SEX-SPECIFIC EFFECTS OF ALTERNATING COMPUTER WORK POSTURES IN YOUNG ADULTS

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ABSTRACT

Previous scientific literature has shown that alternating between sitting and standing during computer work can reduce risk factors associated with developing musculoskeletal disorders. However, the sex-specific mechanisms related to muscle activation amplitude and variability, eye strain, musculoskeletal discomfort, and computer performance remain poorly understood. Twenty-four computer users (n = 12 females) underwent three 60-minute typing tasks, either sitting, standing, or alternating between sitting and standing every 15 minutes on the same day. Muscle activation amplitude and variability, eye strain, musculoskeletal discomfort, and performance outcomes were analyzed for main and interaction effects of Sex, Time, and Condition. Alternating between sitting and standing did not show beneficial eye strain and computer performance responses. The alternating condition revealed a levelling off effect on neck/shoulder discomfort towards the end of the task in males and a beneficial effect on low back discomfort in time in females. Moreover, muscle activation amplitude and variability varied depending on whether the participant was seated or standing over time. Overall, females had more discomfort, muscle activation amplitude and variability than males and should consider adopting postures other than sitting, such as alternating between sitting and standing, when working with a computer to reduce the likelihood of developing upper body work-related musculoskeletal disorders.

RÉSUMÉ

Des publications scientifiques récentes ont montré que l'alternance entre la position assise et la position debout pendant le travail à l'ordinateur peut réduire les facteurs de risque associés aux troubles musculo-squelettiques. Cependant, les mécanismes spécifiques au sexe liés à l'amplitude et à la variabilité de l'activation musculaire, à la fatigue oculaire, à l'inconfort musculo-squelettique et aux performances informatiques restent mal compris. Vingt-quatre utilisateurs d'ordinateurs (n = 12 femmes) ont été soumis à trois tâches de dactylographie de 60 minutes, soit en position assise, debout, ou en alternant entre la position assise et la position debout toutes les 15 minutes. L'amplitude et la variabilité de l'activation musculaire, la fatigue oculaire, l'inconfort musculo-squelettique et les résultats de la performance ont été analysés statistiquement pour les effets principaux et d'interaction du sexe, du temps et de la condition. En général, l'alternance entre la position assise et la position debout n'a pas eu d'effet bénéfique sur la fatigue oculaire et les performances informatiques. La condition d'alternance a révélé un effet de plateau sur l'inconfort du cou/des épaules vers la fin de la tâche chez les hommes et un effet bénéfique sur l'inconfort du bas du dos à travers le temps chez les femmes. De plus, l'amplitude et la variabilité de l'activation musculaire variaient généralement selon que le participant était assis ou debout à travers le temps. Dans l'ensemble, les femmes présentaient des niveaux d'inconfort, d'amplitude d'activation musculaire et de variabilité plus élevés que les hommes et devraient envisager d'adopter des postures autres que la position assise, comme l'alternance entre la position assise et la position debout, lorsqu'elles travaillent avec un ordinateur afin de réduire les risques de développer des troubles musculo-squelettiques du haut du corps.

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CONTRIBUTION OF AUTHORS

Samuel Lamanuzzi, the candidate, oversaw the research design, setup, recruitment, data collection, analysis, writing, and any other steps necessary to complete the research study and submit the thesis as per McGill University requirements.

Julie N. Cote, Ph.D., Department Chair and Professor, Department of Kinesiology and Physical Education, McGill University, the candidate's supervisor, was actively involved in every step and decision made regarding the research study and completion of thesis submission.

Erika Renda, Ph.D. student, assisted with the research design, data collection, and analysis.

INTRODUCTION

Musculoskeletal disorders (MSDs) pose a serious threat of injury and loss of productivity to Canadian workers (Bevan et al., 2015). The CDC (2020) defines MSDs as diseases that can lead to severe chronic pain and discomfort that may be induced by several risk factors, such as repetitive movements and awkward postures. These risk factors are thought to cause MSDs of the upper extremities during seated computer work since individuals are required to sustain continuous periods of sedentary activity and monotonous postures (Tittiranonda et al., 1999). Seated computer work has also been shown to increase low back discomfort and upper trapezius muscle activity amplitude (Fedorowich & Côté, 2018), which are well-known risk factors for developing MSDs (Grondin et al., 2013).

