| Responsibility for children under 18 in your household | [1] |
| Anyone in your family who is elderly or has a long term care disability and depends on you for care | [1, 3] |
| During a typical week, how much time spent cleaning, gardening, home maintenance, playing a musical instrument, or cooking | [1] |
| **History of present illness** | |
| Any pain in past month | [3] |
| Pain severity in past month | [3-5] |
| Duration experiencing pain | [6] |
| Workdays missed in past 2 months due to an MSD | |
| Serious traumatic injury in past year | |
| **Past medical history** | |
| Has a Health Care Provider (HCP) told you that you CURRENTLY have sciatica or a ruptured disc in your low back or neck | |
| Has a HCP told you that you CURRENTLY have rheumatoid arthritis, gout, lupus, acromegaly, diabetes, connective tissue disease, TB, kidney failure or thyroid problem | [7] |
| Are any of these problems CURRENTLY being treated with medication | [7] |
| **Physical and temporal load items** | |
| Daily hours on computer at work | [8] |
| Years worked in current job title | |
| Total years worked at General Assembly | |
| Hours at computer without leaving workstation | [8, 9] |
| **Department** | |
| **Job title** | |

## Appendix D. References for Self-Administered Surveys: Baseline and Follow-Up

| SELF-ADMINISTERED SURVEY | REFERENCE |
|---|---|
| **Psychosocial factors** | |
| Working very fast | [10] |
| Working very hard | [10] |
| Not asked to do an excessive amount of work | [10] |
| Enough time to get job done | [10] |
| Free from conflicting demands others make | [10] |
| Job requires you learn new things | [10] |
| Job involves a lot of repetitive work | [10] |
| Job requires you to be creative | [10] |
| Job requires a high level of skill | [10] |
| Do a variety of things on your job | [10] |
| Opportunity to develop your own special abilities | [10] |
| Make a lot of decisions on your own | [10] |
| Very little freedom to decide how you do your work | [10] |
| A lot of say about what happens on your job | [10] |
| Supervisor concerned about the welfare of those under him/her | [10] |
| Supervisor pays attention to what you are saying | [10] |
| Supervisor is helpful in getting the job done | [10] |
| Supervisor is successful in getting people to work together | [10] |
| How satisfied are you with your job | [11] |
| Leave this job in next 2 years because you are dissatisfied | [12] |
| Obligated to turn away from the computer to do non-computer tasks | [13] |
| Have the appropriate supplies, materials, and equipment | [11] |
| **Socio demographic** | |
| Handedness | |
| Daily accumulation of 30 minutes of PHYSICAL ACTIVITY, moderate to vigorous in intensity | [6, 15] |
| **Females only** | |
| Pregnant | |
| Peri-menopausal | |
| **History of present illness** | |
| Difficulty sleeping | [14] |
| Difficulty using usual technique for work | [15] |
| Active workers' compensation case for neck or upper extremity (UE) | [16] |
| Seek medical care, including PT or OT in past 4 weeks | |
| Difficulty doing your work as well as you would like | [15] |
| Able to do your current job two years from now | [17] |
| **Past medical history** | |
| In past 5 years, have you had surgery in neck, low back or UE | |
| **Physical and temporal load items** | |
| Time spent in home computer use | [18] |
| Time spent in personal digital assistant use, such as Blackberry or Iphone | |

Appendix D continued

| | |
|---|---|
| **Office ergonomic knowledge** | [19] |
| Describe overall knowledge of office ergonomics | |
| Knowledge of ergonomic risk factors | |
| Knowledge of what is an ergonomically correct posture | |
| Knowledge of what is an ergonomically designed workspace | |
| **Quality of life health status** | |
| MOS | [20] |
| **FOLLOW-UP SELF-ADMINISTERED SURVEY ONLY** | |
| **Questions about engineering controls for intervention group** | [7] |
| Did the keyboard tray decrease or increase your pain | |
| Did the touch pad decrease or increase your pain | |
| Did you like or dislike using the keyboard tray | |
| Did you like or dislike using the touch pad | |
| Was the keyboard tray difficult to use | |
| Was the touch pad difficult to use | |
| Did the keyboard tray improve your productivity | |
| Did the touch pad improve your productivity | |

## Appendix E. References for Interviewer-Administered Surveys: Baseline and Follow-Up

| INTERVIEWER-ADMINISTERED SURVEY | REFERENCE |
|---|---|
| **Physical and temporal load items** | |
| Typical workday with an average workload | [13] |
| Hours per week, ON AVERAGE, do you work on this job | |
| Hours per week, ON AVERAGE, do you use the computer keyboard at work | [8, 9] |
| Hours per week, ON AVERAGE, do you use the computer mouse at work | [8, 9] |
| Often required to perform hand or keyboard work without an arm or wrist support | [21] |
| Often required to bend or twist your wrists to do your job | [22] |
| Often required to use a lot of effort with your fingers to do your job | [22] |
| Often required to hold your neck, shoulder, arms or hands in one position for a long time | [21] |
| Often expected to meet a deadline | [23] |
| Often required to work overtime | [24] |
| Hours per day, ON AVERAGE, are spent on the telephone | [23] |
| Other than computer work, often required to perform repetitive tasks, in which motions are repeated every fifteen seconds or less | [21] |
| Often expected to hold an object by pinching with your fingers | [21] |
| Total amount of break time, including lunch, in minutes, over a workday | [7] |
| Work more than one job in which you use a computer | |
| How many hours per week, ON AVERAGE, do you work at those OTHER computer-related jobs, combined | [3] |
| How many years have you been using a computer over your lifetime | [6] |
| **History of present illness** | |
| During the past 4 weeks, have you had an exacerbation of pain in your neck or UE | [3] |
| Pain severity in past month | [3-5] |

## Appendix F. References for Observational assessment: Baseline and Follow-Up

| OBSERVATIONAL ASSESSMENT | REFERENCE |
|---|---|
| **Socio demographic items** | |
| BMI | [25] |
| Baseline mousing UE | [7] |
| **Physical and temporal load items** | |
| HAL | [26] |
| RULA | [8, 9] |

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# APPENDIX G

**APPENDIX G1:** Telephone-Screening Questionnaire

**APPENDIX G2:** Baseline Self-Administered Survey

**APPENDIX G3:** SF 36 – Your Health and Well-Being

**APPENDIX G4:** Baseline Interviewer-Administered Survey

**APPENDIX G5:** Intervention Compliance Survey

**APPENDIX G6:** Follow-up Take-Home

**APPENDIX G7:** Post Intervention Interviewer-Administered Survey

# APPENDIX G1

# TELEPHONE-SCREENING QUESTIONNAIRE

ID number:

| | | | |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 |
| 2 | 2 | 2 | 2 |
| 3 | 3 | 3 | 3 |
| 4 | 4 | 4 | 4 |
| 5 | 5 | 5 | 5 |
| 6 | 6 | 6 | 6 |
| 7 | 7 | 7 | 7 |
| 8 | 8 | 8 | 8 |
| 9 | 9 | 9 | 9 |

Remember that all surveys will be kept completely confidential. There will be no personal identifiers that can be linked back to you. The Joint Committee on Legislative Management will not have access to individual employee results.

**QUESTIONS 1-14 ARE FOR ALL EMPLOYEES:**

1. Gender:

   ☐ Male ☐ Female

2. What month and year were you born? Enter the month and year the subject was born on the line and then fill in the corresponding bubbles.

Month: _____ Year: _____

| | |
|---|---|
| ☐ January | ☐ July |
| ☐ February | ☐ August |
| ☐ March | ☐ September |
| ☐ April | ☐ October |
| ☐ May | ☐ November |
| ☐ June | ☐ December |

| | | | |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 |
| 2 | 2 | 2 | 2 |
| 3 | 3 | 3 | 3 |
| 4 | 4 | 4 | 4 |
| 5 | 5 | 5 | 5 |
| 6 | 6 | 6 | 6 |
| 7 | 7 | 7 | 7 |
| 8 | 8 | 8 | 8 |
| 9 | 9 | 9 | 9 |

3. How many hours per day, on average, do you use the computer at work?

Hours: _____

| | |
|---|---|
| 0 | 0 |
| 1 | 1 |
| 2 | 2 |
| 3 | 3 |
| 4 | 4 |
| 5 | 5 |
| 6 | 6 |
| 7 | 7 |
| 8 | 8 |
| 9 | 9 |

4. During the past 4 weeks, have you had pain in your neck, upper back, shoulders, arms, elbows, forearms, wrists, or fingers?

   ☐ Yes ☐ No

5. If you answered yes to the above question, how much pain during the past 4 weeks have you had in your:

| | NO PAIN | MILD PAIN, ANNOYING: Pain present but does not limit activity | NAGGING PAIN, UNCOMFORTABLE, TROUBLESOME: Can do most activities with rest periods | MISERABLE, DISTRESSING: Unable to do some activities b/c of pain | INTENSE, DREADFUL, HORRIBLE: Unable to do most activities b/c of pain |
|---|---|---|---|---|---|
| R Neck/UB | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Neck/UB | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Shoulders | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Shoulders | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Arms | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Arms | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Elbows | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Elbows | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Forearms | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Forearms | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Wrists | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Wrists | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Fingers | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Fingers | ☐ | ☐ | ☐ | ☐ | ☐ |

6. How long have you been experiencing the pain in your:

| | < 1Year | 1Year | 2Years | 3Years | 4Years | 5Years | 6Years | 7Years | 8Years | 9Years | ≥10 Years |
|---|---|---|---|---|---|---|---|---|---|---|---|
| R Neck/UB | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Neck/UB | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Shoulders | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Shoulders | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Arms | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Arms | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Elbows | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Elbows | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Forearms | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Forearms | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Wrists | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Wrists | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Fingers | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Fingers | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

7. In the past 12 months, have you had a serious traumatic injury to your neck, upper back, shoulders, arms, elbows, forearms, wrists, hands or fingers?

☐ Yes ☐ No

8. What is your CURRENT job title or assignment? _____

☐ Administrative Assistant ☐ Aide
☐ Attorney ☐ Administrator
☐ Director ☐ Coordinator

- ☐ IT Analyst
- ☐ Press
- ☐ Researcher
- ☐ Secretary
- ☐ Other

9. Please list your computer tasks?

_____ _____
_____ _____
_____ _____
_____ _____

10. How many years have you worked in your CURRENT job title? Write the number of years on the line, and then fill in the corresponding bubbles.

Years: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

11. What unit or department do you CURRENTLY work in? _____

- ☐ Information Technology Services
- ☐ Legislative Commissioners' Office
- ☐ Office of Fiscal Analysis
- ☐ Program Review and Investigation
- ☐ House Clerk's Office
- ☐ Senate Clerk's Office
- ☐ Office of Legislative Research
- ☐ Office of Legislative Management
- ☐ State Capitol Police Office
- ☐ Committee Administrators
- ☐ House Democrats
- ☐ House Republicans
- ☐ Senate Democrats
- ☐ Senate Republicans
- ☐ Permanent Commission on the Status of Women
- ☐ Commission on Children
- ☐ Commission on Aging
- ☐ African American Affairs Commission
- ☐ Latino and Puerto Rican Affairs Commission
- ☐ Other

12. How many years have you worked at the Joint Committee on Legislative Management? Write the number of years on the line, and then fill in the corresponding bubbles.

Years: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

13. How many hours, on average, do you sit at your workstation without getting up?

☐ Less than 30 minutes
☐ Between 30 min - 1 hour
☐ Between 1-3 hours
☐ Between 3-6 hours
☐ Between 6-9 hours
☐ More than 9 hours

14. During the past 8 weeks, how many days of work have you missed or been absent due to a problem in your neck, upper back, shoulders, arms, elbows, forearms, wrists, hands or fingers? Write the number of days on the line and then fill in the corresponding bubbles.

Days: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

**QUESTIONS 15-16 ARE ONLY FOR POTENTIAL EMPLOYEES INTERESTED IN PARTICIPATING.**

15. You will be receiving some ergonomic equipment **either** approximately 1 month after the study begins or approximately 6 months after the study begins. Are you willing to use a touch pad mouse in your non-mousing hand **and** a 35 inch fully adjustable keyboard tray, **in addition** to the mouse that you are currently using in your mousing hand?

☐ Yes ☐ No

16. There will be 3 worksite visits over a 6 month period. You will be required to have 30 minutes of interview time per visit in order to complete an interviewer-administered survey. Over the 6 month period, that equals 1.5 hours. You will also receive the equipment listed above at about the first or sixth month of the study. Installation and training will take 2.5 hours over the 6 month period. The entire process – equipment installation, training and interview – will take a total of about 4 hours over a 6 month period. Do you feel comfortable taking 4 hours of work time over the six month study for installation of and training on the intervention, and the interviewer-administered surveys?

☐ Yes ☐ No

**QUESTIONS 17-28 ARE ONLY FOR EMPLOYEES WHO HAVE SELECTED OPTION 2 (DO NOT WANT TO PARTICIPATE IN THE STUDY, BUT HAVE AGREED TO ANSWER THE FOLLOWING QUESTIONS):**

17. Do you consider yourself?

- ☐ White, European ancestry
- ☐ American Indian, Alaska Native
- ☐ Black, African American, African
- ☐ Asian, Asian American, Filipino, Korean, Chinese
- ☐ Latino or Hispanic

18. Please indicate the highest grade or year of school that you have completed?

- ☐ Less than high school
- ☐ High school graduate or GED
- ☐ Some college
- ☐ 2 or 4 year college degree
- ☐ Graduate degree

19. What is your current marital status?

- ☐ Married or live with partner
- ☐ Widowed
- ☐ Not married

20. What is your current smoking status?

- ☐ Smoke
- ☐ Not smoke

21. How many cans of beer, glasses of wine or alcoholic drinks do you consume each week?

- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3 or more

22. Which range best describes your yearly income.

- ☐ Less than $35,000
- ☐ Between $35,000 and $74,999
- ☐ Equal to or greater than $75,000

23. How much responsibility do you personally have for any children under 18 in your household?

- ☐ There are no children under 18 at home
- ☐ I have primary responsibility
- ☐ I share responsibility with another adult(s)
- ☐ Another adult has primary responsibility

24. Is there anyone in your family or household, or living nearby, who is elderly or who has a long term care illness or disability and depends on you for care?

- ☐ Yes
- ☐ No

25. During a typical week, how much time do you usually spend cleaning, gardening, home maintenance, playing a musical instrument, or cooking?

- ☐ None
- ☐ Between 3 and 6 hrs/week

☐ Less than 1 hr/week
☐ Between 1 and 3 hrs/week
☐ Between 6 and 10 hrs/week
☐ More than 10 hrs/week

26. Has a doctor or health care provider told you that you CURRENTLY have sciatica or a ruptured disc in your low back or neck?

☐ Yes ☐ No

27. Has a doctor or health care provider told you that you CURRENTLY have rheumatoid arthritis, gout, lupus, acromegaly, high blood sugar or diabetes, connective tissue disorder, tuberculosis, kidney failure or thyroid problem?

☐ Yes ☐ No

28. Are any of these problems CURRENTLY being treated with medication?

☐ Yes ☐ No

Once again, thank you for your time and consideration. Your help is greatly appreciated.

# APPENDIX G2

# BASELINE SELF-ADMINISTERED SURVEY

ID number: ⓪⓪⓪⓪
①①①①
②②②②
③③③③
④④④④
⑤⑤⑤⑤
⑥⑥⑥⑥
⑦⑦⑦⑦
⑧⑧⑧⑧
⑨⑨⑨⑨

Remember that all surveys will be kept completely and strictly confidential. There will be no personal identifiers that can be linked back to you. The Joint Committee on Legislative Management will not have access to individual employee results.

This first set of questions asks about your current job at the Joint Committee on Legislative Management. For each statement, fill in the box for the answer that best describes your job.

1. Your job requires working very fast.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

2. Your job requires working very hard.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

3. You are not asked to do an excessive amount of work.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

4. You have enough time to get the job done.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

5. You are free from conflicting demands that others make.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

6. Your job requires that you learn new things.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

7. Your job involves a lot of repetitive work.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

8. Your job requires you to be creative.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

9. Your job requires a high level of skill.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

10. You get to do a variety of things on your job.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

11. You have an opportunity to develop your own special abilities.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

12. Your job allows you to make a lot of decisions on your own.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

13. On your job, you have very little freedom to decide how you do your work.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

14. You have a lot of say about what happens on your job.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

15. Your supervisor is concerned about the welfare of those under him/her.

| Strongly Disagree | Disagree | Agree | Strongly Agree | I Have No Supervisor |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

16. Your supervisor pays attention to what you are saying.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

17. Your supervisor is helpful in getting the job done.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

18. Your supervisor is successful in getting people to work together.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

19. Considering everything, how satisfied are you with your job?

| Very Dissatisfied | Somewhat Dissatisfied | Neither Satisfied nor Dissatisfied | Somewhat Satisfied | Very Satisfied |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

20. You have the appropriate supplies, materials, and equipment to perform your job well.

| Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

21. You are obligated to turn away from the computer to do non-computer tasks throughout the day.

| Never | Sometimes | Often or Almost Always |
|---|---|---|
| ☐ | ☐ | ☐ |

22. You can voluntarily decide to combine computer tasks with non-computer tasks every hour.

| Cannot Voluntarily Decide | Can Voluntarily Decide | Not Specified |
|---|---|---|
| ☐ | ☐ | ☐ |

23. You are likely to leave this job in the next 2 years because you are dissatisfied.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

24. During the past week, how much difficulty have you had sleeping because of any neck, upper back, shoulder, arm, elbow, forearm, hand, or finger problem?

| No Difficulty | Mild Difficulty | Moderate Difficulty | Severe Difficulty | So Much Difficulty That I Can't Sleep |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

25. During the past week, did you have any difficulty using your usual technique for your work?

| No Difficulty | Mild Difficulty | Moderate Difficulty | Severe Difficulty | Unable |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

26. During the past week, did you have any difficulty doing your work as well as you would like?

| No Difficulty | Mild Difficulty | Moderate Difficulty | Severe Difficulty | Unable |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

27. Do you believe that, from the standpoint of your health, you will be able to do your current job two years from now?

| Unlikely | Not Certain | Relatively Certain |
|---|---|---|
| ☐ | ☐ | ☐ |

**We are now going to ask you GENERAL questions. Fill in the box for the answer that best describes each statement.**

28. Are you right or left handed?
☐ Right ☐ Left

29. Do you consider yourself?
☐ White, European descent
☐ Latino or Hispanic
☐ Asian, Asian American, Filipino, Korean, Chinese
☐ Black, African American, African
☐ American Indian, Alaska Native

30. Please indicate the highest grade or year of school that you have completed?
☐ Less than high school
☐ High school graduate or GED
☐ Some college
☐ 2 or 4 year college degree
☐ Graduate degree

31. What is your current marital status?
☐ Married or live with partner
☐ Not married
☐ Widowed

32. How much responsibility do you personally have for any children under 18 in your household?
☐ There are no children under 18 at home
☐ I have primary responsibility
☐ I share responsibility with another adult(s)
☐ Another adult has primary responsibility

33. Is there anyone in your family or household, or living nearby, who is elderly or who has a long term care illness or disability and depends on you for care?

☐ Yes ☐ No

34. During a typical week, how much time do you usually spend cleaning, gardening, doing home maintenance, playing a musical instrument, or cooking?

☐ None
☐ Less than 1 hr/week
☐ Between 1 and 3 hrs/week
☐ Between 3 and 6 hrs/week
☐ Between 6 and 10 hrs/week
☐ More than 10 hrs/week

35. Which range best describes your CURRENT yearly income.

☐ Less than $35,000
☐ Between $35,000 and $74,999
☐ More than $75,000

36. What is your CURRENT smoking status?

☐ Smoke ☐ Not smoke

37. How many cans of beer, glasses of wine or alcoholic drinks do you CURRENTLY consume a week?

☐ 0 ☐ 1 ☐ 2 ☐ 3 or more

38. Has a doctor or health care provider told you that you CURRENTLY have sciatica or a ruptured disc in your low back or neck?

☐ Yes ☐ No

39. Has a doctor or health care provider told you that you CURRENTLY have rheumatoid arthritis, gout, lupus, acromegaly, high blood sugar or diabetes, connective tissue disorder, tuberculosis, kidney failure or thyroid problem?