Although both sexes are susceptible to MSDs, studies demonstrate that females are more likely to develop MSDs during seated computer work (Juul-Kristensen & Jensen, 2005). However, Hooftman et al. (2009) reported that in some work-related cases males are more at risk of developing lower back injuries, while females are more vulnerable to injuries of the neck and shoulder region. The mechanisms underlying these differences are still unclear and could have sex (biologically)- based, and/or gender (psychosocial)- based origins. In addition, women have been shown to suffer more from visual discomfort, computer work-related vision syndrome, and eye strain (Shantakumari et al. 2014), suggesting a link between visual and musculoskeletal systems to explain why women suffer more from some types of computer work-related disorders.

To address the high rates of upper-body MSDs during seated computer work, experts have suggested using standing postures, as they are thought to help reduce exposure to sedentary activity and MSD risk factors (Callaghan et al., 2015; Nourbakhsh et al., 2001). However, standing computer work has also shown other risk factors linked to developing MSDs, such as increased activation of back and leg muscles, and blood pooling in the thigh and leg muscles (Gao et al., 2017). In addition, both seated and standing computer work postures are static, and neither one can solve the well-documented risk factor of sedentarism related to computer work (Waters & Dick, 2014; World Health Organization, 2003). As a result, alternating between sitting and standing has been recommended, via the use of sit-stand desks (Callaghan et al., 2015). Alternating computer work postures have been observed to possess several biomechanical advantages, such as the reduction of whole-back discomfort and trunk muscle activation, which could potentially help prevent MSDs (Karakolis et al., 2016; Park & Srinivasan, 2021).

Although studies have compared kinematic and electromyographical differences during standing and seated computer work, no studies to our knowledge have established the sex-specific effects of alternating computer postures on physical, performance, and discomfort outcomes. Therefore, the goal of this thesis was to analyze the impact of alternating between sitting and standing, as compared to sustained sitting and sustained standing, on parameters indicative of the sex-based mechanisms underlying MSDs. We hypothesized that alternating between sitting and standing during computer work would reduce muscle activation and increase their variability. In addition, we hypothesized that the effects of the sitting-standing alternation would affect the sexes differently, with females receiving the greatest benefits.

LITERATURE REVIEW

Musculoskeletal Disorders

Work-Related Musculoskeletal Disorders

Musculoskeletal disorders (MSDs) are diseases caused by fatigue, muscular overuse, awkward postures, and/or repetitive movements which can lead to health complications such as musculoskeletal discomfort and chronic pain (CDC, 2020). Approximately 22 billion dollars CAD per year in direct and indirect costs are invested to address MSDs in Canada, which characterizes MSDs as the costliest medical condition in the country (Arthritis Community Research and Evaluation Unit Toronto, 2010). Moreover, MSDs represent a substantial burden to the healthcare system and occupational setting, with approximately one in four Quebec workers reporting a non-traumatic work-related MSD (Tissot et al., 2020). The risk of injury, absenteeism, and loss of productivity imposed by work-related MSDs represent a significant burden to the Canadian workforce that needs to be addressed immediately with the help of evidence-based occupational interventions (Bevan, 2015).

Computer Work-Related Musculoskeletal Disorders

Individuals who sustain prolonged bouts of sedentary activity during computer work are at an increased risk of experiencing upper-extremity MSDs (Tittiranonda et al., 1999). For instance, computer work has been shown to significantly increase upper trapezius electromyographical (EMG) activity amplitude (Fedorowich & Côté, 2018), a well-known risk factor for developing MSDs in the neck and shoulder region (Kleine et al., 1999). Other well-known general risk factors for MSDs associated with computers are the placement of the video display terminal, constant typing and/or mousing, as well as improper workstation design (Jaschinski et al., 1998; Shikdar & Al-Kindi, 2007). Shikdar & Al-Kindi (2007) observed that major issues that arise from deficiencies in computer workplace design were eyestrain, shoulder pain and back pain. Moreover, static seated computer work is another risk factor for MSDs, with injury mechanisms thought to be due to insufficient blood return to the upper body due to sedentary and/or static efforts, visual symptoms, and/or forward head postures (Keller et al., 1998; Rempel et al., 2007). Seated computer work has also been shown to increase visual discomfort and fatigue which can itself, in turn, induce a forward head posture. This postural adjustment can increase the load on the upper trapezius, which supports an association of the visual and musculoskeletal systems (Rempel et al., 2007). Indeed, adults are also at a 90% risk of developing computer vision syndrome (blurred vision and eyestrain) when working with a computer for ≥ 3 hours/day (Blehm et al., 2005).

Sitting for an extended period during computer work has also been demonstrated to increase low back and other body discomfort. Grondin et al. (2013) evaluated 28 male participants who either received lumbar support or no lumbar support during a 30-minute seated computer task. It was determined that low back discomfort increased compared to baseline for both groups. Moreover, Chang et al. (2007), who examined the musculoskeletal symptoms of 27 undergraduate students (n = 14 females) for one week, reported a dose-response relationship between computer usage and musculoskeletal symptoms. The authors determined that computer use of ≥ 3 hours/day significantly increased the risk of self-reporting signs of musculoskeletal symptoms. Toomingas et al. (2012), who sampled 156 call center operators (n = 109 females), revealed that on average, individuals spent approximately 80% of their working day seated and only 38% of them took a 5–10-minute standing break every hour, even though it is recommended to reduce risk of injury. Further, Eltayeb et al. (2009), who longitudinally followed 264 computer users over 2 years, determined that a combination of physical and psychosocial risk factors could lead to upper body musculoskeletal complaints. For instance, the authors identified that outcomes such as the number of working hours and/or an irregular head posture could elicit neck and shoulder complaints. Taken together, the literature has identified prolonged seated computer use and improper computer workstation design as two of the main risk factors for computer work-related MSDs.

Sex/Gender Differences in Mechanisms of Work-Related MSDs

Sex-specific responses during upper body fatiguing tasks

Epidemiological differences between men's and women's workplace health consider several factors which may be linked to biological determinants of musculoskeletal health, such as anthropometric, functional (e.g., strength), and physiological (e.g., body composition) differences (Côté, 2012); however, we cannot rule out the potential impact of gender-based factors. For example, there may be gender differences in the assignment of computer work tasks and in everyday exercise habits that could affect the likelihood of developing MSDs (Messing et al., 2009). For one, it is speculated that these previously mentioned sex-based differences play a fundamental role in explaining why females experience a greater likelihood of MSDs (Côté, 2012). For instance, Otto et al. (2018), recruited 28 young adults (14 females) who completed a task of fastening bolts on a vertical surface adjusted to each individual's shoulder height until reaching a pre-determined state of fatigue. They determined that although males and females had similar time to fatigue, females displayed higher levels of activation amplitude in the upper trapezius and anterior deltoid muscles compared to males, suggesting that the same task is more demanding from females' shoulders, compared to males. Further, Nordander et al. (2008) sampled 37 individuals (19 females) who completed a series of industrial tasks. They determined that muscle activation amplitude of the upper trapezius and forearm extensors was higher in females. These results could be explained by sex differences in fibre composition (type I versus type II) of the muscles in the upper body since males have been shown to have a greater proportion of type II fatigue-resistant fibres (Kupa et al., 1995). The Cinderella Hypothesis states that muscle fibres with lower activation thresholds, which are a sub-category of type 1 oxidative muscle fibres, are activated first and for prolonged periods with little to no rest (Hagg, 1991). In turn, this may lead to tissue damage and the risk of developing MSDs. With fewer type 2 muscle fibres, females may place a more sustained effort on the already activated type 1 muscle fibres. This prolonged activation could explain why females are more susceptible to upper limb MSDs than males during static seated computer work where low-intensity muscle activation of the upper body is required for an extended period with infrequent breaks to recover. In sum, it appears that females are more susceptible to MSDs of the upper limb due to their disproportionate muscle fibre type composition, however, more research is needed to uncover whether this remains true during computer work.

Sex-specific responses during computer work

Although there is a clear link between the development of MSDs and seated computer work, there is still a lack of understanding about the underlying physiological mechanisms that cause MSDs and how they might differ between males and females (Fedorowich & Côté, 2018; Hooftman et al., 2009). Studies show that females are at a greater risk of MSDs during seated computer work and are more likely to experience work-related symptoms in all regions of the body (Juul-Kristensen & Jensen, 2005). Hooftman et al. (2009) longitudinally followed roughly 1800 employees across 34 companies who engaged in a series of work-related tasks including computer programming. The authors determined that in some cases males were more at risk of developing work-related MSDs than females. For instance, the authors reported that males were more susceptible to lower back injuries, while females were more susceptible to injuries of the neck/shoulder region. This difference in body region-specific MSDs was also similarly observed in Karakolis et al. (2016), who recruited 24 adults (12 females) to perform a 60-minute computer task either sitting, standing, or alternating between the two postures. The authors determined that males perceived greater levels of whole-body discomfort than females over time when standing, while females perceived greater discomfort while sitting. However, Park & Srinivasan (2021), who sampled 12 young adults (6 females), did not observe a significant main effect of sex on low back discomfort or trunk muscle activation measures during a computer task protocol similar to Karakolis et al. (2016). These contradictory results could be related to the differences in the methodology of the authors' studies since Karakolis et al. (2016) implemented a different sit-stand ratio and had participants perform all three 60-minute conditions on the same day as opposed to 2-hour tasks on separate days. Shantakumari et al. (2014) sampled 471 university students (311 females) through a series of questionnaires. They found that female computer users were more at risk of problems that could affect vision, such as headaches, tired eyes and burning eye sensations. Overall, it appears as though males and females elicit similar responses to fatigue when performing computer-related tasks, however, they demonstrate significant differences in terms of the muscles which are fatigued, muscle activity amplitude, and perceived levels of discomfort. These sex differences are most likely related to the previously mentioned underlying physiological mechanisms which may cause MSDs (Côté, 2012), although more studies are needed to investigate these sex-specific responses in mechanisms of computer work-related MSDs.