☐ Yes ☐ No

40. Are any of these problems CURRENTLY being treated with medication?

☐ Yes ☐ No

41. In the past 5 years, have you had surgery to any of these body regions:

| | Yes | No |
|---|---|---|
| Neck | ☐ | ☐ |
| Lower Back | ☐ | ☐ |
| Shoulder | ☐ | ☐ |
| Elbow | ☐ | ☐ |
| Forearm | ☐ | ☐ |
| Wrist | ☐ | ☐ |
| Hand | ☐ | ☐ |
| Fingers | ☐ | ☐ |

42. During the past 8 weeks, how many days of work have you missed or been absent due to a problem in your neck, upper back, shoulders, arms, elbows, forearms, wrists, hands or fingers?

Days: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

43. During the past 4 weeks, did you seek medical care for a problem in your:

| | Yes | No |
|---|---|---|
| Neck | ☐ | ☐ |
| Upper Back | ☐ | ☐ |
| Shoulders | ☐ | ☐ |
| Arms | ☐ | ☐ |
| Elbows | ☐ | ☐ |
| Forearms | ☐ | ☐ |
| Wrists | ☐ | ☐ |
| Hands | ☐ | ☐ |
| Fingers | ☐ | ☐ |

44. Do you have an active Workers' Compensation case involving any of these body regions:

| | Yes | No |
|---|---|---|
| Neck | ☐ | ☐ |
| Shoulder | ☐ | ☐ |
| Elbow | ☐ | ☐ |
| Forearm | ☐ | ☐ |
| Wrist | ☐ | ☐ |
| Hand | ☐ | ☐ |
| Fingers | ☐ | ☐ |

45. Do you perform a daily accumulation of at least 30 minutes of some sort of PHYSICAL ACTIVITY that is at least moderate to vigorous in its intensity?

☐ Yes ☐ No

46. In a typical week, how much time do you spend in home computer use?

☐ None
☐ Less than 1 hr/week
☐ Between 1 and 3 hrs/week
☐ Between 3 and 6 hrs/week
☐ Between 6 and 10 hrs/week
☐ More than 10 hrs/week

47. In a typical week, how much time do you spend in personal digital assistant use, such as a Blackberry or Iphone?

☐ None
☐ Less than 1 hr/week
☐ Between 1 and 3 hrs/week
☐ Between 3 and 6 hrs/week
☐ Between 6 and 10 hrs/week
☐ More than 10 hrs/week

48. How would you describe your overall knowledge of office ergonomics?

| No Knowledge | A Little Knowledge | Moderate Knowledge | Expert Knowledge |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

49. How would you describe your knowledge of ergonomic risk factors?

| No Knowledge | A Little Knowledge | Moderate Knowledge | Expert Knowledge |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

50. How would you describe your knowledge of what is an ergonomically correct posture?

| No Knowledge | A Little Knowledge | Moderate Knowledge | Expert Knowledge |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

51. How would you describe your knowledge of what is an ergonomically designed workspace?

| No Knowledge | A Little Knowledge | Moderate Knowledge | Expert Knowledge |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

**Females only:**

52. Are you pregnant?

☐ Yes ☐ No ☐ Don't know

53. Are you peri-menopausal?

☐ Yes ☐ No

# APPENDIX G3

# Your Health and Well-Being

ID number:

| | | | |
|---|---|---|---|
| ⓪ | ⓪ | ⓪ | ⓪ |
| ① | ① | ① | ① |
| ② | ② | ② | ② |
| ③ | ③ | ③ | ③ |
| ④ | ④ | ④ | ④ |
| ⑤ | ⑤ | ⑤ | ⑤ |
| ⑥ | ⑥ | ⑥ | ⑥ |
| ⑦ | ⑦ | ⑦ | ⑦ |
| ⑧ | ⑧ | ⑧ | ⑧ |
| ⑨ | ⑨ | ⑨ | ⑨ |

| Baseline | 1st Post-Intervention | 2nd Post-Intervention |
|---|---|---|
| ☐ | ☐ | ☐ |

**This survey asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities.** ***Thank you for completing this survey!***

**For each of the following questions, please mark an ☒ in the one box that best describes your answer.**

**1. In general, would you say your health is:**

| Excellent | Very good | Good | Fair | Poor |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

**2. <u>Compared to one year ago</u>, how would you rate your health in general <u>now</u>?**

| Much better now than one year ago | Somewhat better now than one year ago | About the same as one year ago | Somewhat worse now than one year ago | Much worse now than one year ago |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

3. **The following questions are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?**

| | Yes, limited a lot | Yes, limited a little | No, not limited at all |
|---|---|---|---|
| a. Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports | ☐ | ☐ | ☐ |
| b. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf | ☐ | ☐ | ☐ |
| c. Lifting or carrying groceries | ☐ | ☐ | ☐ |
| d. Climbing several flights of stairs | ☐ | ☐ | ☐ |
| e. Climbing one flight of stairs | ☐ | ☐ | ☐ |
| f. Bending, kneeling, or stooping | ☐ | ☐ | ☐ |
| g. Walking more than a mile | ☐ | ☐ | ☐ |
| h. Walking several hundred yards | ☐ | ☐ | ☐ |
| i. Walking one hundred yards | ☐ | ☐ | ☐ |
| j. Bathing or dressing yourself | ☐ | ☐ | ☐ |

4. **During the past 4 weeks, how much of the time have you had any of the following problems with your work or other regular daily activities as a result of your physical health?**

| | All of the time | Most of the time | Some of the time | A little of the time | None of the time |
|---|---|---|---|---|---|
| a. Cut down on the amount of time you spent on work or other activities | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. Accomplished less than you would like | ☐ | ☐ | ☐ | ☐ | ☐ |
| c. Were limited in the kind of work or other activities | ☐ | ☐ | ☐ | ☐ | ☐ |
| d. Had difficulty performing the work or other activities (for example, it took extra effort) | ☐ | ☐ | ☐ | ☐ | ☐ |

5. **During the past 4 weeks, how much of the time have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?**

| | All of the time | Most of the time | Some of the time | A little of the time | None of the time |
|---|---|---|---|---|---|
| a. Cut down on the amount of time you spent on work or other activities | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. Accomplished less than you would like | ☐ | ☐ | ☐ | ☐ | ☐ |
| c. Did work or other activities less carefully than usual | ☐ | ☐ | ☐ | ☐ | ☐ |

6. **During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?**

| Not at all | Slightly | Moderately | Quite a bit | Extremely |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

7. **How much bodily pain have you had during the past 4 weeks?**

| None | Very mild | Mild | Moderate | Severe | Very Severe |
|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**8. During the <u>past 4 weeks</u>, how much did <u>pain</u> interfere with your normal work (including both work outside the home and housework)?**

| Not at all | A little bit | Moderately | Quite a bit | Extremely |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

**9. These questions are about how you feel and how things have been with you <u>during the past 4 weeks</u>. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the <u>past 4 weeks</u>...**

| | All of the time | Most of the time | Some of the time | A little of the time | None of the time |
|---|---|---|---|---|---|
| a. Did you feel full of life? | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. Have you been very nervous? | ☐ | ☐ | ☐ | ☐ | ☐ |
| c. Have you felt so down in the dumps that nothing could cheer you up? | ☐ | ☐ | ☐ | ☐ | ☐ |
| d. Have you felt calm and peaceful? | ☐ | ☐ | ☐ | ☐ | ☐ |
| e. Did you have a lot of energy? | ☐ | ☐ | ☐ | ☐ | ☐ |
| f. Have you felt downhearted and depressed? | ☐ | ☐ | ☐ | ☐ | ☐ |
| g. Did you feel worn out? | ☐ | ☐ | ☐ | ☐ | ☐ |
| h. Have you been happy? | ☐ | ☐ | ☐ | ☐ | ☐ |
| i. Did you feel tired? | ☐ | ☐ | ☐ | ☐ | ☐ |

**10. During the <u>past 4 weeks</u>, how much of the time has your <u>physical health or emotional problems</u> interfered with your social activities (like visiting friends, relatives, etc.)?**

| All of the time | Most of the time | Some of the time | A little of the time | None of the time |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

**11. How TRUE or FALSE is <u>each</u> of the following statements for you?**

| | Definitely true | Mostly true | Don't know | Mostly false | Definitely false |
|---|---|---|---|---|---|
| a. I seem to get sick a little easier than other people | ☐ | ☐ | ☐ | ☐ | ☐ |
| b. I am as healthy as anybody I know | ☐ | ☐ | ☐ | ☐ | ☐ |
| c. I expect my health to get worse | ☐ | ☐ | ☐ | ☐ | ☐ |
| d. My health is excellent | ☐ | ☐ | ☐ | ☐ | ☐ |

***THANK YOU FOR COMPLETING THESE QUESTIONS!***

# APPENDIX G4

# BASELINE INTERVIEWER-ADMINISTERED SURVEY

ID number:

| | | | |
|---|---|---|---|
| ⓪ | ⓪ | ⓪ | ⓪ |
| ① | ① | ① | ① |
| ② | ② | ② | ② |
| ③ | ③ | ③ | ③ |
| ④ | ④ | ④ | ④ |
| ⑤ | ⑤ | ⑤ | ⑤ |
| ⑥ | ⑥ | ⑥ | ⑥ |
| ⑦ | ⑦ | ⑦ | ⑦ |
| ⑧ | ⑧ | ⑧ | ⑧ |
| ⑨ | ⑨ | ⑨ | ⑨ |

Remember that all surveys will be kept completely and strictly confidential. There will be no personal identifiers that can be linked back to you. The Joint Committee on Legislative Management will not have access to individual employee results.

These questions ask you about your current job at the Joint Committee on Legislative Management. For each statement, fill in the box for the answer that best describes your job. The last few questions ask you about your pain intensity.

1. Is this a typical workday with an average workload?
   ☐ Yes ☐ No

2. How many hours per week, ON AVERAGE, do you work on this job? Write the number of hours on the line, and then fill in the corresponding bubbles.
   Hours: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

3. How many hours per week, ON AVERAGE, do you use the computer keyboard at work? Write the number of hours on the line, and then fill in the corresponding bubbles.

Hours: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

4. How many hours per week, ON AVERAGE, do you use the computer mouse at work? Write the number of hours on the line, and then fill in the corresponding bubbles.

Hours: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

5. How many hours, ON AVERAGE, do you sit at your workstation without getting up?

☐ None
☐ Less than 1 hr
☐ Between 1 and 3 hrs
☐ Between 3 and 6 hrs
☐ Between 6 and 9 hrs
☐ More than 9 hrs

6. You are often required to perform hand or keyboard work without an arm or wrist support.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

7. You are often required to bend or twist your wrists to do your job.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

8. You are often required to use a lot of effort with your fingers to do your job.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

9. You are often required to hold your neck, shoulder, arms or hands in one position for a long time.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

10. You are often expected to meet a deadline.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

11. You are often required to work overtime.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

12. How many hours per day, ON AVERAGE, are spent on the telephone. Please write number of hours on the line and then fill in the corresponding bubbles.

Hours: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

13. Other than computer work, you often required to perform repetitive tasks, in which motions are repeated every fifteen seconds or less, with your fingers, wrists, forearms, elbows or shoulders.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

14. You are often expected to hold an object by pinching with your fingers.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

15. ON AVERAGE, what is your total amount of break time, including lunch, in minutes, over a workday?

☐ 30 minutes ☐ 90 minutes

☐ 60 minutes ☐ Other:_____

16. Do you work more than one job in which you use a computer?

☐ Yes ☐ No

17. If yes, how many hours per week, ON AVERAGE, do you work at those OTHER computer-related jobs, combined? (NOT including your job at the Joint Committee on Legislative Management.) Please write number of hours on the line and then fill in the corresponding bubbles.

Hours: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

18. How many years have you worked in this job title? Please write number of years on the line and then fill in the corresponding bubbles.

Years: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

19. How many years have you worked at the Joint Committee on Legislative Management/General Assembly? Please write number of years on the line and then fill in the corresponding bubbles.

Years: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

20. How many years have you been using a computer over your lifetime? Please write number of years on the line and then fill in the corresponding bubbles.

Years: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

21. During the past 4 weeks, how much pain, ON AVERAGE, have you had in your:

| | NO PAIN | MILD PAIN, ANNOYING: Pain present but does not limit activity | NAGGING PAIN, UNCOMFORTABLE, TROUBLESOME: Can do most activities with rest periods | MISERABLE, DISTRESSING: Unable to do some activities b/c of pain | INTENSE, DREADFUL, HORRIBLE: Unable to do most activities b/c of pain |
|---|---|---|---|---|---|
| R Neck/UB | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Neck/UB | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Shoulders | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Shoulders | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Arms | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Arms | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Elbows | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Elbows | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Forearms | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Forearms | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Wrists | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Wrists | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Fingers | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Fingers | ☐ | ☐ | ☐ | ☐ | ☐ |

22. During the past 4 weeks, have you developed a NEW ONSET of pain in your:

| | Yes | No |
|---|---|---|
| R Neck/UB | ☐ | ☐ |
| L Neck/UB | ☐ | ☐ |
| R Shoulders | ☐ | ☐ |
| L Shoulders | ☐ | ☐ |
| R Arms | ☐ | ☐ |
| L Arms | ☐ | ☐ |
| R Elbows | ☐ | ☐ |
| L Elbows | ☐ | ☐ |
| R Forearms | ☐ | ☐ |
| L Forearms | ☐ | ☐ |
| R Wrists | ☐ | ☐ |
| L Wrists | ☐ | ☐ |
| R Fingers | ☐ | ☐ |
| L Fingers | ☐ | ☐ |

# APPENDIX G5

# Intervention Compliance Survey

ID number:

| | | | |
|---|---|---|---|
| ⓪ | ⓪ | ⓪ | ⓪ |
| ① | ① | ① | ① |
| ② | ② | ② | ② |
| ③ | ③ | ③ | ③ |
| ④ | ④ | ④ | ④ |
| ⑤ | ⑤ | ⑤ | ⑤ |
| ⑥ | ⑥ | ⑥ | ⑥ |
| ⑦ | ⑦ | ⑦ | ⑦ |
| ⑧ | ⑧ | ⑧ | ⑧ |
| ⑨ | ⑨ | ⑨ | ⑨ |

Remember that all surveys will be kept completely and strictly confidential. There will be no personal identifiers that can be linked back to you. The Joint Committee on Legislative Management will not have access to individual employee results.

Does equipment appear to be used regularly?

1a. KB/mouse tray:

☐ Yes ☐ No

1b. Touch pad:

☐ Yes ☐ No

Subject adherence to recommended adjustments?

2a. KB/mouse tray:

☐ Yes ☐ No

2b. Touch pad:

☐ Yes ☐ No

Subject adherence to recommended positions?

3a. KB/mouse tray:

☐ Yes ☐ No

3b. Touch pad:

☐ Yes ☐ No

Subject alterations to recommended equipment?

4a. KB/mouse tray:

☐ Yes ☐ No

4b. Touch pad:

☐ Yes ☐ No

Subject alterations to recommended technique?

5a. KB/mouse tray:

☐ Yes ☐ No

5b. Touch pad:

☐ Yes ☐ No

6. If you have dropped out of the study, please indicate the reason:

| | Yes | No |
|---|---|---|
| Change in jobs | ☐ | ☐ |
| Laid off | ☐ | ☐ |
| Declined to participate in follow up | ☐ | ☐ |
| Parental leave | ☐ | ☐ |
| Long term sick leave or disability | ☐ | ☐ |
| Other:_____ | ☐ | ☐ |
| Not applicable | ☐ | ☐ |

# APPENDIX G6

# FOLLOW-UP TAKE-HOME SURVEY

ID number:

| | | | |
|---|---|---|---|
| ⓪ | ⓪ | ⓪ | ⓪ |
| ① | ① | ① | ① |
| ② | ② | ② | ② |
| ③ | ③ | ③ | ③ |
| ④ | ④ | ④ | ④ |
| ⑤ | ⑤ | ⑤ | ⑤ |
| ⑥ | ⑥ | ⑥ | ⑥ |
| ⑦ | ⑦ | ⑦ | ⑦ |
| ⑧ | ⑧ | ⑧ | ⑧ |
| ⑨ | ⑨ | ⑨ | ⑨ |

Remember that all surveys will be kept completely and strictly confidential. There will be no personal identifiers that can be linked back to you. The Joint Committee on Legislative Management will not have access to individual employee results.

This first set of questions asks you about your current job at the Joint Committee on Legislative Management. For each statement, fill in the box for the answer that best describes your job.

1. Your job requires working very fast.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

2. Your job requires working very hard.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

3. You are not asked to do an excessive amount of work.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

4. You have enough time to get the job done.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

5. You are free from conflicting demands that others make.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

6. Your job requires that you learn new things.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

7. Your job involves a lot of repetitive work.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

8. Your job requires you to be creative.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

9. Your job requires a high level of skill.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

10. You get to do a variety of things on your job.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

11. You have an opportunity to develop your own special abilities.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

12. Your job allows you to make a lot of decisions on your own.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

13. On your job, you have very little freedom to decide how you do your work.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

14. You have a lot of say about what happens on your job.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

15. Your supervisor is concerned about the welfare of those under him/her.

| Strongly Disagree | Disagree | Agree | Strongly Agree | I Have No Supervisor |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

16. Your supervisor pays attention to what you are saying.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

17. Your supervisor is helpful in getting the job done.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

18. Your supervisor is successful in getting people to work together.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

19. Considering everything, how satisfied are you with your job?

| Very Dissatisfied | Somewhat Dissatisfied | Neither Satisfied nor Dissatisfied | Somewhat Satisfied | Very Satisfied |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

20. You have the appropriate supplies, materials, and equipment to perform your job well.

| Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

21. You are obligated to turn away from the computer to do non-computer tasks throughout the day.

| Never | Sometimes | Often or Almost Always |
|---|---|---|
| ☐ | ☐ | ☐ |

22. You can voluntarily decide to combine computer tasks with non-computer tasks every hour.

| Cannot Decide | Can Decide | Not Specified |
|---|---|---|
| ☐ | ☐ | ☐ |

23. You are likely to leave this job in the next 2 years because you are dissatisfied.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

24. During the past week, how much difficulty have you had sleeping because of any neck, upper back, shoulder, arm, elbow, forearm, hand, or finger problem?

| No Difficulty | Mild Difficulty | Moderate Difficulty | Severe Difficulty | So Much Difficulty That I Can't Sleep |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

25. During the past week, did you have any difficulty using your usual technique for your work?

| No Difficulty | Mild Difficulty | Moderate Difficulty | Severe Difficulty | Unable |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

26. During the past week, did you have any difficulty doing your work as well as you would like?

| No Difficulty | Mild Difficulty | Moderate Difficulty | Severe Difficulty | Unable |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

27. Do you believe that, from the standpoint of your health, you will be able to do your current job two years from now?

| Unlikely | Not Certain | Relatively Certain |
|---|---|---|
| ☐ | ☐ | ☐ |

**We are now going to ask you GENERAL questions. Fill in the box for the answer that best describes each statement.**

28. During a typical week, how much time do you usually spend cleaning, gardening, doing home maintenance, playing a musical instrument, or cooking?

☐ None
☐ Less than 1 hr/week
☐ Between 1 and 3 hrs/week
☐ Between 3 and 6 hrs/week
☐ Between 6 and 10 hrs/week
☐ More than 10 hrs/week

29. Has a doctor or health care provider told you that you CURRENTLY have sciatica or a ruptured disc in your low back or neck?

☐ Yes ☐ No

30. Has a doctor or health care provider told you that you CURRENTLY have rheumatoid arthritis, gout, lupus, acromegaly, high blood sugar or diabetes, connective tissue disorder, tuberculosis, kidney failure or thyroid problem?

☐ Yes ☐ No

31. Are any of these problems CURRENTLY being treated with medication?

☐ Yes ☐ No

32. During the past 8 weeks, how many days of work have you missed or been absent due to a problem in your neck, upper back, shoulders, arms, elbows, forearms, wrists, hands or fingers?

Days: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

33. During the past 4 weeks, did you seek medical care for a problem in your:

| | Yes | No |
|---|---|---|
| Neck | ☐ | ☐ |
| Upper Back | ☐ | ☐ |
| Shoulders | ☐ | ☐ |
| Arms | ☐ | ☐ |
| Elbows | ☐ | ☐ |
| Forearms | ☐ | ☐ |
| Wrists | ☐ | ☐ |
| Hands | ☐ | ☐ |
| Fingers | ☐ | ☐ |

34. Do you have an active Workers' Compensation case involving any of these body regions:

| | Yes | No |
|---|---|---|
| Neck | ☐ | ☐ |
| Shoulder | ☐ | ☐ |
| Elbow | ☐ | ☐ |
| Forearm | ☐ | ☐ |
| Wrist | ☐ | ☐ |
| Hand | ☐ | ☐ |
| Fingers | ☐ | ☐ |

35. Do you perform a daily accumulation of at least 30 minutes of some sort of PHYSICAL ACTIVITY that is at least moderate to vigorous in its intensity?

☐ Yes ☐ No

36. In a typical week, how much time do you spend in home computer use?

☐ None
☐ Less than 1 hr/week
☐ Between 1 and 3 hrs/week
☐ Between 3 and 6 hrs/week
☐ Between 6 and 10 hrs/week
☐ More than 10 hrs/week

37. In a typical week, how much time do you spend in personal digital assistant use, such as a Blackberry or Iphone?

☐ None
☐ Less than 1 hr/week
☐ Between 1 and 3 hrs/week
☐ Between 3 and 6 hrs/week
☐ Between 6 and 10 hrs/week
☐ More than 10 hrs/week

38. How would you describe your overall knowledge of office ergonomics?

| No Knowledge | A Little Knowledge | Moderate Knowledge | Expert Knowledge |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

39. How would you describe your knowledge of ergonomic risk factors?

| No Knowledge | A Little Knowledge | Moderate Knowledge | Expert Knowledge |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

40. How would you describe your knowledge of what is an ergonomically correct posture?

| No Knowledge | A Little Knowledge | Moderate Knowledge | Expert Knowledge |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

41. How would you describe your knowledge of what is an ergonomically designed workspace?

| No Knowledge | A Little Knowledge | Moderate Knowledge | Expert Knowledge |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

**We are now going to ask you questions about the INTERVENTION. Fill in the box for the answer that best describes each statement.**

42. Did the keyboard tray decrease your pain?

| Yes | No | Not Applicable |
|---|---|---|
| ☐ | ☐ | ☐ |

43. Did the touch pad decrease your pain?

| Yes | No | Not Applicable |
|---|---|---|
| ☐ | ☐ | ☐ |

44. Did the keyboard tray increase your pain?

| Yes | No | Not Applicable |
|---|---|---|
| ☐ | ☐ | ☐ |

45. Did the touch pad increase your pain?

| Yes | No | Not Applicable |
|---|---|---|
| ☐ | ☐ | ☐ |

46. Did you like using the keyboard tray?

| Yes | No | Not Applicable |
|---|---|---|
| ☐ | ☐ | ☐ |

47. Did you like using the touch pad?

| Yes | No | Not Applicable |
|---|---|---|
| ☐ | ☐ | ☐ |

48. Did you dislike using the keyboard tray?

| Yes | No | Not Applicable |
|---|---|---|
| ☐ | ☐ | ☐ |

49. Did you dislike using the touch pad?

| Yes | No | Not Applicable |
|---|---|---|
| ☐ | ☐ | ☐ |

50. Was the keyboard tray difficult to use?

| Yes | No | Not Applicable |
|---|---|---|
| ☐ | ☐ | ☐ |

51. Was the touch pad difficult to use?

| Yes | No | Not Applicable |
|---|---|---|
| ☐ | ☐ | ☐ |

52. Did the keyboard tray improve your productivity?

| Yes | No | Not Applicable |
|---|---|---|
| ☐ | ☐ | ☐ |

53. Did the touch pad improve your productivity?

| Yes | No | Not Applicable |
|---|---|---|
| ☐ | ☐ | ☐ |

**Females only:**

54. Are you pregnant?

| Yes | No | Don't Know |
|---|---|---|
| ☐ | ☐ | ☐ |

# APPENDIX G7

## POST INTERVENTION INTERVIEWER-ADMINISTERED SURVEY

ID number:

| | | | |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 |
| 2 | 2 | 2 | 2 |
| 3 | 3 | 3 | 3 |
| 4 | 4 | 4 | 4 |
| 5 | 5 | 5 | 5 |
| 6 | 6 | 6 | 6 |
| 7 | 7 | 7 | 7 |
| 8 | 8 | 8 | 8 |
| 9 | 9 | 9 | 9 |

Remember that all surveys will be kept completely and strictly confidential. There will be no personal identifiers that can be linked back to you. The Joint Committee on Legislative Management will not have access to individual employee results.

These questions ask you about your current job at the Joint Committee on Legislative Management. For each statement, fill in the box for the answer that best describes your job. The last few questions ask you about your pain intensity.

1. Is this a typical workday with an average workload?
   ☐ Yes ☐ No

2. How many hours per week, ON AVERAGE, do you work on this job? Write the number of hours on the line, and then fill in the corresponding bubbles.
Hours: _____

| | |
|---|---|
| 0 | 0 |
| 1 | 1 |
| 2 | 2 |
| 3 | 3 |
| 4 | 4 |
| 5 | 5 |
| 6 | 6 |
| 7 | 7 |
| 8 | 8 |
| 9 | 9 |

3. How many hours per week, ON AVERAGE, do you use the computer keyboard at work? Write the number of hours on the line, and then fill in the corresponding bubbles.

Hours: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

4. How many hours per week, ON AVERAGE, do you use the computer mouse at work? Write the number of hours on the line, and then fill in the corresponding bubbles.

Hours: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

5. How many hours, ON AVERAGE, do you sit at your workstation without getting up?

☐ None
☐ Less than 1 hr
☐ Between 1 and 3 hrs
☐ Between 3 and 6 hrs
☐ Between 6 and 9 hrs
☐ More than 9 hrs

6. You are often required to perform hand or keyboard work without an arm or wrist support.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

7. You are often required to bend or twist your wrists to do your job.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

8. You are often required to use a lot of effort with your fingers to do your job.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

9. You are often required to hold your neck, shoulder, arms or hands in one position for a long time.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

10. You are often expected to meet a deadline.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

11. You are often required to work overtime.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

12. How many hours per day, ON AVERAGE, are spent on the telephone. Please write number of hours on the line and then fill in the corresponding bubbles.

Hours: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

13. Other than computer work, you often required to perform repetitive tasks, in which motions are repeated every fifteen seconds or less, with your fingers, wrists, forearms, elbows or shoulders.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

14. You are often expected to hold an object by pinching with your fingers.

| Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

15. ON AVERAGE, what is your total amount of break time, including lunch, in minutes, over a workday?

☐ 30 minutes ☐ 90 minutes
☐ 60 minutes ☐ Other:_____

16. Do you work more than one job in which you use a computer?

☐ Yes ☐ No

17. If yes, how many hours per week, ON AVERAGE, do you work at those OTHER computer-related jobs, combined? (NOT including your job at the Joint Committee on Legislative Management.) Please write number of hours on the line and then fill in the corresponding bubbles.

Hours: _____

| | |
|---|---|
| ⓪ | ⓪ |
| ① | ① |
| ② | ② |
| ③ | ③ |
| ④ | ④ |
| ⑤ | ⑤ |
| ⑥ | ⑥ |
| ⑦ | ⑦ |
| ⑧ | ⑧ |
| ⑨ | ⑨ |

18. During the past 4 weeks, how much pain, ON AVERAGE, have you had in your:

| | NO PAIN | MILD PAIN, ANNOYING: Pain present but does not limit activity | NAGGING PAIN, UNCOMFORTABLE, TROUBLESOME: Can do most activities with rest periods | MISERABLE, DISTRESSING: Unable to do some activities b/c of pain | INTENSE, DREADFUL, HORRIBLE: Unable to do most activities b/c of pain |
|---|---|---|---|---|---|
| R Neck/UB | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Neck/UB | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Shoulders | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Shoulders | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Arms | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Arms | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Elbows | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Elbows | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Forearms | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Forearms | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Wrists | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Wrists | ☐ | ☐ | ☐ | ☐ | ☐ |
| R Fingers | ☐ | ☐ | ☐ | ☐ | ☐ |
| L Fingers | ☐ | ☐ | ☐ | ☐ | ☐ |

19. During the past 4 weeks, have you developed a NEW ONSET of pain in your:

| | Yes | No |
|---|---|---|
| R Neck/UB | ☐ | ☐ |
| L Neck/UB | ☐ | ☐ |
| R Shoulders | ☐ | ☐ |
| L Shoulders | ☐ | ☐ |
| R Arms | ☐ | ☐ |
| L Arms | ☐ | ☐ |
| R Elbows | ☐ | ☐ |
| L Elbows | ☐ | ☐ |
| R Forearms | ☐ | ☐ |
| L Forearms | ☐ | ☐ |
| R Wrists | ☐ | ☐ |
| L Wrists | ☐ | ☐ |
| R Fingers | ☐ | ☐ |
| L Fingers | ☐ | ☐ |

20. If you have dropped out of the study, please indicate the reason:

| | Yes | No |
|---|---|---|
| Change in jobs | ☐ | ☐ |
| Laid off | ☐ | ☐ |
| Declined to participate in follow up | ☐ | ☐ |
| Parental leave | ☐ | ☐ |
| Long term sick leave or disability | ☐ | ☐ |
| Other:_____ | ☐ | ☐ |
| Not applicable | ☐ | ☐ |

# Appendix H

## Multivariable regression models

Table1. Final multivariable linear regression model examining the association between change in ß coefficient of intervention and modified RULA spine and lower extremity non-neutral posture (n=109)

| Variable | Unadjusted ß coefficient | 95% CI | | Adjusted ß coefficient | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | -0.52 | -1.38 | 0.33 | -0.80 | -1.64 | 0.05 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 0.19 | -0.87 | 1.23 | 0.09 | -0.93 | 1.12 |
| >50 | 0.39 | -0.69 | 1.46 | 0.35 | -0.72 | 1.41 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.14 | -0.77 | 1.04 | -0.15 | -1.05 | 0.76 |
| Weekly hours using mouse at work | -0.07 | -0.10 | -0.03 | -0.06 | -0.09 | -0.04 |
| JCQ Quadrant term job strain | | | | | | |
| Low | REF | | | REF | | |
| Moderate | -1.52 | -2.66 | -0.38 | -1.76 | -2.78 | -0.73 |
| High | -1.69 | -3.00 | -0.43 | -1.78 | -3.00 | -0.57 |
| Constant | 9.19 | 8.84 | 9.53 | 12.5 | 11.6 | 13.4 |

Regression models were fit using the Generalized Estimating Equation model for normal distributions: $Y = B_0 + B_1X_1 + B_2X_2 + ... B_kX_k + E$
Results indicate the intervention resulted in a -0.80 unit reduction on a 2-24 point RULA scale.
A negative ß coefficient indicates a protective effect against non-neutral posture at follow up.
RULA = rapid upper limb assessment. CI = confidence interval.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, systemic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, deadlines, overtime, job strain quadrant term.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
REF=reference category.

Table2. Final multivariable linear regression model examining the association between change in ß coefficient of intervention and modified RULA preferred limb non-neutral posture (n=109)

| Variable | Unadjusted ß coefficient | 95% CI | | Adjusted ß coefficient | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | -1.82 | -3.06 | -0.58 | **-1.89** | -3.10 | -0.68 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 0.08 | -1.44 | 1.60 | 0.10 | -1.37 | 1.57 |
| >50 | -1.40 | -3.00 | 0.17 | -1.19 | -2.72 | 0.35 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | -0.51 | -1.83 | 0.83 | -0.68 | -1.98 | 0.63 |
| Trouble sleeping (yes) | 1.88 | 1.87 | 1.89 | 1.55 | 0.63 | 2.47 |
| Current medication for MSD | -3.01 | -5.10 | -0.93 | -2.75 | -4.80 | -0.70 |
| Constant | 19.03 | 18.83 | 19.24 | 19.42 | 18.41 | 20.40 |

Regression models were fit using the Generalized Estimating Equation model for normal distributions: $Y = B_0 + B_1X_1 + B_2X_2 + ... B_kX_k + E$
Results indicate the intervention resulted in a -1.89 unit reduction on a 0-21 point RULA scale.
A negative ß coefficient indicates a protective effect against non-neutral posture at follow up.
RULA = rapid upper limb assessment. CI = confidence interval.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, deadlines, overtime, hold object by pinching, job strain quadrant term.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
Bold=significant value.
REF=reference category.

Table3. Final multivariable linear regression model examining the association between change in ß coefficient of intervention and modified RULA non-preferred limb non-neutral posture (n=109)

| Variable | Unadjusted ß coefficient | 95% CI | | Adjusted ß coefficient | 95% CI | |
|---|---|---|---|---|---|---|
| **Intervention** | -2.73 | -3.99 | -1.47 | **-2.64** | -3.92 | -1.37 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 0.78 | -0.80 | 2.36 | 0.86 | -0.67 | 2.37 |
| >50 | -0.44 | -2.07 | 1.19 | -0.32 | -1.89 | 1.25 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.02 | -1.40 | 1.36 | 0.06 | -1.27 | 1.40 |
| JCQ Linear Function term job strain | | | | | | |
| Low | REF | | | REF | | |
| Moderate | -2.03 | -3.22 | -0.83 | -1.99 | -3.15 | -0.82 |
| High | -0.43 | -1.50 | 0.64 | -1.25 | -2.24 | -0.27 |
| Constant | 16.20 | 16.08 | 16.31 | 18.38 | 17.17 | 19.59 |

Regression models were fit using the Generalized Estimating Equation model for normal distributions: $Y = B_0 + B_1X_1 + B_2X_2 + \ldots B_kX_k + E$
Results indicate the intervention resulted in a -2.64 unit reduction on a 0-21 point RULA scale.
A negative ß coefficient indicates a protective effect against non-neutral posture at follow up.
RULA = rapid upper limb assessment. CI = confidence interval.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, systemic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, deadlines, overtime, hold object by pinching, job strain linear function term.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
Bold=significant value.
REF=reference category.

Table4. Final multivariable linear regression model examining the association between change in ß coefficient of intervention and modified RULA spine, lower extremity, and preferred limb non-neutral posture (n=109)

| Variable | Unadjusted ß coefficient | 95% CI | | Adjusted ß coefficient | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | -2.75 | -6.03 | 0.54 | -3.16 | -6.44 | 0.13 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 0.47 | -3.56 | 4.48 | 0.04 | -3.93 | 4.02 |
| >50 | 1.05 | -3.09 | 5.20 | 0.39 | -3.76 | 4.53 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | -1.50 | -4.94 | 2.01 | -0.86 | -4.43 | 2.70 |
| Weekly hours using mouse at work | -0.17 | -0.19 | -0.15 | -0.11 | -0.18 | -0.04 |
| Deadlines | -10.28 | -16.21 | -4.33 | -5.98 | -13.48 | 1.52 |
| Constant | 21.21 | 20.66 | 21.76 | 31.02 | 28.96 | 33.28 |

Regression models were fit using the Generalized Estimating Equation model for normal distributions: $Y = B_0 + B_1X_1 + B_2X_2 + \ldots B_kX_k + E$
Results indicate the intervention resulted in a -3.16 unit reduction on a 2-35 point RULA scale.
A negative ß coefficient indicates a protective effect against non-neutral posture at follow up.
RULA = rapid upper limb assessment. CI = confidence interval.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, systemic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, deadlines, overtime, hold object by pinching, job strain quadrant term.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
REF=reference category.

Table5. Final multivariable linear regression model examining the association between change in ß coefficient of intervention and modified RULA spine, lower extremity, and non-preferred limb non-neutral posture (n=109)

| Variable | Unadjusted ß coefficient | 95% CI | | Adjusted ß coefficient | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | -2.93 | -5.94 | 0.08 | **-3.45** | -6.44 | -0.46 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 0.86 | -2.82 | 4.55 | 0.46 | -3.16 | 4.08 |
| >50 | 1.64 | -2.17 | 5.45 | 0.80 | -2.99 | 4.59 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | -1.04 | -4.24 | 2.16 | -0.30 | -3.54 | 2.93 |
| Weekly hours using mouse at work | -0.12 | -0.13 | -0.12 | -0.07 | -0.16 | 0.02 |
| Deadlines | -11.81 | -13.94 | -9.68 | -5.96 | -12.82 | 0.90 |
| Current medication for MSD | 3.48 | -1.54 | 8.50 | 4.21 | -0.74 | 9.16 |
| Constant | 18.92 | 18.52 | 19.31 | 30.75 | 28.75 | 32.75 |

Regression models were fit using the Generalized Estimating Equation model for normal distributions: $Y = B_0 + B_1X_1 + B_2X_2 + \ldots B_kX_k + E$
Results indicate the intervention resulted in a -3.45 unit reduction on a 2-35 point RULA scale.
A negative ß coefficient indicates a protective effect against non-neutral posture at follow up.
RULA = rapid upper limb assessment. CI = confidence interval.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, deadlines, overtime, hold object by pinching, job strain quadrant term.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
Bold=significant value.
REF=reference category.

Table6. Final multivariable linear regression model examining the association between change in ß coefficient of intervention and modified hand activity in the preferred limb (n=109)

| Variable | Unadjusted ß coefficient | 95% CI | | Adjusted ß coefficient | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | -0.48 | -0.93 | -0.02 | -0.40 | -0.85 | 0.04 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | -0.52 | -1.07 | 0.03 | -0.39 | -0.93 | 0.15 |
| >50 | -0.80 | -1.37 | -0.23 | -0.60 | -1.17 | -0.03 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.15 | -0.34 | 0.63 | 0.17 | -0.30 | 0.64 |
| Weekly hours using mouse at work | 0.04 | 0.01 | 0.06 | 0.03 | 0.01 | 0.06 |
| Constant | 5.01 | 4.39 | 5.63 | 4.66 | 3.65 | 5.70 |

Regression models were fit using the Generalized Estimating Equation model for normal distributions: $Y = B_0 + B_1X_1 + B_2X_2 + \ldots B_kX_k + E$
Results indicate the intervention resulted in a -0.40 unit reduction on a 0-10 point HAL scale.
A negative ß coefficient indicates a protective effect against high hand activity at follow up.
Hand activity measured by HAL (hand activity level). CI = confidence interval.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, systemic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, deadlines, overtime, hold object by pinching, job strain quadrant term.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
REF=reference category.

Table7. Final multivariable linear regression model examining the association between change in ß coefficient of intervention and modified hand activity in the non-preferred limb (n=109)

| Variable | Unadjusted ß coefficient | 95% CI | | Adjusted ß coefficient | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 0.87 | 0.37 | 1.38 | **0.86** | 0.36 | 1.37 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | -0.06 | -0.68 | 0.57 | -0.09 | -0.70 | 0.52 |
| >50 | 0.09 | -0.56 | 0.74 | 0.03 | -0.61 | 0.66 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.06 | -0.49 | 0.60 | -0.05 | -0.59 | 0.49 |
| Medical care in past month | 0.68 | -0.18 | 1.53 | -0.54 | -1.22 | 0.14 |
| Constant | 3.03 | 2.63 | 3.43 | 2.57 | 1.95 | 3.20 |

Regression models were fit using the Generalized Estimating Equation model for normal distributions: $Y = B_0 + B_1X_1 + B_2X_2 + \ldots B_kX_k + E$
Results indicate the intervention resulted in a 0.86 unit increase on a 0-10 point HAL scale.
A positive ß coefficient indicates high hand activity at follow up.
Hand activity measured by HAL (hand activity level). CI = confidence interval.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, deadlines, overtime, hold object by pinching, job strain quadrant term.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
Bold=significant value.
REF=reference category.

## Summary of tables

Table 1 shows the effect of engineering controls and training resulted in a -0.80 (95% CI =-1.64 to 0.05) unit reduction of modified RULA spine and lower extremity non-neutral posture; this indicated the intervention was associated with a mean reduction in non-neutral posture of 0.80 points on a 2 to 21 point RULA scale.

Table 2 shows the effect of engineering controls and training resulted in a -1.89 (95% CI =-3.10 to -0.68) unit reduction of modified RULA preferred limb non-neutral posture; this indicated the intervention was associated with a mean reduction in non-neutral posture of 1.89 points on a 0 to 21 point RULA scale. Table 3 shows the effect of engineering controls and training resulted in a -2.64 (95% CI =-3.92 to -1.37) unit reduction of modified RULA non-preferred limb non-neutral posture; this indicated the intervention was associated with a mean reduction in non-neutral posture of 2.64 points on this same scale.

Table 4 shows the effect of engineering controls and training resulted in a -3.16 (95% CI =-6.44 to 0.13) unit reduction of modified RULA spine, lower extremity, and preferred limb non-neutral posture; this indicated the intervention was associated with a mean reduction in non-neutral posture of 3.16 points on a 2 to 35 point RULA scale, although the CI included the null. Table 5 shows the effect of engineering controls and training resulted in a -3.45 (95% CI =-6.44 to -1.46) unit reduction of modified RULA spine, lower extremity, and non-preferred limb non-neutral posture; this indicated the intervention was associated with a mean reduction in non-neutral posture of 3.45 points on this same scale.