Seated and Standing Work

Most scientific literature on office ergonomics focuses on reducing sedentary exposure during seated occupational tasks. However, researchers are also beginning to investigate potential risk factors associated with prolonged standing. For instance, Tissot et al. (2009), who examined a 1998 Quebec Social and Health Survey determined that regardless of sex, standing during work could elicit similar levels of low back pain as seated work in individuals who had never experienced low back injuries before. The authors also observed that individuals who were able to self-select a sitting break experienced less low back pain compared to those who could not. Antle & Côté (2013) observed similar findings when examining 18 healthy volunteers (n = 8 females) during a 34-minute stationary standing box-folding task. The authors determined that although individuals suffer from high loads to the lower back while standing, loads are significantly higher on the lower limbs. Previous research has also shown that prolonged standing can elicit increases in muscle activation of the lower limbs and accelerate the onset of fatigue (Balasubramanian et al., 2009; Dempsey, 1998). As a result, these findings suggest that stationary standing rather than sitting might not be the optimal posture to prevent injuries or MSDs during work.

Computer Work Postures

Seated and Standing Computer Work Postures

Since seated computer work has been associated with a high prevalence of low back pain and risk of developing MSDs, some have advocated using postures other than sitting, such as standing, while working with a computer (Callaghan et al., 2015; Nourbakhsh et al., 2001). For instance, Buckley et al. (2015) recommend breaking up seated-based work with approximately four hours of either standing or light activity per day to avoid prolonged static postures. Moreover, in a study conducted by Fedorowich & Côté (2018), in which 20 healthy adults (n = 10 females) performed two 90-minute computer work sessions either sitting or standing, it was found that standing computer work showed some beneficial effects, such as reduced upper body discomfort and increased typing speed. However, standing computer work has also been shown to be associated with some negative effects, such as increases in muscle activation and blood pooling in the lower body (thigh and leg muscles) compared to seated computer work. This was shown by Gao et al. (2017) who recruited 18 healthy middle-aged females to perform 2-hours of either seated or standing desk work. Moreover, our laboratory's previous research has shown that there are some sex differences in how the standing posture affects muscles during computer work. For instance, Cui et al. (2020), who recruited 24 participants (n = 12 females), found significantly less upper body muscle activity during a 90-minute standing computer task compared to a seated posture, with females experiencing higher muscle activation amplitude for the middle trapezius when standing and the anterior deltoid while seated. In sum, both the seated and standing postures have static components that prevent movement (Waters & Dick, 2014; World Health Organization, 2003), which we know is necessary to promote healthy blood circulation, overload of the same muscle fibres, and overall sedentarism, suggesting the need for computer work methods that are more dynamic.