Table 6 shows the effect of engineering controls and training resulted in a -0.40 (95% CI =-0.85 to 0.04) unit reduction in hand activity in the preferred limb; this indicated the intervention was associated with a mean reduction in hand activity of 0.40 points on a 0 to 10 point modified HAL scale, although the CI included the null. Table 7 shows the effect of engineering controls and training resulted in a 0.86 (95% CI =0.36 to 1.37) unit increase in hand activity in the non-preferred limb; this indicated the intervention was associated with a mean increase in hand activity of 0.86 points on this same scale.

# Appendix I

## Poisson regression models

Table1. Final Poisson multivariable regression model estimating effect of intervention on dichotomized musculoskeletal pain severity in the preferred limb neck and upper back region (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 0.93 | 0.91 | 0.95 | **0.95** | 0.93 | 0.98 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 1.04 | 0.99 | 1.10 | 0.97 | 0.91 | 1.03 |
| >50 | 0.82 | 0.64 | 1.04 | 0.77 | 0.61 | 0.99 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.95 | 0.91 | 0.99 | 0.95 | 0.89 | 1.01 |
| Medical care in past month | 1.39 | 1.37 | 1.40 | 1.40 | 1.37 | 1.42 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0+\beta_1$*intervention $+\sum_{i=2}^{4}\beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Outcome variable was dichotomized at the median: ≤ mild pain and ≥ uncomfortable musculoskeletal pain.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, systemic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, deadlines, holding an object by pinching, job strain quadrant term, supervisor support, job satisfaction.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
Bold=significant value.
REF=reference category.

Table2. Final Poisson multivariable regression model estimating effect of intervention on dichotomized musculoskeletal pain severity in the non-preferred limb neck and upper back region (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 1.03 | 0.90 | 1.18 | 0.99 | 0.98 | 1.01 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 1.10 | 0.97 | 1.24 | 1.06 | 0.98 | 1.15 |
| >50 | 0.89 | 0.75 | 1.06 | 0.88 | 0.80 | 0.97 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.99 | 0.93 | 1.03 | 0.99 | 0.93 | 1.04 |
| Sleeping | 1.48 | 1.39 | 1.59 | 1.47 | 1.37 | 1.57 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0 + \beta_1$*intervention $+\sum_{i=2}^{4} \beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). *CI* = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Outcome variable was dichotomized at the median: ≤ mild pain and ≥ uncomfortable musculoskeletal pain.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, deadlines, holding an object by pinching, job strain linear function term, supervisor support, job satisfaction.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
REF=reference category.

Table3. Final Poisson multivariable regression model estimating effect of intervention on dichotomized musculoskeletal pain severity in the preferred limb shoulder region (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 0.97 | 0.87 | 1.09 | **0.96** | 0.92 | 1.00 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 1.02 | 0.98 | 1.07 | 0.90 | 0.86 | 0.95 |
| >50 | 0.87 | 0.78 | 0.98 | 0.81 | 0.73 | 0.90 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.94 | 0.91 | 0.97 | 0.93 | 0.90 | 0.97 |
| JCQ Quadrant term job strain | | | | | | |
| Low | REF | | | REF | | |
| Moderate | 0.89 | 0.83 | 0.95 | 0.86 | 0.81 | 0.91 |
| High | 1.06 | 0.99 | 1.12 | 0.96 | 0.92 | 1.00 |
| MSD onset | 1.03 | 1.03 | 1.04 | 1.04 | 1.04 | 1.05 |
| Medical care in past month | 1.47 | 1.39 | 1.56 | 1.50 | 1.39 | 1.61 |
| Trouble sleeping | 1.28 | 1.27 | 1.28 | 1.26 | 1.26 | 1.26 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0 + \beta_i$*intervention $+\sum_{i=2}^{7} \beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Outcome variable was dichotomized at the median: ≤ mild pain and ≥ uncomfortable musculoskeletal pain.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, deadlines, holding an object by pinching, job strain quadrant term, supervisor support, job satisfaction.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
Bold=borderline significant value.
REF=reference category.

Table4. Final Poisson multivariable regression model estimating effect of intervention on dichotomized musculoskeletal pain severity in the non-preferred limb shoulder region (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 1.00 | 0.94 | 1.06 | 0.97 | 0.92 | 1.01 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 1.11 | 0.98 | 1.26 | 1.10 | 0.96 | 1.25 |
| >50 | 1.01 | 0.97 | 1.07 | 1.03 | 1.03 | 1.03 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.98 | 0.84 | 1.13 | 0.99 | 0.90 | 1.08 |
| High job satisfaction | 0.89 | 0.78 | 1.02 | 0.90 | 0.89 | 0.91 |
| High workability | 0.98 | 0.76 | 1.26 | 1.05 | 1.01 | 1.09 |
| Trouble sleeping | 1.49 | 1.49 | 1.50 | 1.49 | 1.45 | 1.54 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0 + \beta_1$*intervention $+\sum_{i=2}^{6} \beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Outcome variable was dichotomized at the median: ≤ mild pain and ≥ uncomfortable musculoskeletal pain.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, deadlines, holding an object by pinching, job strain quadrant term, supervisor support, job satisfaction.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
REF=reference category.

Table5. Final Poisson multivariable regression model estimating effect of intervention on dichotomized musculoskeletal pain severity in the preferred limb elbow region (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 1.02 | 0.91 | 1.15 | **0.94** | 0.90 | 0.99 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 1.13 | 0.96 | 1.33 | 1.14 | 0.94 | 1.38 |
| >50 | 1.01 | 0.86 | 1.20 | 0.97 | 0.83 | 1.14 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.09 | 1.07 | 1.10 | 1.08 | 1.02 | 1.15 |
| High workability | 0.63 | 0.43 | 0.92 | 0.64 | 0.48 | 0.84 |
| Trouble sleeping | 1.38 | 1.30 | 1.46 | 1.30 | 1.09 | 1.56 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0 + \beta_i$*intervention $+\sum_{i=2}^{5} \beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Outcome variable was dichotomized at the median: ≤ mild pain and ≥ uncomfortable musculoskeletal pain.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, systemic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, deadlines, holding an object by pinching, job strain quadrant term, supervisor support, job satisfaction.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
Bold=significant value.
REF=reference category.

Table6. Final Poisson multivariable regression model estimating effect of intervention on dichotomized musculoskeletal pain severity in the non-preferred limb elbow region (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 1.02 | 0.91 | 1.15 | 1.00 | 0.95 | 1.04 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 1.13 | 1.10 | 1.16 | 1.17 | 1.13 | 1.20 |
| >50 | 1.18 | 0.97 | 1.43 | 1.29 | 1.10 | 1.50 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.09 | 1.07 | 1.10 | 1.10 | 1.07 | 1.12 |
| Trouble sleeping | 1.20 | 1.20 | 1.20 | 1.29 | 1.25 | 1.32 |
| Weekly time spent on home computer use | | | | | | |
| 0-3 hours (n, %) | REF | | | REF | | |
| 3-6 hours (n, %) | 0.99 | 0.91 | 1.07 | 0.97 | 0.97 | 0.97 |
| >6hours (n, %) | 1.11 | 1.02 | 1.21 | 1.07 | 1.03 | 1.11 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0 + \beta_1$*intervention $+\sum_{i=2}^{5} \beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Outcome variable was dichotomized at the median: ≤ mild pain and ≥ uncomfortable musculoskeletal pain.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, deadlines, holding an object by pinching, job strain quadrant term, supervisor support, job satisfaction.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
REF=reference category.

Table7. Final Poisson multivariable regression model estimating effect of intervention on dichotomized musculoskeletal pain severity in the preferred limb forearm region (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 0.98 | 0.92 | 1.05 | 0.98 | 0.88 | 1.09 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 1.10 | 0.99 | 1.23 | 1.13 | 1.00 | 1.29 |
| >50 | 0.94 | 0.92 | 0.96 | 0.95 | 0.92 | 0.97 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.11 | 0.99 | 1.24 | 1.06 | 0.91 | 1.24 |
| JCQ Linear Function job strain | | | | | | |
| Low | REF | | | REF | | |
| Moderate | 0.87 | 0.79 | 0.95 | 0.85 | 0.75 | 0.97 |
| High | 0.99 | 0.96 | 1.03 | 0.94 | 0.89 | 1.00 |
| High workability | 0.81 | 0.74 | 0.89 | 0.75 | 0.67 | 0.82 |
| Deadlines | 1.30 | 1.28 | 1.32 | 1.31 | 1.20 | 1.44 |
| MSD onset > 1year | 0.96 | 0.94 | 0.98 | 0.95 | 0.93 | 0.97 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0 + \beta_1$*intervention $+\sum_{i=2}^{7}\beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Outcome variable dichotomized at the median: ≤ mild pain and ≥ uncomfortable musculoskeletal pain.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, deadlines, holding an object by pinching, job strain linear function term, supervisor support, job satisfaction.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
REF=reference category.

Table8. Final Poisson multivariable regression model estimating effect of intervention on dichotomized musculoskeletal pain severity in the non-preferred limb forearm region (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 1.05 | 1.02 | 1.10 | **1.03** | 1.02 | 1.05 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 1.01 | 1.00 | 1.03 | 1.03 | 1.01 | 1.05 |
| >50 | 0.99 | 0.95 | 1.04 | 1.04 | 1.00 | 1.07 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.09 | 0.96 | 1.23 | 1.12 | 0.94 | 1.30 |
| High job satisfaction | 1.04 | 1.02 | 1.05 | 1.07 | 1.06 | 1.07 |
| Trouble sleeping | 1.23 | 1.14 | 1.31 | 1.20 | 1.11 | 1.29 |
| Exacerbation of MSD in past 2 months | 1.13 | 1.08 | 1.19 | 1.09 | 1.03 | 1.15 |
| MD care or physical rehab | 0.91 | 0.84 | 0.99 | 0.91 | 0.85 | 0.96 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0 + \beta_1$*intervention $+\sum_{i=2}^{7}\beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Outcome variable dichotomized at the median: ≤ mild pain and ≥ uncomfortable musculoskeletal pain.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, deadlines, holding an object by pinching, job strain quadrant term, supervisor support, job satisfaction.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
Bold=significant value.
REF=reference category.

Table9. Final Poisson multivariable regression model estimating effect of intervention on dichotomized musculoskeletal pain severity in the preferred limb wrist region (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 0.89 | 0.80 | 0.98 | **0.86** | 0.79 | 0.95 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 1.08 | 0.86 | 1.34 | 1.15 | 0.88 | 1.51 |
| >50 | 1.05 | 0.91 | 1.20 | 1.12 | 0.91 | 1.38 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.06 | 1.01 | 1.11 | 1.02 | 0.99 | 1.04 |
| High Workability | 0.88 | 0.85 | 0.92 | 0.81 | 0.79 | 0.85 |
| Deadlines | 1.48 | 1.32 | 1.64 | 1.48 | 1.42 | 1.54 |
| Weekly time spent on home computer use | | | | REF | | |
| 0-3 hours (n, %) | REF | | | 0.86 | 0.82 | 0.89 |
| 3-6 hours (n, %) | 0.91 | 0.86 | 0.96 | 1.08 | 1.03 | 1.13 |
| >6hours (n, %) | 1.10 | 1.09 | 1.10 | | | |
| Currently on medication for MSD | 0.94 | 0.67 | 1.33 | 0.72 | 0.58 | 0.90 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0 + \beta_1$*intervention $+\sum_{i=2}^{8} \beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Outcome variable was dichotomized at the median: ≤ mild pain and ≥ uncomfortable musculoskeletal pain.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, deadlines, holding an object by pinching, job strain quadrant term, supervisor support, job satisfaction.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
Bold=significant value.
REF=reference category.

Table10. Final Poisson multivariable regression model estimating effect of intervention on dichotomized musculoskeletal pain severity in the non-preferred limb wrist region (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 1.01 | 0.98 | 1.05 | **0.98** | 0.97 | 0.98 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 1.08 | 0.86 | 1.34 | 1.13 | 1.02 | 1.27 |
| >50 | 1.05 | 0.91 | 1.20 | 1.09 | 0.93 | 1.28 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.06 | 1.01 | 1.11 | 1.03 | 0.89 | 1.19 |
| Deadlines | 1.12 | 1.32 | 1.64 | 1.12 | 1.02 | 1.22 |
| JCQ Linear Function job strain | | | | | | |
| Low | | | | REF | | |
| Moderate | 0.91 | 0.86 | 0.96 | 0.90 | 0.83 | 0.97 |
| High | 1.10 | 1.09 | 1.10 | 0.77 | 0.77 | 0.78 |
| Trouble sleeping | 0.94 | 0.67 | 1.33 | 1.32 | 1.31 | 1.32 |
| MD care or physical rehab | 1.13 | 0.96 | 1.33 | 0.87 | 0.84 | 0.91 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0 + \beta_1$*intervention $+\sum_{i=2}^{7} \beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Outcome variable was dichotomized at median: ≤ no pain or mild pain and ≥ uncomfortable musculoskeletal pain.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, systemic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, deadlines, holding an object by pinching, job strain linear function term, supervisor support, job satisfaction.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
Bold=significant value.
REF=reference category.

Table11. Final Poisson multivariable regression model estimating effect of intervention on dichotomized musculoskeletal pain severity in the preferred limb digits (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 0.88 | 0.83 | 0.93 | **0.85** | 0.77 | 0.93 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 1.03 | 0.84 | 1.26 | 1.09 | 0.95 | 1.26 |
| >50 | 1.12 | 1.06 | 1.19 | 1.22 | 1.13 | 1.31 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.23 | 1.19 | 1.27 | 1.26 | 1.19 | 1.34 |
| JCQ Linear Function job strain | | | | | | |
| Low | REF | | | REF | | |
| Moderate | 0.90 | 0.89 | 0.90 | 0.88 | 0.87 | 0.89 |
| High | 0.93 | 0.84 | 1.03 | 0.88 | 0.81 | 0.95 |
| High job satisfaction | 0.85 | 0.72 | 1.00 | 0.84 | 0.73 | 0.96 |
| Deadlines | 1.35 | 1.35 | 1.36 | 1.16 | 1.14 | 1.18 |
| Pinching object | 1.13 | 1.05 | 1.23 | 1.23 | 1.14 | 1.32 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0+\beta_1$*intervention $+\sum_{i=2}^{7}\beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Outcome variable was dichotomized at median: ≤ mild pain and ≥ uncomfortable musculoskeletal pain.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, deadlines, holding an object by pinching, job strain linear function term, supervisor support, job satisfaction.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
Bold=significant value.
REF=reference category.

Table12. Final Poisson multivariable regression model estimating effect of intervention on dichotomized musculoskeletal pain severity in the non-preferred limb digits (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 1.01 | 0.91 | 1.11 | 1.00 | 0.95 | 1.04 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 1.18 | 1.01 | 1.38 | 1.12 | 1.02 | 1.44 |
| >50 | 1.16 | 1.13 | 1.19 | 1.21 | 1.14 | 1.29 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.12 | 1.03 | 1.22 | 1.12 | 1.02 | 1.21 |
| Deadlines | 1.24 | 1.14 | 1.34 | 1.30 | 1.22 | 1.38 |
| Missed workdays in past 2 months due to MSD | 1.05 | 1.01 | 1.10 | 1.06 | 1.01 | 1.12 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0+\beta_1$*intervention $+\sum_{i=2}^{5}\beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Outcome variable was dichotomized at median: ≤ mild pain and ≥ uncomfortable musculoskeletal pain.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, systemic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, deadlines, holding an object by pinching, job strain quadrant term, supervisor support, job satisfaction.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
REF=reference category.

Table13. Final Poisson multivariable regression model estimating effect of intervention on dichotomized MOS physical component summary (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 1.03 | 0.99 | 1.08 | 1.01 | 0.83 | 1.20 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 1.09 | 1.05 | 1.13 | 1.03 | 0.97 | 1.09 |
| >50 | 1.16 | 1.10 | 1.23 | 1.11 | 1.10 | 1.11 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.94 | 0.86 | 1.03 | 0.95 | 0.90 | 1.00 |
| High job satisfaction | 0.93 | 0.85 | 1.02 | 0.95 | 0.93 | 0.96 |
| Trouble sleeping | 1.26 | 1.16 | 1.37 | 1.25 | 1.11 | 1.41 |
| MD care or physical rehab in past month | 1.25 | 1.19 | 1.31 | 1.24 | 1.16 | 1.34 |
| Systemic or metabolic co-morbidity | 1.13 | 1.02 | 1.25 | 1.11 | 1.05 | 1.18 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0 + \beta_1$*intervention $+\sum_{i=2}^{7} \beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
MOS dichotomized at median: <50 or ≥50. Scale range 0-100.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, systemic or metabolic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, deadlines, holding an object by pinching, job strain linear function term, supervisor support, job satisfaction.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
REF=reference category.

Table14. Final Poisson multivariable regression model estimating effect of intervention on dichotomized MOS mental component summary (n=109)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Intervention | 0.99 | 0.90 | 1.10 | 1.01 | 0.91 | 1.11 |
| Age (years) | | | | | | |
| <35 | REF | | | REF | | |
| 35-50 | 1.00 | 0.85 | 1.17 | 1.00 | 0.83 | 1.21 |
| >50 | 1.06 | 0.90 | 1.25 | 1.01 | 0.92 | 1.22 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.96 | 0.91 | 1.02 | 0.98 | 0.93 | 1.03 |
| Weekly time spent on home computer use | | | | | | |
| 0-3 hours (n, %) | REF | | | REF | | |
| 3-6 hours (n, %) | 1.06 | 0.94 | 1.20 | 1.07 | 0.99 | 1.16 |
| >6hours (n, %) | 1.02 | 0.97 | 1.08 | 1.04 | 1.01 | 1.08 |

Final regression model was fit using the Generalized Estimating Equation model for dichotomized health outcome:
$Poi(\mu_t)=\beta_0 + \beta_1$*intervention $+\sum_{i=2}^{4} \beta_i * x_i$ + offset + $\varepsilon$.
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
MOS dichotomized at median: <50 or ≥50. Scale range 0-100.
Preliminary determinants in model = intervention, age, gender, trouble sleeping, missed workdays, workability, MSD onset, exacerbation of MSD in past 2 months, seeking medical care or physical rehab in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, deadlines, job strain linear function term, supervisor support, job satisfaction.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the intervention variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the intervention variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the intervention variable by ≥5%, the variable was retained in the final model.
Age and gender were forced into the model.
REF=reference category.

## Summary of tables

Table 1 shows there was 5% less likelihood the intervention group had an adverse musculoskeletal pain outcome in the neck and upper back of the preferred limb (RR = 0.95, 95% CI = 0.93-0.98). Table 2 shows there was 1% less likelihood the intervention group had an adverse musculoskeletal pain outcome in the neck and upper back of the non-preferred limb (RR = 0.99, 95% CI = 0.98-1.01), although the CI included the null.

Table 3 shows there was 4% less likelihood the intervention group had an adverse musculoskeletal pain outcome in the shoulder of the preferred limb (RR = 0.96, 95% CI = 0.92-1.00), although the CI included the null. Table 4 shows there was 3% less likelihood the intervention group had an adverse musculoskeletal pain outcome in the shoulder of the non-preferred limb (RR = 0.97, 95% CI = 0.92-1.01), although the CI included the null.

Table 5 shows there was 6% less likelihood the intervention group had an adverse musculoskeletal pain outcome in the elbow of the preferred limb (RR = 0.94, 95% CI = 0.90-0.99). Table 6 shows that the intervention had no effect on the likelihood of an adverse musculoskeletal pain outcome in the elbow of the non-preferred limb (RR = 1.00, 95% CI = 0.95-1.04).

Table 7 shows there was 2% less likelihood the intervention group had an adverse musculoskeletal pain outcome in the forearm of the preferred limb (RR = 0.98, 95% CI = 0.88-1.09), although the CI included the null. Table 8 shows there was 3% more likelihood the intervention group had an adverse musculoskeletal pain outcome in the forearm of the non-preferred limb (RR = 1.03, 95% CI = 1.02-1.05).

Table 9 shows there was 14% less likelihood the intervention group had an adverse musculoskeletal pain outcome in the wrist of the preferred limb (RR = 0.86, 95% CI = 0.79-0.95). Table 10 shows there was 2% less likelihood the intervention group had an adverse musculoskeletal pain outcome in the wrist of the non-preferred limb (RR = 0.98, 95% CI = 0.97-0.98).

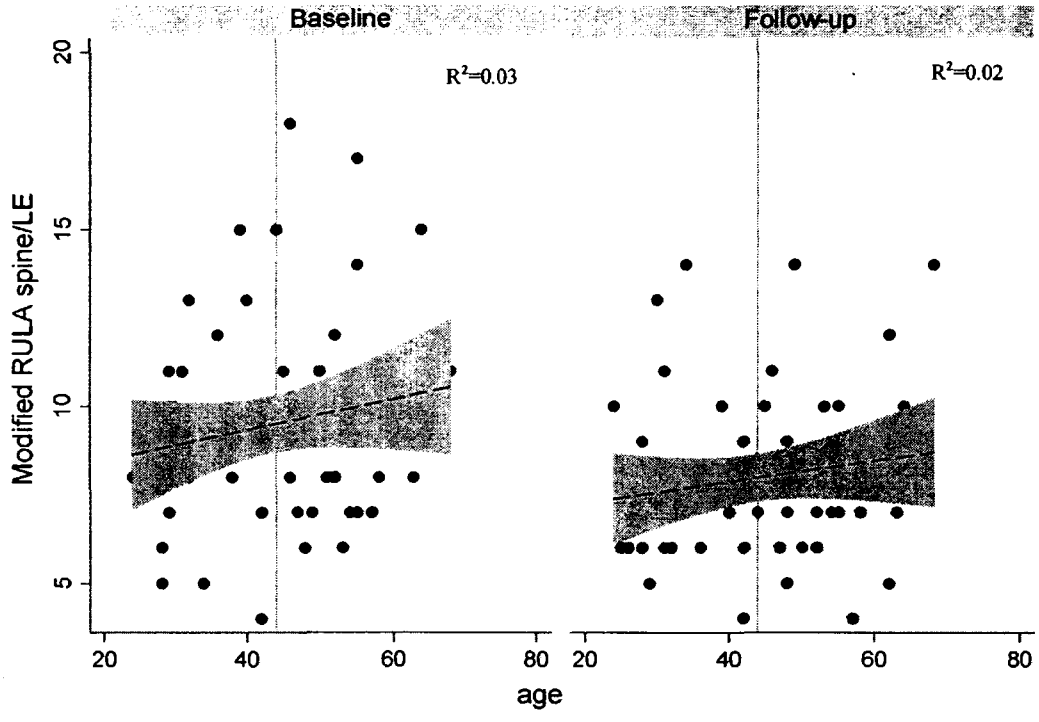
Table 11 shows there was 15% less likelihood the intervention group had an adverse musculoskeletal pain outcome in the digits of the preferred limb (RR = 0.85, 95% CI = 0.77-0.93). Table 12 shows that the intervention had no effect on the likelihood of an adverse musculoskeletal pain outcome in the digits non-preferred limb (RR = 1.00, 95% CI = 0.95-1.04).

GEE Poisson models for dichotomous MOS outcomes were used to examine the relation between quality of life and intervention in Tables 13 and 14. Differences were small and non-significant.

# Appendix J1

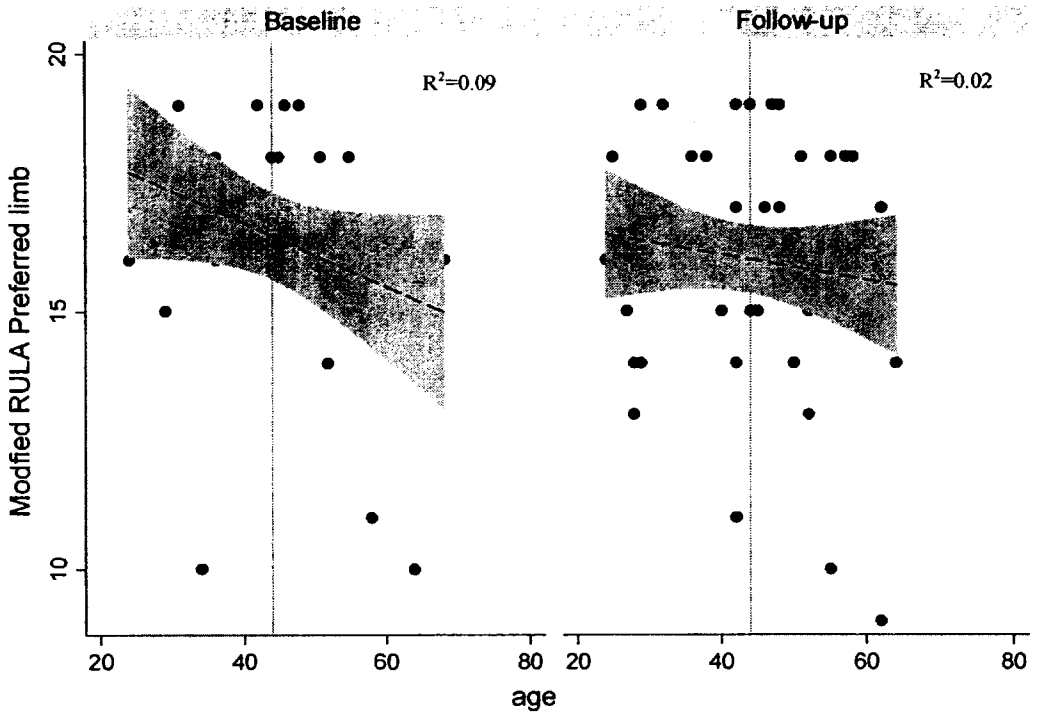
## Relation between physical exposure and age over time

Figure1. Relation between spine and lower extremity posture and age at baseline and after the intervention (follow-up)



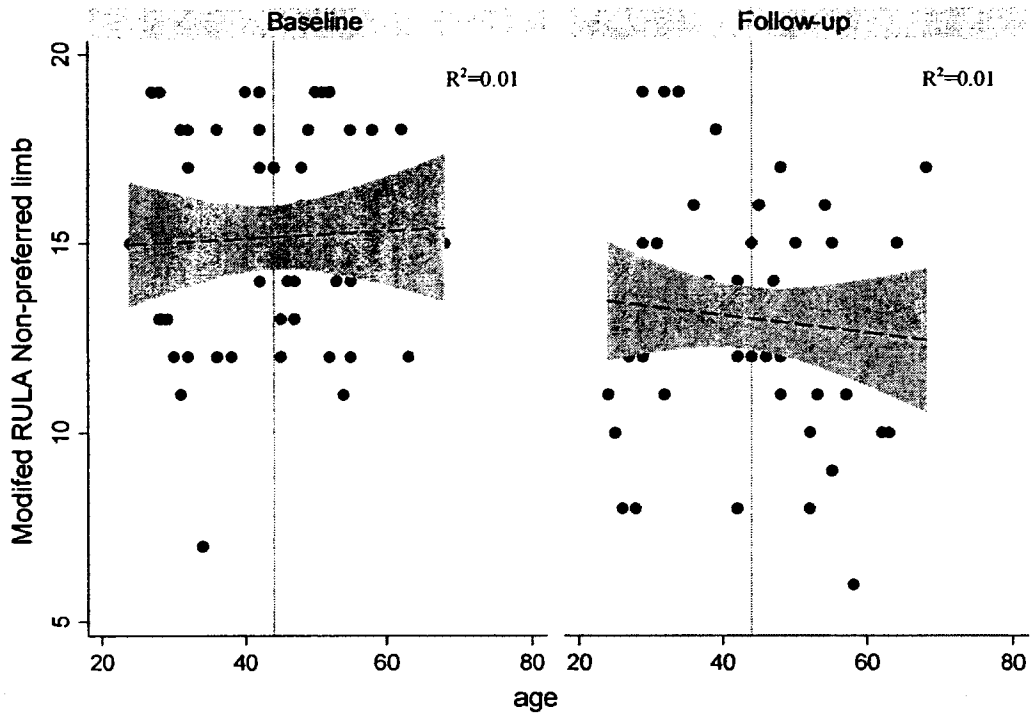

Younger and older age groups (<44 versus ≥44, respectively) both received the identical intervention: a keyboard/mouse tray, a touch pad for the non-preferred limb, training on these devices, and keyboard shortcuts. For most participants, the preferred limb continued to use a traditional, corded optical mouse.
Solid vertical line denotes dichotomized age groups.
Posture was measured by modified Computer RULA= rapid upper limb assessment measured on an absolute scale.
Spine= neck, trunk, upper back.
LE = lower extremity.
$R^2$ = goodness of fit (% variation of the data explained by the fitted line; the closer the points to the line, the better the fit)

Figure2. Relation between preferred limb posture and age at baseline and after the intervention (follow-up)



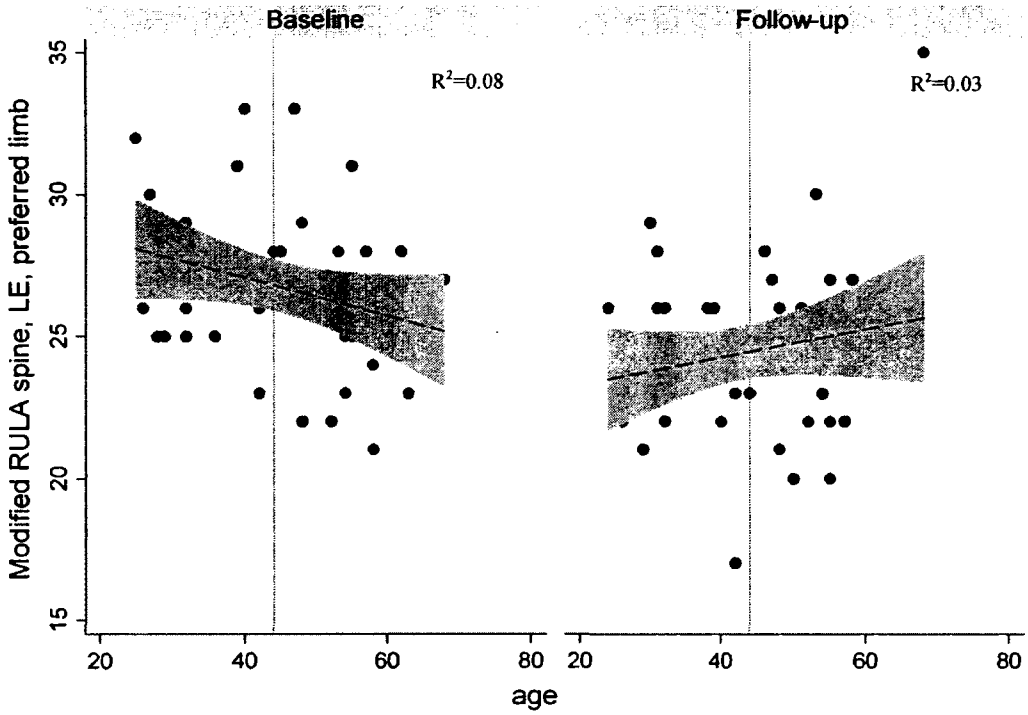

Younger and older age groups (<44 versus ≥44, respectively) both received the identical intervention: a keyboard/mouse tray, a touch pad for the non-preferred limb, training on these devices, and keyboard shortcuts. For most participants, the preferred limb continued to use a traditional, corded optical mouse.
Solid vertical line denotes dichotomized age groups.
Posture was measured by modified Computer RULA = rapid upper limb assessment measured on an absolute scale.
Preferred limb=shoulder, elbow, forearm, wrist using mouse.
$R^2$ = goodness of fit (% variation of the data explained by the fitted line; the closer the points to the line, the better the fit)

Figure3. Relation between non-preferred limb posture and age at baseline and after the intervention (follow-up)



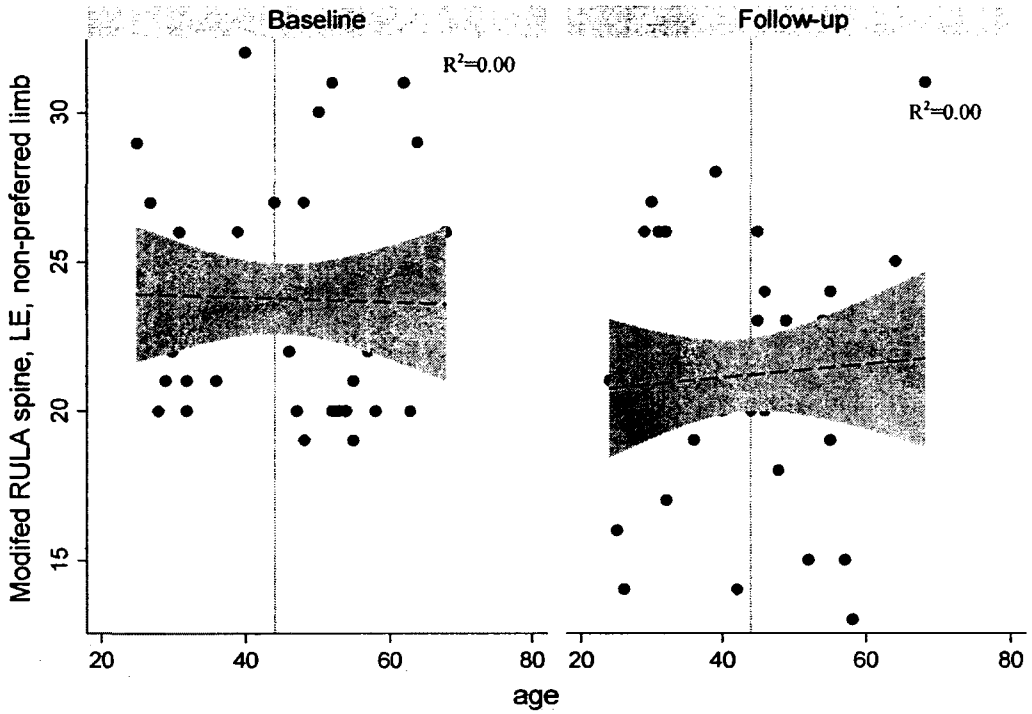

Younger and older age groups (<44 versus ≥44, respectively) both received the identical intervention: a keyboard/mouse tray, a touch pad for the non-preferred limb, training on these devices, and keyboard shortcuts. For most participants, the preferred limb continued to use a traditional, corded optical mouse.
Solid vertical line denotes dichotomized age groups.
Posture was measured by modified Computer RULA = rapid upper limb assessment measured on an absolute scale.
Non-preferred limb=shoulder, elbow, forearm, wrist using touch pad.
$R^2$ = goodness of fit (% variation of the data explained by the fitted line; the closer the points to the line, the better the fit)

Figure4. Relation between spine, lower extremity, and preferred limb posture and age at baseline and after the intervention (follow-up)



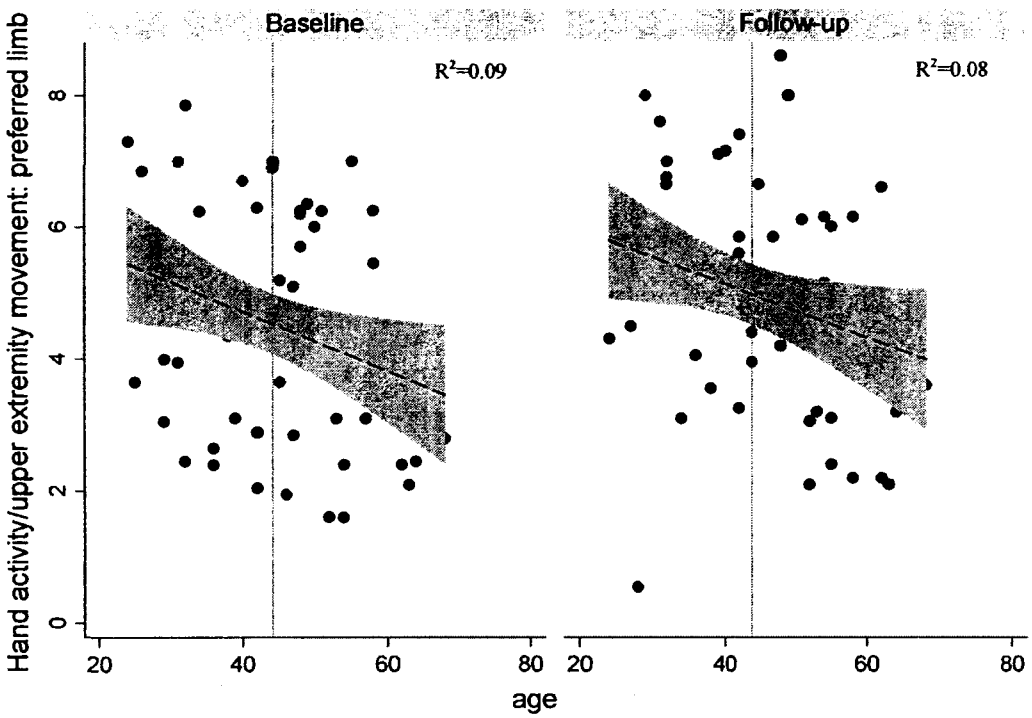

Younger and older age groups (<44 versus ≥44, respectively) both received the identical intervention: a keyboard/mouse tray, a touch pad for the non-preferred limb, training on these devices, and keyboard shortcuts. For most participants, the preferred limb continued to use a traditional, corded optical mouse.
Solid vertical line denotes dichotomized age groups.
Posture was measured by modified Computer RULA= rapid upper limb assessment measured on an absolute scale.
Spine= neck, trunk, upper back.
LE = lower extremity.
Preferred limb=shoulder, elbow, forearm, wrist using mouse.
$R^2$ = goodness of fit (% variation of the data explained by the fitted line; the closer the points to the line, the better the fit)

Figure5. Relation between spine, lower extremity, and non-preferred limb posture and age at baseline and after the intervention (follow-up)



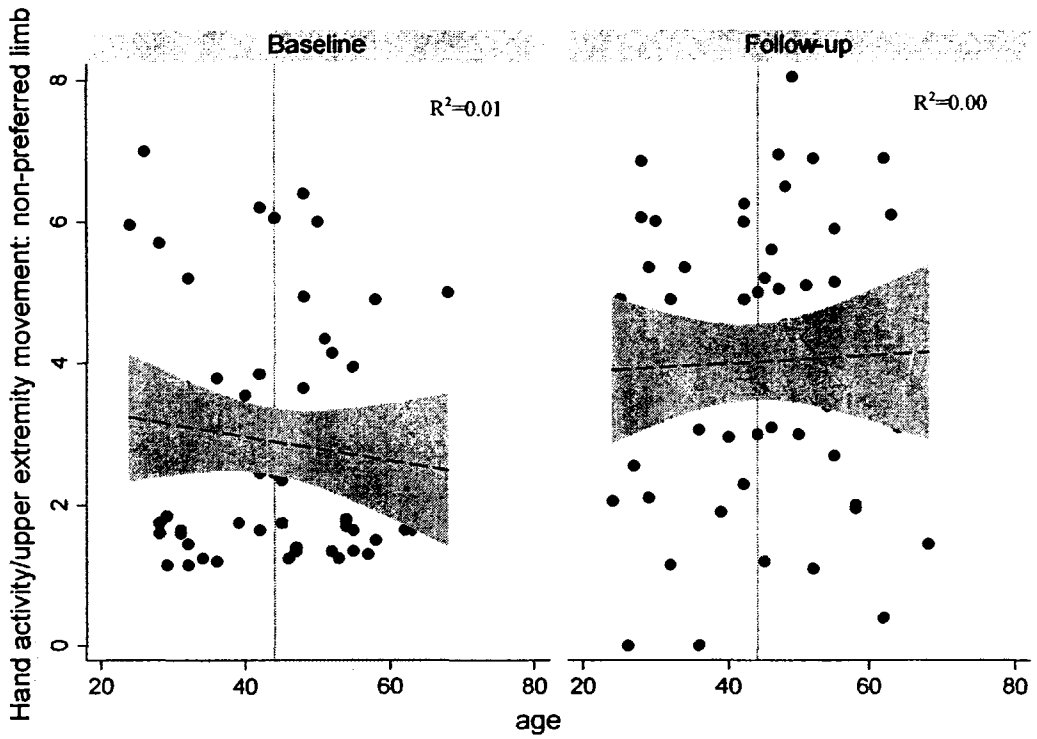

Younger and older age groups (<44 versus ≥44, respectively) both received the identical intervention: a keyboard/mouse tray, a touch pad for the non-preferred limb, training on these devices, and keyboard shortcuts. For most participants, the preferred limb continued to use a traditional, corded optical mouse.
Solid vertical line denotes dichotomized age groups.
Posture was measured by modified Computer RULA= rapid upper limb assessment measured on an absolute scale.
Spine= neck, trunk, upper back.
LE = lower extremity.
Non-preferred limb=shoulder, elbow, forearm, wrist using touch pad.
$R^2$ = goodness of fit (% variation of the data explained by the fitted line; the closer the points to the line, the better the fit)

Figure6. Relation between modified hand activity/upper extremity movement in the preferred limb and age at baseline and after the intervention (follow-up)




Younger and older age groups (<44 versus ≥44, respectively) both received the identical intervention: a keyboard/mouse tray, a touch pad for the non-preferred limb, training on these devices, and keyboard shortcuts. For most participants, the preferred limb continued to use a traditional, corded optical mouse.
Solid vertical line denotes dichotomized age groups.
Hand activity was measured by hand activity level. Hand activity values were measured on an absolute scale.
Preferred limb=shoulder, elbow, forearm, wrist using mouse.
$R^2$ = goodness of fit (% variation of the data explained by the fitted line; the closer the points to the line, the better the fit)

Figure7. Relation between modified hand activity/upper extremity movement in the non-preferred limb and age at baseline and after the intervention (follow-up)




Younger and older age groups (<44 versus ≥44, respectively) both received the identical intervention: a keyboard/mouse tray, a touch pad for the non-preferred limb, training on these devices, and keyboard shortcuts. For most participants, the preferred limb continued to use a traditional, corded optical mouse.
Solid vertical line denotes dichotomized age groups.
Hand activity was measured by hand activity level. Hand activity values were measured on an absolute scale.
Non-preferred limb=shoulder, elbow, forearm, wrist using touch pad.
$R^2$ = goodness of fit (% variation of the data explained by the fitted line; the closer the points to the line, the better the fit)

# Appendix J2

## Main effects and interaction Models

Table1. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred proximal upper extremity quadrant and modified Computer RULA spine, LE posture (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| RULA spine, LE (high) | 0.96 | 0.84 | 1.09 | 0.96 | 0.79 | 1.16 |
| Age (≥44 years) | 0.92 | 0.74 | 1.13 | 0.95 | 0.78 | 1.16 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.95 | 0.91 | 0.97 | 0.99 | 0.99 | 0.99 |
| Overtime (yes) | 1.00 | 0.86 | 1.17 | 0.93 | 0.88 | 0.97 |
| Trouble sleeping (yes) | 1.20 | 1.15 | 1.26 | 1.19 | 1.17 | 1.20 |
| Medical care or physical rehab in past month (yes) | 1.42 | 1.26 | 1.61 | 1.42 | 1.30 | 1.56 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model=RULA spine, LE, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{6} \beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized using the baseline median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median RULA spine, LE value.
RULA spine=neck, trunk, upper back.
LE= lower extremity.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table2. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred proximal upper extremity quadrant and interaction between modified Computer RULA spine, LE posture*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| RULA spine, LE (high) | 1.01 | 0.93 | 1.11 |
| Age (≥44 years) | 1.02 | 0.73 | 1.42 |
| RULA spine, LE (high)*Age (≥44 years) | 0.89 | 0.74 | 1.08 |
| Gender | | | |
| Female | REF | | |
| Male | 0.99 | 0.98 | 1.00 |
| Overtime (yes) | 0.92 | 0.86 | 0.99 |
| Trouble sleeping (yes) | 1.17 | 1.16 | 1.18 |
| Medical care or physical rehab in past month (yes) | 1.42 | 1.28 | 1.57 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Regression models were fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{7} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized using the baseline median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median RULA spine, LE value.
RULA spine=neck, trunk, upper back.
LE=lower extremity.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 1.
REF=reference category.

Table3. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred proximal upper extremity quadrant and modified Computer RULA preferred limb posture (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| RULA preferred limb (high) | 1.09 | 0.98 | 1.21 | 1.15 | 1.02 | 1.30 |
| Age (≥44 years) | 0.92 | 0.74 | 1.13 | 0.96 | 0.79 | 1.17 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.95 | 0.91 | 0.97 | 0.97 | 0.93 | 1.01 |
| Overtime (yes) | 1.00 | 0.86 | 1.17 | 0.92 | 0.86 | 0.98 |
| Trouble sleeping (yes) | 1.20 | 1.15 | 1.26 | 1.19 | 1.13 | 1.26 |
| Education | | | | | | |
| Some college | REF | | | REF | | |
| 2 or 4 year degree, or graduate degree | 1.05 | 0.88 | 1.25 | 1.11 | 1.10 | 1.11 |
| Medical care or physical rehab in past month (yes) | 1.42 | 1.26 | 1.61 | 1.44 | 1.36 | 1.53 |
| Current medication | 1.02 | 0.83 | 1.24 | 1.19 | 1.14 | 1.25 |

Table represents only participants who received ergonomic intervention consist of 2 engineering control and training.
Determinants in preliminary model= RULA preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{8} \beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized using the baseline median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median RULA preferred limb value.
RULA preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table4. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred proximal upper extremity quadrant and interaction between modified Computer RULA preferred limb posture*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| RULA preferred limb (high) | 1.13 | 1.09 | 1.17 |
| Age (≥44 years) | 0.94 | 0.86 | 1.04 |
| RULA preferred limb (high)*Age (≥44 years) | 1.04 | 0.89 | 1.21 |
| Gender | | | |
| Female | REF | | |
| Male | 0.97 | 0.92 | 1.03 |
| Overtime (yes) | 0.92 | 0.86 | 0.99 |
| Trouble sleeping (yes) | 1.19 | 1.13 | 1.26 |
| Education | | | |
| Some college | REF | | |
| 2 or 4 year degree, or graduate degree | 1.10 | 1.10 | 1.11 |
| Medical care or physical rehab in past month (yes) | 1.44 | 1.36 | 1.53 |
| Current medication | 1.18 | 1.17 | 1.20 |

Table represents only participants who received ergonomic intervention consist of 2 engineering control and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{9} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized using the baseline median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median RULA preferred limb value.
RULA preferred limb comprised the shoulder, elbow, forearm, and wrist using the mouse.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 3.
REF=reference category.

Table5. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred proximal upper extremity quadrant and modified Computer RULA non-preferred limb posture (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| RULA non-preferred limb (high) | 0.91 | 0.78 | 1.06 | 0.92 | 0.86 | 0.99 |
| Age (≥44 years) | 0.92 | 0.74 | 1.13 | 0.93 | 0.75 | 1.16 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.95 | 0.91 | 0.97 | 0.97 | 0.91 | 1.04 |
| Deadline (yes) | 1.19 | 1.13 | 1.25 | 1.14 | 1.05 | 1.23 |
| Trouble sleeping (yes) | 1.20 | 1.15 | 1.26 | 1.16 | 1.15 | 1.17 |
| Medical care or physical rehab in past month (yes) | 1.42 | 1.26 | 1.61 | 1.35 | 1.16 | 1.57 |
| Current medication | 1.02 | 0.83 | 1.24 | 1.12 | 1.08 | 1.17 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model = RULA non-preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{7} \beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median RULA non-preferred limb value.
RULA non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table6. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred proximal upper extremity quadrant and interaction between modified Computer RULA non-preferred limb posture*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| RULA non-preferred limb (high) | 0.83 | 0.71 | 0.96 |
| Age (≥44 years) | 0.84 | 0.86 | 0.94 |
| RULA non-preferred limb (high)*Age (≥44 years) | **1.22** | 1.06 | 1.40 |
| Gender | | | |
| Female | REF | | |
| Male | 0.97 | 0.89 | 1.06 |
| Deadline (yes) | 1.10 | 1.00 | 1.21 |
| Trouble sleeping (yes) | 1.18 | 1.13 | 1.23 |
| Medical care or physical rehab in past month (yes) | 1.38 | 1.19 | 1.58 |
| Current medication | 0.97 | 0.91 | 1.04 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{8} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median RULA non-preferred limb value.
RULA non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 5.
Bold=significant interaction at $p<0.01$
REF=reference category.

Table7. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred proximal upper extremity quadrant and modified Computer RULA spine, LE, preferred limb posture (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| RULA spine, LE, preferred limb (high) | 0.93 | 0.77 | 1.11 | 0.97 | 0.81 | 1.15 |
| Age (≥44 years) | 0.92 | 0.74 | 1.13 | 0.94 | 0.77 | 1.14 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.95 | 0.91 | 0.97 | 0.99 | 0.94 | 1.04 |
| Trouble sleeping (yes) | 1.20 | 1.15 | 1.26 | 1.16 | 1.15 | 1.18 |
| Medical care or physical rehab in past month (yes) | 1.42 | 1.26 | 1.61 | 1.37 | 1.17 | 1.60 |
| Current medication | 1.02 | 0.83 | 1.24 | 1.16 | 1.11 | 1.20 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model = RULA spine, LE, preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{6} \beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median RULA spine, LE, preferred limb value.
RULA spine=neck, trunk, upper back.
RULA preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, and wrist.
LE=lower extremity.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table8. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred proximal upper extremity quadrant and interaction between modified Computer RULA spine, LE, preferred limb posture*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| RULA spine, LE, preferred limb (high) | 0.89 | 0.70 | 1.12 |
| Age (≥44 years) | 0.85 | 0.76 | 0.96 |
| RULA spine, LE, preferred limb (high)*Age (≥44 years) | **1.18** | 1.06 | 1.32 |
| Gender | | | |
| Female | REF | | |
| Male | 1.00 | 0.94 | 1.06 |
| Trouble sleeping (yes) | 1.18 | 1.13 | 1.23 |
| Medical care or physical rehab in past month (yes) | 1.38 | 1.19 | 1.58 |
| Current medication | 1.13 | 1.09 | 1.17 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{7} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median RULA spine, LE, preferred limb value.
RULA spine=neck, trunk, upper back.
RULA preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, and wrist.
LE=lower extremity.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 7.
Bold=significant interaction at p<0.01
REF=reference category.

Table9. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred proximal upper extremity quadrant and modified Computer RULA spine, LE, non-preferred limb posture (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| RULA spine, LE, non-preferred limb (high) | 0.85 | 0.76 | 0.95 | 0.87 | 0.74 | 1.02 |
| Age (≥44 years) | 0.92 | 0.74 | 1.13 | 0.97 | 0.75 | 1.24 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.95 | 0.91 | 0.97 | 0.96 | 0.88 | 1.04 |
| Deadlines (yes) | 1.19 | 1.13 | 1.25 | 1.15 | 1.07 | 1.23 |
| Overtime (yes) | 1.00 | 0.86 | 1.17 | 0.93 | 0.91 | 0.95 |
| MSD exacerbation in past 2 months | 1.03 | 0.99 | 1.07 | 1.03 | 1.00 | 1.06 |
| Trouble sleeping (yes) | 1.20 | 1.15 | 1.26 | 1.17 | 1.17 | 1.18 |
| Medical care or physical rehab in past month (yes) | 1.42 | 1.26 | 1.61 | 1.39 | 1.31 | 1.48 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model= RULA spine, LE, non-preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{8} \beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median RULA spine, LE, non-preferred limb value.
RULA spine=neck, trunk, upper back.
RULA non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
LE=lower extremity.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table10. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred proximal upper extremity quadrant and interaction between modified Computer RULA spine, LE, non-preferred limb posture*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| RULA spine, LE, non-preferred limb (high) | 0.84 | 0.78 | 0.90 |
| Age (≥44 years) | 0.92 | 0.66 | 1.32 |
| RULA spine, LE, non-preferred limb (high)*Age (≥44 years) | 1.08 | 0.91 | 1.30 |
| Gender | | | |
| Female | REF | | |
| Male | 0.97 | 0.87 | 1.07 |
| Deadlines (yes) | 1.14 | 1.06 | 1.25 |
| Overtime (yes) | 0.93 | 0.90 | 0.97 |
| MSD exacerbation in past 2 months | 1.03 | 1.00 | 1.05 |
| Trouble sleeping (yes) | 1.19 | 1.14 | 1.23 |
| Medical care or physical rehab in past month (yes) | 1.39 | 1.31 | 1.47 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{9} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median RULA spine, LE, non-preferred limb value.
RULA spine=neck, trunk, upper back.
RULA non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
LE=lower extremity
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 9.
REF=reference category.

Table11 Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred proximal upper extremity quadrant and modified Computer RULA spine, LE posture (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| RULA spine, LE (high) | 0.97 | 0.81 | 1.16 | 1.00 | 0.80 | 1.26 |
| Age (≥44 years) | 1.00 | 0.97 | 1.02 | 1.05 | 1.03 | 1.07 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.04 | 0.81 | 1.32 | 1.07 | 0.91 | 1.27 |
| Years using computer over lifetime | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| Trouble sleeping (yes) | 1.47 | 1.35 | 1.61 | 1.47 | 1.38 | 1.57 |
| Eldercare (yes) | 1.06 | 0.98 | 1.16 | 1.02 | 1.01 | 1.03 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model= RULA spine, LE, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{6} \beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA spine, LE.
RULA spine=neck, trunk, upper back.
LE= lower extremity.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table12. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred proximal upper extremity quadrant and interaction between modified Computer RULA spine, LE posture*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| RULA spine, LE (high) | 1.09 | 1.00 | 1.19 |
| Age (≥44 years) | 1.16 | 0.92 | 1.46 |
| RULA spine and LE (high)*Age (≥44 years) | 0.85 | 0.65 | 1.12 |
| Gender | | | |
| Female | REF | | |
| Male | 1.07 | 0.90 | 1.27 |
| Years using computer over lifetime | 0.99 | 0.99 | 0.99 |
| Trouble sleeping (yes) | 1.45 | 1.35 | 1.55 |
| Eldercare (yes) | 1.00 | 0.95 | 1.06 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Regression models were fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{7} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA spine, LE.
RULA spine=neck, trunk, upper back.
LE=lower extremity.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 11.
REF=reference category.

Table13. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred proximal upper extremity quadrant and modified Computer RULA preferred limb posture (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| RULA preferred limb (high) | 1.10 | 1.04 | 1.17 | 1.15 | 1.02 | 1.30 |
| Age (≥44 years) | 1.00 | 0.97 | 1.02 | 0.96 | 0.79 | 1.17 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.04 | 0.81 | 1.32 | 0.97 | 0.93 | 1.01 |
| Years using computer over lifetime | 0.99 | 0.99 | 0.99 | 0.92 | 0.86 | 0.98 |
| Trouble sleeping (yes) | 1.47 | 1.35 | 1.61 | 1.19 | 1.13 | 1.26 |
| MSD onset ≥1year | 0.99 | 0.99 | 0.99 | 0.99 | 0.98 | 0.99 |

Table represents only participants who received ergonomic intervention consist of 2 engineering control and training.
Determinants in preliminary model = RULA preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{6} \beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA preferred limb.
RULA preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table14. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred proximal upper extremity quadrant and interaction between modified Computer RULA preferred limb posture*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| RULA preferred limb (high) | 1.13 | 1.07 | 1.19 |
| Age (≥44 years) | 1.06 | 0.92 | 1.22 |
| RULA preferred limb (high)*Age (≥44 years) | 0.99 | 0.75 | 1.31 |
| Gender | | | |
| Female | REF | | |
| Male | 1.06 | 0.99 | 1.15 |
| Years using computer over lifetime | 0.99 | 0.99 | 0.99 |
| Trouble sleeping (yes) | 1.58 | 1.51 | 1.65 |
| MSD onset ≥1year | 0.99 | 0.99 | 1.00 |

Table represents only participants who received ergonomic intervention consist of 2 engineering control and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{7} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA preferred limb.
RULA preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 13.
REF=reference category.

Table15. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred proximal upper extremity quadrant and modified Computer RULA non-preferred limb posture (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| RULA non-preferred limb (high) | 0.95 | 0.81 | 1.10 | 0.99 | 0.89 | 1.10 |
| Age (≥44 years) | 1.00 | 0.97 | 1.02 | 1.07 | 1.06 | 1.07 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.04 | 0.81 | 1.32 | 1.09 | 0.94 | 1.26 |
| JCQ Quadrant term job strain | | | | | | |
| Low | REF | | | REF | | |
| Moderate | 1.11 | 1.06 | 1.15 | 1.05 | 1.03 | 1.07 |
| High | 1.19 | 0.96 | 1.48 | 1.02 | 0.83 | 1.28 |
| Overtime (yes) | 1.03 | 1.00 | 1.07 | 0.91 | 0.86 | 0.97 |
| Trouble sleeping (yes) | 1.47 | 1.35 | 1.61 | 1.53 | 1.47 | 1.58 |
| Years using computer over lifetime | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| MSD onset ≥1year | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model = RULA non-preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{8} \beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA non-preferred limb.
RULA non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table16. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred proximal upper extremity quadrant and interaction between modified Computer RULA non-preferred limb*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| RULA non-preferred limb (high) | 1.02 | 0.69 | 1.49 |
| Age (≥44 years) | 0.84 | 0.91 | 1.39 |
| RULA non-preferred limb (high)*Age (≥44 years) | 0.90 | 0.59 | 1.37 |
| Gender | | | |
| Female | REF | | |
| Male | 1.08 | 0.94 | 1.26 |
| JCQ Quadrant term job strain | | | |
| Low | REF | | |
| Moderate | 1.07 | 1.07 | 1.08 |
| High | 1.06 | 0.85 | 1.32 |
| Overtime (yes) | 0.92 | 0.86 | 1.00 |
| Trouble sleeping (yes) | 1.47 | 1.41 | 1.52 |
| Years using computer over lifetime | 0.99 | 0.99 | 0.99 |
| MSD onset ≥1year | 0.99 | 0.99 | 1.00 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{9} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA non-preferred limb.
RULA non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 15.
REF=reference category.

Table17. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred proximal upper extremity quadrant and modified Computer RULA spine, LE, preferred limb posture (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| RULA spine, LE, preferred limb (high) | 1.09 | 0.98 | 1.21 | 1.08 | 0.97 | 1.20 |
| Age (≥44 years) | 1.00 | 0.97 | 1.02 | 1.06 | 1.06 | 1.06 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.04 | 0.81 | 1.32 | 1.08 | 0.90 | 1.29 |
| Overtime (yes) | 1.03 | 1.00 | 1.07 | 0.90 | 0.85 | 0.96 |
| Trouble sleeping (yes) | 1.47 | 1.35 | 1.61 | 1.59 | 1.56 | 1.63 |
| Years using computer over lifetime | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model = RULA spine, LE, preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0+\beta_1$*physical exposure $+\beta_2$*age $+\sum_{i=3}^{6}\beta_i * x_i$ + offset $+\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA spine, LE, preferred limb.
RULA preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, and wrist.
RULA spine=neck, trunk, upper back.
LE=lower extremity.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table18. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred proximal upper extremity quadrant and interaction between modified Computer RULA spine, LE, preferred limb*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| RULA spine, LE, preferred limb (high) | 1.00 | 0.79 | 1.28 |
| Age (≥44 years) | 0.85 | 0.85 | 1.16 |
| RULA spine, LE, preferred limb (high)*Age (≥44 years) | 1.12 | 0.88 | 1.42 |
| Gender | | | |
| Female | REF | | |
| Male | 1.09 | 0.93 | 1.28 |
| Overtime (yes) | 0.91 | 0.89 | 0.94 |
| Trouble sleeping (yes) | 1.60 | 1.57 | 1.62 |
| Years using computer over lifetime | 0.99 | 0.99 | 0.99 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{7} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA spine, LE, preferred limb.
RULA preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, and wrist.
RULA spine=neck, trunk, upper back.
LE=lower extremity.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 17.
REF=reference category.

Table19. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred proximal upper extremity quadrant and modified Computer RULA spine, LE, non-preferred limb (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| RULA spine, LE, non-preferred limb (high) | 0.94 | 0.75 | 1.17 | 1.00 | 0.82 | 1.21 |
| Age (≥44 years) | 1.00 | 0.97 | 1.02 | 1.07 | 1.07 | 1.07 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.04 | 0.81 | 1.32 | 1.08 | 0.93 | 1.26 |
| Overtime (yes) | 1.03 | 1.00 | 1.07 | 0.91 | 0.89 | 0.92 |
| Trouble sleeping (yes) | 1.47 | 1.35 | 1.61 | 1.55 | 1.47 | 1.63 |
| Years using computer over lifetime | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| MSD onset ≥1year | 0.99 | 0.99 | 0.99 | 0.99 | 0.98 | 0.99 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model = RULA spine, LE, non-preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure $+ \beta_2$*age $+ \sum_{i=3}^{7} \beta_i * x_i +$ offset $+ \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA spine, LE, non-preferred limb.
RULA non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
RULA spine=neck, trunk, upper back.
LE=lower extremity.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table20. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred proximal upper extremity quadrant and interaction between modified Computer RULA spine, LE, non-preferred limb*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| RULA spine, LE, non-preferred limb (high) | 0.95 | 0.74 | 1.23 |
| Age (≥44 years) | 0.99 | 0.88 | 1.12 |
| RULA spine, LE, non-preferred limb (high)*Age (≥44 years) | 1.11 | 0.94 | 1.31 |
| Gender | | | |
| Female | REF | | |
| Male | 1.09 | 0.93 | 1.28 |
| Overtime (yes) | 0.91 | 0.89 | 0.93 |
| Trouble sleeping (yes) | 1.59 | 1.55 | 1.62 |
| Years using computer over lifetime | 0.99 | 0.99 | 0.99 |
| MSD onset ≥1year | 0.99 | 0.99 | 0.99 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{8} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA spine, LE, non-preferred limb.
RULA non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
RULA spine=neck, trunk, upper back.
LE=lower extremity.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 19.
REF=reference category.

Table21. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred distal upper extremity quadrant and modified Computer RULA preferred limb posture (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| RULA preferred limb (high) | 1.14 | 0.92 | 1.41 | 1.09 | 0.89 | 1.34 |
| Age (≥44 years) | 1.15 | 1.04 | 1.27 | 1.18 | 1.00 | 1.38 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.13 | 1.03 | 1.24 | 1.09 | 1.01 | 1.12 |
| Supervisor support (high) | 0.98 | 0.98 | 0.98 | 0.99 | 0.98 | 1.00 |
| Deadlines (yes) | 1.17 | 1.06 | 1.38 | 1.11 | 1.07 | 1.15 |
| Trouble sleeping (yes) | 1.38 | 1.38 | 1.38 | 1.26 | 1.06 | 1.50 |
| MSD onset >1 year | 0.99 | 0.97 | 1.00 | 0.96 | 0.96 | 0.97 |
| Number of workdays missed in past 2 months | 0.95 | 0.93 | 0.97 | 0.94 | 0.90 | 0.99 |

Table represents only participants who received ergonomic intervention consist of 2 engineering control and training.
Determinants in preliminary model= RULA preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, systemic or metabolic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0+\beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{8}\beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA preferred limb.
RULA preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table22. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred distal upper extremity quadrant and interaction between modified Computer RULA preferred limb posture*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| RULA preferred limb (high) | 1.11 | 1.03 | 1.19 |
| Age (≥44 years) | 1.19 | 1.17 | 1.21 |
| RULA preferred limb (high)*Age (≥44 years) | 0.99 | 0.75 | 1.30 |
| Gender | | | |
| Female | REF | | |
| Male | 1.10 | 1.06 | 1.13 |
| Supervisor support (high) | 0.98 | 0.98 | 0.99 |
| Deadlines (yes) | 1.09 | 1.05 | 1.13 |
| Trouble sleeping (yes) | 1.27 | 1.07 | 1.51 |
| MSD onset >1 year | 0.96 | 0.96 | 0.97 |
| Number of workdays missed in past 2 months | 0.95 | 0.89 | 1.00 |

Table represents only participants who received ergonomic intervention consist of 2 engineering control and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{9} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA preferred limb.
RULA preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 21.
REF=reference category.

Table23. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred distal upper extremity quadrant and modified Computer RULA spine, LE, preferred limb posture (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| RULA spine, LE, preferred limb (high) | 1.00 | 0.87 | 1.15 | 1.01 | 0.81 | 1.15 |
| Age (≥44 years) | 1.15 | 1.04 | 1.27 | 1.17 | 0.77 | 1.14 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.13 | 1.03 | 1.24 | 1.12 | 0.94 | 1.04 |
| Weekly work hours on pointing device | 1.00 | 1.00 | 1.00 | 1.00 | 1.15 | 1.18 |
| Supervisor support (high) | 0.98 | 0.98 | 0.98 | 0.98 | 0.97 | 0.99 |
| Trouble sleeping (yes) | 1.38 | 1.38 | 1.38 | 1.26 | 1.16 | 1.37 |
| MSD onset >1 year | 0.99 | 0.97 | 1.00 | | | |
| Number of workdays missed in past 2 months | 0.95 | 0.93 | 0.97 | 0.94 | 0.92 | 0.96 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model = RULA spine, LE, preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, systemic or metabolic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{8} \beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA spine, LE, preferred limb.
RULA preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, and wrist.
RULA spine=neck, trunk, upper back.
LE=lower extremity.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table24. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred distal upper extremity quadrant and interaction between modified Computer RULA spine, LE, preferred limb posture*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| RULA spine, LE, preferred limb (high) | 1.07 | 0.96 | 1.20 |
| Age (≥44 years) | 1.26 | 1.08 | 1.46 |
| RULA spine, LE, preferred limb (high)*Age (≥44 years) | **0.88** | 0.86 | 0.90 |
| Gender | | | |
| Female | REF | | |
| Male | 1.11 | 1.07 | 1.14 |
| Weekly work hours on pointing device | 1.00 | 1.00 | 1.00 |
| Supervisor support (high) | 0.98 | 0.97 | 0.99 |
| Trouble sleeping (yes) | 1.22 | 1.16 | 1.28 |
| MSD onset >1 year | 0.97 | 0.95 | 0.98 |
| Number of workdays missed in past 2 months | 0.94 | 0.91 | 0.96 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{9} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA spine, LE, preferred limb.
RULA preferred limb=limb using mouse, which comprised the shoulder, elbow, forearm, and wrist.
RULA spine=neck, trunk, upper back.
LE=lower extremity.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 23.
Bold=significant interaction at p<0.01
REF=reference category.

Table25. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred distal upper extremity quadrant and modified Computer RULA non-preferred limb posture (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| RULA non-preferred limb (high) | 1.00 | 0.97 | 1.04 | 1.00 | 0.99 | 1.00 |
| Age (≥44 years) | 1.00 | 0.91 | 1.11 | 0.84 | 0.80 | 0.88 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.06 | 0.98 | 1.15 | 1.10 | 0.94 | 1.29 |
| Deadlines | 1.09 | 1.02 | 1.17 | 1.10 | 1.04 | 1.17 |
| Years worked in job title | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 |
| Trouble sleeping (yes) | 1.18 | 1.18 | 1.18 | 1.12 | 1.11 | 1.13 |
| Elder care (yes) | 1.07 | 1.01 | 1.13 | 1.15 | 1.11 | 1.19 |
| Weekly hours of PDA use | | | | | | |
| 0-3 | REF | | | REF | | |
| 3-6 | 0.93 | 0.83 | 1.03 | 0.91 | 0.86 | 0.98 |
| >6 | 0.91 | 0.85 | 0.98 | 0.81 | 0.79 | 0.84 |
| Education | | | | | | |
| Some college | REF | | | REF | | |
| 2 or 4 year degree, or graduate degree | 0.83 | 0.79 | 0.88 | 0.73 | 0.72 | 0.74 |
| Systemic or metabolic co-morbidity | 0.97 | 0.96 | 0.98 | 1.18 | 1.03 | 1.35 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model = RULA non-preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, systemic or metabolic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{10} \beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA non-preferred limb.
RULA non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table26. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred distal upper extremity quadrant and interaction between modified Computer RULA non-preferred limb posture*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| RULA non-preferred limb (high) | 1.05 | 1.03 | 1.07 |
| Age (≥44 years) | 0.93 | 0.92 | 0.95 |
| RULA non-preferred limb (high)*Age (≥44 years) | 0.83 | 0.82 | 0.84 |
| Gender | | | |
| Female | REF | | |
| Male | 1.09 | 0.95 | 1.24 |
| Deadlines (yes) | 1.16 | 1.13 | 1.20 |
| Years worked in job title | 1.01 | 1.00 | 1.02 |
| Trouble sleeping (yes) | 1.06 | 1.02 | 1.11 |
| Elder care (yes) | 1.15 | 1.15 | 1.15 |
| Weekly hours of PDA use | | | |
| 0-3 | REF | | |
| 3-6 | 0.94 | 0.89 | 0.99 |
| >6 | 0.83 | 0.83 | 0.85 |
| Education | | | |
| Some college | REF | | |
| 2 or 4 year degree, or graduate degree | 0.70 | 0.70 | 0.71 |
| Systemic or metabolic co-morbidity | 1.16 | 1.16 | 1.33 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{11} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA non-preferred limb.
RULA non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 25.
REF=reference category.

Table27. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred distal upper extremity quadrant and modified Computer RULA spine, LE, non-preferred limb posture (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| RULA spine, LE, non-preferred limb (high) | 0.93 | 0.82 | 1.05 | 0.95 | 0.74 | 1.02 |
| Age (≥44 years) | 1.00 | 0.91 | 1.11 | 0.91 | 0.75 | 1.24 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.06 | 0.98 | 1.15 | 1.08 | 0.96 | 1.23 |
| Weekly work hours on pointing device | 1.00 | 1.00 | 1.01 | 1.00 | 1.00 | 1.00 |
| Trouble sleeping (yes) | 1.38 | 1.38 | 1.38 | 1.14 | 1.10 | 1.19 |
| Education | | | | | | |
| Some college | REF | | | REF | | |
| 2 or 4 year degree, or graduate degree | 0.83 | 0.79 | 0.88 | 0.87 | 0.78 | 0.96 |
| Medical care or physical rehab in past month | 1.09 | 1.04 | 1.13 | 1.10 | 1.09 | 1.11 |
| Number of workdays missed in past 2 months | 0.97 | 0.96 | 0.98 | 0.92 | 0.88 | 0.96 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model= RULA spine, LE, non-preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, systemic or metabolic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{8} \beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA spine, LE, non-preferred limb.
RULA non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
RULA spine=neck, trunk, upper back.
LE=lower extremity.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table28. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred distal upper extremity quadrant and interaction between modified Computer RULA spine, LE, non-preferred limb posture*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| RULA spine, LE, non-preferred limb (high) | 0.99 | 0.84 | 1.16 |
| Age (≥44 years) | 1.00 | 0.89 | 1.12 |
| RULA spine, LE, non-preferred limb (high)*Age (≥44 years) | 0.96 | 0.87 | 1.06 |
| Gender | | | |
| Female | REF | | |
| Male | 1.08 | 0.98 | 1.21 |
| Weekly work hours on pointing device | 1.00 | 1.00 | 1.00 |
| Trouble sleeping (yes) | 1.12 | 1.06 | 1.19 |
| Education | | | |
| Some college | REF | | |
| 2 or 4 year degree, or graduate degree | 0.87 | 0.79 | 0.97 |
| Medical care or physical rehab in past month | 1.15 | 1.12 | 1.20 |
| Number of workdays missed in past 2 months | 0.92 | 0.88 | 0.96 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{9} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
RULA=rapid upper limb assessment. High=high exposure, dichotomized using the baseline median value for RULA spine, LE, non-preferred limb.
RULA non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
RULA spine=neck, trunk, upper back.
LE=lower extremity
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 27.
REF=reference category.

Table29. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred proximal upper extremity quadrant and modified hand activity/upper extremity movement, preferred limb (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Hand activity preferred limb (high) | 1.00 | 0.96 | 1.04 | 1.06 | 0.98 | 1.14 |
| Age (≥44 years) | 0.92 | 0.74 | 1.13 | 0.96 | 0.79 | 1.17 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.95 | 0.91 | 0.97 | 0.98 | 0.79 | 1.17 |
| Trouble sleeping (yes) | 1.20 | 1.15 | 1.26 | 1.19 | 1.18 | 1.21 |
| Education | | | | | | |
| Some college | REF | | | REF | | |
| 2 or 4 year degree, or graduate degree | 1.05 | 0.88 | 1.25 | 1.10 | 1.08 | 1.12 |
| Current Medication | 1.02 | 0.83 | 1.24 | 1.17 | 1.15 | 1.18 |
| Medical care or physical rehab in past month (yes) | 1.42 | 1.26 | 1.61 | 1.17 | 1.15 | 1.18 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model= hand activity preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0+\beta_1$*physical exposure $+\beta_2$*age $+\sum_{i=3}^{7}\beta_i * x_i +$ offset $+\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
Hand activity level measured by HAL. High=high exposure, dichotomized using the baseline median value for hand activity preferred limb.
Preferred limb=limb using mouse, which comprised the mousing shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table30. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred proximal upper extremity quadrant and interaction between modified hand activity/upper extremity movement, preferred limb*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| Hand activity preferred limb (high) | 1.06 | 0.99 | 1.14 |
| Age (≥44 years) | 0.96 | 0.79 | 1.18 |
| Hand activity preferred limb (high)*Age (≥44 years) | 0.99 | 0.99 | 1.00 |
| Gender | | | |
| Female | REF | | |
| Male | 0.98 | 0.91 | 1.05 |
| Trouble sleeping (yes) | 1.19 | 1.18 | 1.20 |
| Education | | | |
| Some college | REF | | |
| 2 or 4 year degree, or graduate degree | 1.10 | 1.08 | 1.12 |
| Current medication | 1.17 | 1.15 | 1.18 |
| Medical care or physical rehab in past month (yes) | 1.38 | 1.26 | 1.52 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{8} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
Hand activity level measured by HAL. High=high exposure, dichotomized using the baseline median value for hand activity preferred limb.
Preferred limb=limb using mouse, which comprised the mousing shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 29.
REF=reference category.

Table31. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred proximal upper extremity quadrant and modified hand activity/upper extremity movement, non-preferred limb (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Hand activity non-preferred limb (high) | 0.91 | 0.85 | 0.98 | 0.96 | 0.94 | 0.99 |
| Age (≥44 years) | 0.92 | 0.74 | 1.13 | 0.96 | 0.78 | 1.18 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 0.95 | 0.91 | 0.97 | 0.97 | 0.91 | 1.04 |
| Trouble sleeping (yes) | 1.20 | 1.15 | 1.26 | 1.19 | 1.16 | 1.22 |
| Education | | | | | | |
| Some college | REF | | | REF | | |
| 2 or 4 year degree, or graduate degree | 1.05 | 0.88 | 1.25 | 1.08 | 1.07 | 1.10 |
| Medical care or physical rehab in past month (yes) | 1.42 | 1.26 | 1.61 | 1.38 | 1.22 | 1.56 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model=hand activity in non-preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{6} \beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
Hand activity level measured by HAL. High=high exposure, dichotomized using the baseline median value for hand activity non-preferred limb.
Non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table32. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred proximal upper extremity quadrant and interaction between modified hand activity/upper extremity movement, non-preferred limb*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| Hand activity non-preferred limb (high) | 0.97 | 0.94 | 1.00 |
| Age (≥44 years) | 0.96 | 0.79 | 1.18 |
| Hand activity non-preferred limb (high)*Age (≥44 years) | **0.99** | 0.98 | 0.99 |
| Gender | | | |
| Female | REF | | |
| Male | 0.97 | 0.91 | 1.05 |
| Trouble sleeping (yes) | 1.19 | 1.16 | 1.22 |
| Education | | | |
| Some college | REF | | |
| 2 or 4 year degree, or graduate degree | 1.08 | 1.07 | 1.09 |
| Medical care or physical rehab in past month (yes) | 1.38 | 1.22 | 1.57 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{7} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain. Hand activity level measured by HAL. High=high exposure, dichotomized using the baseline median value for hand activity non-preferred limb.
Non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 31.
Bold=significant interaction at $p<0.01$
REF=reference category.

Table33. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred proximal upper extremity quadrant and modified hand activity/upper extremity movement, preferred limb (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Hand activity preferred limb (high) | 1.06 | 0.97 | 1.15 | 1.07 | 0.98 | 1.16 |
| Age (≥44 years) | 1.00 | 0.97 | 1.02 | 1.09 | 0.98 | 1.21 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.04 | 0.81 | 1.32 | 1.10 | 0.95 | 1.27 |
| Overtime (yes) | 1.03 | 1.00 | 1.07 | 0.89 | 0.86 | 0.92 |
| Trouble sleeping (yes) | 1.47 | 1.35 | 1.61 | 1.62 | 1.53 | 1.71 |
| Years using computer over lifetime | 0.99 | 0.99 | 0.99 | 0.99 | 0.98 | 0.99 |
| Weekly hours spent on PDA or cell phone | | | | | | |
| 0-3 | REF | | | REF | | |
| 3-6 | 0.91 | 0.90 | 0.93 | 0.87 | 0.86 | 0.88 |
| >6 | 1.00 | 0.92 | 1.10 | 0.97 | 0.85 | 1.10 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model = hand activity in preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{7} \beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
Hand activity level measured by HAL. High=high exposure, dichotomized using the baseline median value for hand activity in preferred limb.
Preferred limb=limb using mouse, which comprised the mousing shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table34. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred proximal upper extremity quadrant and interaction between modified hand activity/upper extremity movement, preferred limb*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| Hand activity preferred limb (high) | 1.04 | 1.03 | 1.06 |
| Age (≥44 years) | 1.06 | 1.03 | 1.09 |
| Hand activity, preferred limb (high)*Age (≥44 years) | 1.04 | 0.93 | 1.18 |
| Gender | | | |
| Female | REF | | |
| Male | 1.09 | 0.94 | 1.27 |
| Overtime (yes) | 0.90 | 0.88 | 0.93 |
| Trouble sleeping (yes) | 1.58 | 1.52 | 1.64 |
| Years using computer over lifetime | 0.99 | 0.99 | 0.99 |
| Weekly hours spent on PDA or cell phone | | | |
| 0-3 | REF | | |
| 3-6 | 0.87 | 0.87 | 0.87 |
| >6 | 0.97 | 0.87 | 1.08 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Pot(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{8} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
Hand activity level measured by HAL. High=high exposure, dichotomized using the baseline median value for hand activity in preferred limb.
Preferred limb=limb using mouse, which comprised the mousing shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 33.
REF=reference category.

Table35. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred proximal upper extremity quadrant and modified hand activity/upper extremity movement, non-preferred limb (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Hand activity non-preferred limb (high) | 1.03 | 0.94 | 1.12 | 0.98 | 0.97 | 0.98 |
| Age (≥44 years) | 1.00 | 0.97 | 1.02 | 1.07 | 1.06 | 1.07 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.04 | 0.81 | 1.32 | 1.08 | 0.92 | 1.28 |
| Overtime (yes) | 1.03 | 1.00 | 1.07 | 0.88 | 0.87 | 0.90 |
| Trouble sleeping (yes) | 1.47 | 1.35 | 1.61 | 1.59 | 1.56 | 1.63 |
| Years using computer over lifetime | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| MSD onset >1 year | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model=hand activity in non-preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, current medication, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure + $\beta_2$*age + $\sum_{i=3}^{7} \beta_i * x_i$ + offset + $\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
Hand activity level measured by HAL. High=high exposure, dichotomized using the baseline median value for hand activity in non-preferred limb.
Non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table36. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred proximal upper extremity quadrant and interaction between modified hand activity/upper extremity movement, non-preferred limb*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| Hand activity non-preferred limb (high) | 1.03 | 0.66 | 1.60 |
| Age (≥44 years) | 1.09 | 0.94 | 1.26 |
| Hand activity, non-preferred limb (high)*Age (≥44 years) | 0.92 | 0.44 | 1.89 |
| Gender | | | |
| Female | REF | | |
| Male | 1.09 | 0.92 | 1.29 |
| Overtime (yes) | 0.89 | 0.85 | 0.93 |
| Trouble sleeping (yes) | 1.59 | 1.48 | 1.70 |
| Years using computer over lifetime | 0.99 | 0.99 | 0.99 |
| MSD onset >1 year | 0.99 | 0.97 | 1.00 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{9} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
Hand activity level measured by HAL. High=high exposure, dichotomized using the baseline median value for hand activity in non-preferred limb.
Non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 35.
REF=reference category.

Table37. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred distal upper extremity quadrant and modified hand activity/upper extremity movement, preferred limb (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| Hand activity preferred limb (high) | 1.00 | 0.92 | 1.08 | 1.00 | 0.95 | 1.04 |
| Age (≥44 years) | 1.15 | 1.04 | 1.27 | 1.14 | 0.96 | 1.34 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.13 | 1.03 | 1.24 | 1.09 | 1.05 | 1.14 |
| Weekly work hours on pointing device | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Weekly hours of home computer use | | | | | | |
| 0-3 hours | REF | | | REF | | |
| 3-6 hours | 1.04 | 0.91 | 1.19 | 1.07 | 1.01 | 1.14 |
| >6hours | 1.07 | 0.90 | 1.27 | 1.05 | 0.87 | 1.27 |
| Trouble sleeping (yes) | 1.38 | 1.38 | 1.38 | 1.24 | 1.14 | 1.36 |
| Exacerbation of MSD in past 2 months | 1.06 | 1.01 | 1.11 | 1.07 | 1.06 | 1.08 |
| Number of workdays missed in past 2 months | 0.95 | 0.93 | 0.97 | 0.92 | 0.89 | 0.94 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model= hand activity preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, systemic or metabolic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0+\beta_1$*physical exposure $+\beta_2$*age $+\sum_{i=3}^{9}\beta_i * x_i +$ offset $+\varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
Hand activity level measured by HAL. High=high exposure, dichotomized using the baseline median value for hand activity preferred limb.
Preferred limb=limb using mouse, which comprised the mousing shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table38. Final regression model estimating association between dichotomous musculoskeletal pain severity in preferred distal upper extremity quadrant and interaction between modified hand activity/upper extremity movement, preferred limb*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| Hand activity preferred limb (high) | 1.01 | 0.89 | 1.15 |
| Age (≥44 years) | 1.15 | 1.06 | 1.26 |
| Hand activity preferred limb (high)*Age (≥44 years) | 0.97 | 0.84 | 1.13 |
| Gender | | | |
| Female | REF | | |
| Male | 1.10 | 1.05 | 1.15 |
| Weekly work hours on pointing device | 1.00 | 1.00 | 1.00 |
| Weekly hours of home computer use | | | |
| 0-3 hours | REF | | |
| 3-6 hours | 1.08 | 1.00 | 1.16 |
| >6hours | 1.05 | 0.88 | 1.26 |
| Trouble sleeping (yes) | 1.24 | 1.13 | 1.36 |
| Exacerbation of MSD in past 2 months | 1.07 | 1.06 | 1.08 |
| Number of workdays missed in past 2 months | 0.92 | 0.89 | 0.94 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{9} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
Hand activity level measured by HAL. High=high exposure, dichotomized using the baseline median value for hand activity preferred limb.
Preferred limb=limb using mouse, which comprised the mousing shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 37.
REF=reference category.

Table39. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred distal upper extremity quadrant and modified hand activity/upper extremity movement, non-preferred limb (n=56)

| Variable | Unadjusted RR | 95% CI | | Adjusted RR | 95% CI | |
|---|---|---|---|---|---|---|
| *Hand activity non-preferred limb (high)* | 0.94 | 0.81 | 1.10 | 0.89 | 0.83 | 0.94 |
| Age (≥44 years) | 1.00 | 0.91 | 1.11 | 0.80 | 0.74 | 0.87 |
| Gender | | | | | | |
| Female | REF | | | REF | | |
| Male | 1.06 | 0.98 | 1.15 | 1.12 | 0.99 | 1.29 |
| Supervisor support (high) | 0.98 | 0.96 | 1.00 | 0.99 | 0.98 | 0.99 |
| Deadlines (yes) | 1.09 | 1.02 | 1.17 | 1.12 | 1.00 | 1.25 |
| | | | | 1.00 | 1.00 | 1.00 |
| Years worked at agency | 1.00 | 1.00 | 1.00 | | | |
| | 1.07 | 1.01 | 1.13 | 1.24 | 1.17 | 1.32 |
| Elder care (yes) | | | | | | |
| Weekly hours of PDA use | REF | | | REF | | |
| 0-3 | 0.93 | 0.83 | 1.03 | 0.88 | 0.83 | 0.93 |
| 3-6 | 0.91 | 0.85 | 0.98 | 0.80 | 0.78 | 0.83 |
| >6 | | | | | | |
| Education | | | | | | |
| Some college | REF | | | REF | | |
| 2 or 4 year degree, or graduate degree | 0.83 | 0.79 | 0.88 | 0.70 | 0.69 | 0.71 |
| Systemic or metabolic co-morbidity | 0.97 | 0.96 | 0.98 | 1.23 | 1.21 | 1.25 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Determinants in preliminary model=hand activity in non-preferred limb, age, gender, number of workdays missed in past 2 months, workability, MSD onset, trouble sleeping, exacerbation of MSD in past 2 months, seeking medical care in past month, systemic or metabolic co-morbidity, weekly hours on pointing device, weekly hours of home computer use, weekly hours of PDA use, deadlines, overtime, job strain (trichotomized quadrant term), supervisor support, job satisfaction, education, elder care, years in job title, years at agency, years of computer use over lifetime.
Final model selection was based on a "change in estimate" approach implemented in a stepwise fashion. For all determinants in the preliminary model, the variable that led to the smallest change in the effect estimate of the physical exposure variable following its removal from the model was examined. If the variable removed from the model changed the effect estimate of the physical exposure variable by <5%, the variable was not retained in the final model. If the variable removed from the model changed the effect estimate of the physical exposure variable by ≥5%, the variable was retained in the final model.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t)=\beta_0 + \beta_1$*physical exposure $+ \beta_2$*age $+ \sum_{i=3}^{7} \beta_i * x_i +$ offset $+ \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
Hand activity level measured by HAL. High=high exposure, dichotomized using the baseline median value for hand activity non-preferred limb.
Non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
REF=reference category.
Gender was forced into the model.

Table40. Final regression model estimating association between dichotomous musculoskeletal pain severity in non-preferred distal upper extremity quadrant and interaction between modified hand activity/upper extremity movement, non-preferred limb*age (n=56)

| Variable | Adjusted RR | 95% CI | |
|---|---|---|---|
| Hand activity non-preferred limb (high) | 0.84 | 0.73 | 0.96 |
| Age (≥44 years) | 0.79 | 0.72 | 0.87 |
| Hand activity non-preferred limb (high)*Age (≥44 years) | 1.10 | 1.00 | 1.21 |
| Gender | | | |
| Female | REF | | |
| Male | 1.12 | 1.00 | 1.26 |
| Supervisor support (high) | 0.99 | 0.98 | 0.99 |
| Deadlines (yes) | 1.12 | 1.04 | 1.21 |
| Years worked at agency | 1.00 | 1.00 | 1.01 |
| Elder care (yes) | 1.22 | 1.18 | 1.27 |
| Weekly hours of PDA use | | | |
| 0-3 | REF | | |
| 3-6 | 0.88 | 0.85 | 0.91 |
| >6 | 0.81 | 0.80 | 0.81 |
| Education | | | |
| Some college | REF | | |
| 2 or 4 year degree, or graduate degree | 0.70 | 0.69 | 0.70 |
| Systemic or metabolic co-morbidity | 1.23 | 1.17 | 1.29 |

Table represents only participants who received ergonomic intervention consisting of 2 engineering controls and training.
Final regression model was fit using the Generalized Estimating Equation Poisson model:
$Poi(\mu_t) = \beta_0 + \beta_1 \times physical\ exposure + \beta_2 \times age + \beta_3 \times physical\ exposure * age + \sum_{i=4}^{8} \beta_i \times x_i + offset + \varepsilon$
Exponentiated beta coefficient = relative risk (RR). CI = confidence interval.
Musculoskeletal pain severity scale: 1 to 5, where 1 = no pain, 2= mild pain, 3 = uncomfortable pain, 4 = miserable pain, and 5 = intense pain.
Pain severity was dichotomized based on the median pain severity value in all 4 quadrants: ≤ mild pain and ≥ uncomfortable pain.
Hand activity level measured by HAL. High=high exposure, dichotomized using the baseline median value for hand activity non-preferred limb.
Non-preferred limb=limb using touch pad, which comprised the shoulder, elbow, forearm, and wrist.
Age was dichotomized between <44 years and ≥44 years.
Interaction term was added to final main effects model of Table 39.
REF=reference category.

# Appendix K1

## Relation between physical exposure and age at baseline and follow-up

Figure 1 shows scatter plot relations between age and modified RULA spine and lower extremity posture elements at baseline and follow-up. At baseline, younger workers had less physical exposure to modified RULA spine and lower extremity postures than older workers. Similar findings were observed at follow-up, although both age groups had lower physical exposure than baseline values. Moreover, the slope was not as steep at follow-up, indicating the difference between physical exposure to modified RULA spine and lower extremity postures between age groups diminished at follow-up. Specifically, older workers improved their postures more at follow-up than younger workers.

Figure 2 shows scatter plot relations between age and modified RULA preferred limb posture at baseline and follow-up. At baseline, younger workers had higher physical exposures to modified RULA preferred limb postures than older workers. The same pattern appeared at follow-up. However, younger workers reduced their modified RULA preferred limb postures more than older workers from baseline to follow-up. Figure 3 shows that both age groups had similar physical exposures to modified RULA non-preferred limb postures at baseline. At follow-up, younger workers had higher physical exposures to modified RULA non-preferred limb postures than older workers.

Additionally, at follow-up, physical exposures to RULA non-preferred limb postures were lower for both age groups than baseline values.

Figure 4 shows scatter plot relations between age and modified RULA spine, lower extremity, and preferred limb postures at baseline and follow-up. At baseline, younger workers had higher physical exposure to modified RULA spine, lower extremity, and preferred limb postures than older workers. Conversely, at follow-up, younger workers had lower physical exposure to modified RULA spine, lower extremity, and preferred limb postures than older workers. Compared with baseline values for both age groups, physical exposures were slightly lower at follow-up.

Figure 5 shows that both age groups had similar patterns in modified RULA spine, lower extremity, and non-preferred limb postures at baseline. At follow-up, younger workers had slightly less physical exposure to modified RULA spine, lower extremity, and non-preferred limb postures than older workers at follow-up. Compared with baseline values, physical exposure to modified RULA spine, lower extremity, and non-preferred limb postures for both age groups decreased at follow-up.

Figure 6 shows scatter plot relations between age and modified hand activity/upper extremity movement in the preferred limb at baseline and follow-up. At both time points, younger workers had greater hand activity/upper extremity movement in the preferred limb than older workers. Hand activity/upper extremity movement also increased in the preferred limb in both age groups at follow-up. Figure 7 shows scatter plot relations between age and hand activity/upper extremity movement in the non-preferred limb at baseline and follow-up. At baseline, younger workers had greater hand activity/upper extremity movement in the non-preferred limb than older workers.

Although hand activity/upper extremity movement increased in both groups at follow-up, younger workers had slightly less hand activity/upper extremity movement in the non-preferred limb than older workers.

In general, these figures suggest the effects of the keyboard/mouse tray on postural changes were similar between age groups. However, because of the potential for greater impairment in motor control and co-morbidity in older workers (the latter can further impair motor control), these findings may suggest that despite these burdens, older workers were still able to improve posture to approximately the same extent as younger workers over the study.

The intervention effect on touch pad use and keyboard shortcuts with respect to hand activity/upper extremity movement in preferred and non-preferred limbs appeared to be more effective in older workers, as touch pad use and keyboard shortcuts involved greater hand activity/upper extremity movement, bilaterally. These findings may suggest greater intervention compliance in older workers performing computer work. It may also indicate the ability to change established motor patterns, develop novel motor patterns, and learn complicated pointing device technology to a greater extent than younger workers.

# Appendix K2

## Interpretation of interaction terms

Table 1 presents the main effects model for the interaction term used in Table 2. The 2 main effects used in the interaction term were high non-neutral postures in the spine/lower extremity and older age. The outcome variable was musculoskeletal pain in the preferred proximal upper extremity quadrant. The interaction term in shows there was 11% less likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 0.89, 95% CI = 0.74-1.08). The direction of the interaction term suggests the joint effects of physical exposure and age provided a protective effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant. However, the CI for the interaction term included the null; the findings may have been due to chance.

Table 3 presents the main effects model for the interaction term used in Table 4. The 2 main effects used in the interaction term were high non-neutral postures in the preferred limb and older age. The outcome variable was musculoskeletal pain in the preferred proximal upper extremity quadrant. The interaction term shows there was 4% greater likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 1.04, 95% CI = 0.89-1.21). The direction of the interaction term suggests the joint effects of physical exposure and older age increased the likelihood of an adverse musculoskeletal pain outcome in this quadrant.

However, the CI for the interaction term included the null; the findings may have been due to chance.

Table 5 presents the main effects model for the interaction term used in Table 6. The 2 main effects used in the interaction term were high non-neutral postures in the non-preferred limb and older age. The outcome variable was musculoskeletal pain in the preferred proximal upper extremity quadrant. The interaction term shows there was 22% greater likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 1.22, 95% CI = 1.06-1.40). The direction of the interaction term suggests the joint effects of physical exposure and older age increased the likelihood of an adverse musculoskeletal pain outcome in this quadrant.

Table 7 presents the main effects model for the interaction term used in Table 8. The 2 main effects used in the interaction term were high non-neutral postures in the spine, lower extremity, and preferred limb, and older age. The outcome variable was musculoskeletal pain in the preferred proximal upper extremity quadrant. The interaction term shows there was 18% greater likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 1.18, 95% CI = 1.06-1.32). The direction of the interaction term suggests the joint effects of physical exposure and older age increased the likelihood of an adverse musculoskeletal pain outcome in this quadrant.

Table 9 presents the main effects model for the interaction term used in Table 10. The 2 main effects used in the interaction term were high non-neutral postures in the spine, lower extremity, and non-preferred limb, and older age. The outcome variable was musculoskeletal pain in the preferred proximal upper extremity quadrant. The interaction

term shows there was 8% greater likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 1.08, 95% CI = 0.91-1.30). The direction of the interaction term suggests the joint effects of physical exposure and older age increased the likelihood of an adverse musculoskeletal pain outcome in this quadrant. However, the CI included the null; the findings may have been due to chance.

Table 11 presents the main effects model for the interaction term used in Table 12. The 2 main effects used in the interaction term were high non-neutral postures in the spine/lower extremity and older age. The outcome variable was musculoskeletal pain in the non-preferred proximal upper extremity quadrant. The interaction term shows there was 15% less likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 0.85, 95% CI = 0.65-1.12). The direction of the interaction term suggests the joint effects of physical exposure and older age provided a protective effect against the likelihood of an adverse musculoskeletal pain severity outcome in this quadrant. However, the CI for the interaction term included the null; the findings may have been due to chance.

Table 13 presents the main effects model for the interaction term used in Table 14. The 2 main effects used in the interaction term were high non-neutral postures in the preferred limb and older age. The outcome variable was musculoskeletal pain in the non-preferred proximal upper extremity quadrant. The interaction term shows there was 1% less likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 0.99, 95% CI = 0.75-1.31). The direction of the interaction term suggests the joint effects of physical exposure and older

age provided a small protective effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant. However, the CI for the interaction term included the null; the findings may have been due to chance.

Table 15 presents the main effects model for the interaction term used in Table 16. The 2 main effects used in the interaction term were high non-neutral postures in the non-preferred limb and older age. The outcome variable was musculoskeletal pain in the non-preferred proximal upper extremity quadrant. The interaction term shows there was 10% less likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 0.90, 95% CI = 0.59-1.37). The direction of the interaction term suggests the joint effects of physical exposure and older age provided a protective effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant. However, the CI for the interaction term included the null; the findings may have been due to chance.

Table 17 presents the main effects model for the interaction term used in Table 18. The 2 main effects used in the interaction term were high non-neutral postures in the spine, lower extremity, and preferred limb, and older age. The outcome variable was musculoskeletal pain in the non-preferred proximal upper extremity quadrant. The interaction term shows there was 12% greater likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 1.12, 95% CI = 0.88-1.42). The direction of the interaction term suggests the joint effects of physical exposure and older age increased the likelihood of an adverse musculoskeletal pain outcome in this quadrant. However, the CI for the interaction term included the null; the findings may have been due to chance.

Table 19 presents the main effects model for the interaction term used in Table 20. The 2 main effects used in the interaction term were high non-neutral postures in the spine, lower extremity, and non-preferred limb, and older age. The outcome variable was musculoskeletal pain in the non-preferred proximal upper extremity quadrant. The interaction term shows there was 11% greater likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 1.11, 95% CI = 0.94-1.31). The direction of the interaction term suggests the joint effects of physical exposure and older age increased the likelihood of an adverse musculoskeletal pain outcome in this quadrant. However, the CI for the interaction term included the null; the findings may have been due to chance.

Table 21 presents the main effects model for the interaction term used in Table 22. The 2 main effects used in the interaction term were high non-neutral postures in the preferred limb, and older age. The outcome variable was musculoskeletal pain in the preferred distal upper extremity quadrant. The interaction term shows there was 1% less likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 0.99, 95% CI = 0.75-1.30). The direction of the interaction term suggests the joint effects of physical exposure and older age provided a small protective effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant. However, the CI for the interaction term included the null; the findings may have been due to chance.

Table 23 presents the main effects model for the interaction term used in Table 24. The 2 main effects used in the interaction term were high non-neutral postures in the spine, lower extremity, and preferred limb, and older age. The outcome variable was

musculoskeletal pain in the preferred distal upper extremity quadrant. The interaction term shows there was 12% less likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 0.88, 95% CI = 0.86-0.90). The direction of the interaction term suggests the joint effects of physical exposure and older age had a protective effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant.

Table 25 presents the main effects model for the interaction term used in Table 26. The 2 main effects used in the interaction term were high non-neutral postures in the non-preferred limb, and older age. The outcome variable was musculoskeletal pain in the non-preferred distal upper extremity quadrant. The interaction term shows there was 17% less likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 0.83, 95% CI = 0.82-0.84). The direction of the interaction term suggests the joint effects of physical exposure and older age had a protective effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant.

Table 27 presents the main effects model for the interaction term used in Table 28. The 2 main effects used in the interaction term were high non-neutral postures in the spine, lower extremity, and non-preferred limb, and older age. The outcome variable was musculoskeletal pain in the non-preferred distal upper extremity quadrant. The interaction term shows there was 4% less likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 0.96, 95% CI = 0.87-1.06). The direction of the interaction term suggests the joint effects of physical exposure and older age provided a small protective effect against the likelihood

of an adverse musculoskeletal pain outcome in this quadrant. However, the CI for the interaction term included the null; the findings may have been due to chance.

Table 29 presents the main effects model for the interaction term used in Table 30. The 2 main effects used in the interaction term were high modified hand activity/upper extremity movement in the preferred limb and older age. The outcome variable was musculoskeletal pain in the preferred proximal upper extremity quadrant. The interaction term shows there was 1% less likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 0.99, 95% CI = 0.99-1.00). The direction of the interaction term suggests the joint effects of physical exposure and older age provided a small protective effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant. However, the CI for the interaction term included the null; the findings may have been due to chance.

Table 31 presents the main effects model for the interaction term used in Table 32. The 2 main effects used in the interaction term were high modified hand activity/upper extremity movement in the non-preferred limb and older age. The outcome variable was musculoskeletal pain in the preferred proximal upper extremity quadrant. The interaction term shows there was 1% less likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 0.99, 95% CI = 0.98-0.99). The direction of the interaction term suggests the joint effects of physical exposure and older age had a small protective effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant.

Table 33 presents the main effects model for the interaction term used in Table 34. The 2 main effects used in the interaction term were high modified hand

activity/upper extremity movement in the preferred limb and older age. The outcome variable was musculoskeletal pain in the non-preferred proximal upper extremity quadrant. The interaction term shows there was 4% greater likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 1.04, 95% CI = 0.93-1.18). The direction of the interaction term suggests the joint effects of physical exposure and older age increased the likelihood of an adverse musculoskeletal pain outcome in this quadrant. However, the CI for the interaction term included the null; the findings may have been due to chance.

Table 35 presents the main effects model for the interaction term used in Table 36. The 2 main effects used in the interaction term were high modified hand activity/upper extremity movement in the non-preferred limb and older age. The outcome variable was musculoskeletal pain in the non-preferred proximal upper extremity quadrant. The interaction term shows there was 8% less likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 0.92, 95% CI = 0.44-1.89). The direction of the interaction term suggests the joint effects of physical exposure and older age provided a protective effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant. However, the CI for the interaction term included the null; the findings may have been due to chance.

Table 37 presents the main effects model for the interaction term used in Table 38. The 2 main effects used in the interaction term were high modified hand activity/upper extremity movement in the preferred limb and older age. The outcome variable was musculoskeletal pain in the preferred distal upper extremity quadrant. The interaction term shows there was 3% less likelihood the magnitude of the effect of

physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 0.97, 95% CI = 0.84-1.13). The direction of the interaction term suggests the joint effects of physical exposure and older age provided a protective effect against the likelihood of an adverse musculoskeletal pain outcome in this quadrant. However, the CI for the interaction term included the null; the findings may have been due to chance.

Table 39 presents the main effects model for the interaction term used in Table 40. The 2 main effects used in the interaction term were high modified hand activity/upper extremity movement in the non-preferred limb and older age. The outcome variable was musculoskeletal pain in the non-preferred distal upper extremity quadrant. The interaction term shows there was 10% greater likelihood the magnitude of the effect of physical exposure on an adverse musculoskeletal pain outcome varied by age (RR = 1.10, 95% CI = 1.00-1.21). The direction of the interaction term suggests the joint effects of physical exposure and older age increased the likelihood of an adverse musculoskeletal pain outcome in this quadrant. However, the CI for the interaction term included the null; the findings may have been due to chance.