Alternating Computer Work Postures

To address the shortcomings of the seated and standing computer work postures, alternating between seated and standing (sit-stand) postures have been proposed, and can ideally be implemented by using sit-stand desks (Callaghan et al., 2015). Indeed, Pronk et al. (2012) sampled 34 adults who were either given a sit-stand desk or no treatment over 4 weeks. It was shown that alternating between seated and standing postures with the help of a sit-stand desk may reduce sedentary activity and low back pain. Further, in the previously mentioned study by Karakolis et al. (2016), 24 young adults were either seated, standing, or alternated between seated and standing postures (15 minutes of sitting and 5 minutes of standing) for 60 minutes. Results showed some benefits of the alternating condition in reducing whole-back discomfort when compared to static seated or standing postures. This reduction in whole-back discomfort could be related to a reduction in lumbar flexion and viscoelastic tissue creep while sitting (Howarth et al., 2013; O'Sullivan et al., 2006). Essentially, standing could offer a postural break that reduces the loading of tissue creep caused by lumbar flexion while seated (Karakolis et al., 2016), but to a more effective level when alternations between the two postures are incorporated. Moreover, Park & Srinivasan (2021), observed a decrease in trunk muscle activation during a two-hour computer task where participants switched between sitting and standing every 30 minutes compared to seated and standing computer work conditions. This decrease in trunk muscle activity could indicate reduced active stiffening created by the alternations in posture, which could potentially prevent MSDs experienced when sitting (Park & Srinivasan, 2021). However, although Park & Srinivasan (2021) did use the recommended ratio of 1:1 for alternating between sitting and standing, they did not limit standing to 15 minutes or less to optimize the reduction of lower back discomfort and improve performance as suggested by Callaghan et al. (2015). This prolonged 30 minutes of standing and sitting could explain why Park & Srinivasan (2021) did not observe a decrease in low back discomfort during their sit-stand condition but did notice an increase during the sitting and standing conditions. Further, Park & Srinivasan (2021) observed no significant main or interaction effects of Sex on trunk EMG outcomes. Barbieri et al. (2019) recruited 24 office workers (16 females) for two hours in 6 conditions involving either sitting, standing, or alternating between the two. The authors identified high degrees of upper body postural variability during alternating postures. This variability could be beneficial to the neck, trunk, and upper arm muscles in reducing their prolonged sustained effort, a risk factor for MSDs during computer work (Keller et al., 1998). Overall, it appears as though there are differences in results when identifying biomechanical and discomfort outcomes during alternating computer work (Barbieri et al., 2019; Karakolis et al., 2016; Park & Srinivasan, 2021). These differences could be related to several factors, such as sample characteristics and temporal characteristics of alternating between sitting and standing during the experimental protocol. In addition, Gallagher et al. (2014), who recruited 20 young adults (10 females) for a two-hour alternating sitting and standing computer task, observed similar results to Tissot et al. (2009) where non-pain developers could also experience low back pain during standing compared to pain developers, however, to a lesser extent. Further, the authors observed that sitting during computer work could alleviate some of the low back pain that was experienced during standing (Gallagher et al. 2014). Overall, these studies suggest that there are some beneficial (less upper body effort), but also some detrimental findings (more lower-body discomfort and blood pooling) effects of the standing posture during computer work. However, a clearer understanding of optimal sit-to-stand ratio during computer work, and whether this is the same for men and women, are needed to better understand and limit the development MSDs during computer work.

Knowledge Gaps

Although many studies have compared health outcomes and mechanistic exposures of standing and seated postures, no studies to our knowledge have identified the sex-specific impacts of alternating computer postures on physical, performance, or discomfort outcomes during a computer task. The proposed project will provide information for the prevention of MSDs in adult computer users. Specifically, the understanding of sex differences in muscle activity, and body discomfort will help understand the underlying mechanisms for any benefit of alternating sitting and standing computer workstations, which will ultimately serve to improve evidence-based ergonomic interventions in the workplace for both male and female computer users.

Objectives and Hypotheses

To fill the previously mentioned knowledge gaps, the primary objective of this thesis was to compare seated, standing, and seated/standing alternating postures, on biomechanical, performance, and symptom characteristics during computer work. The secondary objective was to uncover any sex differences for the above-mentioned outcomes which could lead to a clearer understanding of sex-specific work-related MSDs. We hypothesized that alternating postures would improve upper body muscle activity patterns and reduce discomfort and eye strain over time while also improving computer performance. Moreover, we hypothesized that these effects would vary between the sexes when compared to sitting and standing, with females experiencing greater levels of musculoskeletal discomfort, eye strain and muscle activation amplitude in the upper body compared to males when alternating between the two postures over time.

RESEARCH ARTICLE

Sex-Specific Effects of Alternating Computer Work Postures in Young Adults

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Abstract

Alternating between sitting and standing during computer work may reduce risk factors for musculoskeletal disorders. However, sex-specific mechanisms underlying muscle activity, discomfort and performance remain poorly understood. Twenty-four computer users (n = 12 females) participated in three 60-minute typing tasks either sitting, standing, or alternating between sitting and standing every 15 minutes. Electromyography (EMG) was measured from 5 back and upper body muscles using bipolar surface electrodes, and all measures were collected every 5min. There were significant Sex x Time x Condition effects ($p < 0.001$) on discomfort, with the alternating condition leading to decreases with time in males' low back, and females' neck/shoulder. EMG amplitude and variability were higher in females and varied with time, especially in the alternating condition (3-way interaction, $p < 0.001$). Results suggest sex-specificity in the effects of the alternating posture, although more studies including lower limb measures are required to confirm this interpretation.

Keywords: Electromyography, Musculoskeletal Discomfort, Sit to Stand Desk

1. Introduction

Repetitive movements and prolonged sustained, and/or awkward postures are risk factors that may cause the development of musculoskeletal disorders (MSDs) (CDC, 2020). MSDs have the potential to inflict long-lasting injuries which can then lead to loss of time in the workplace (Bevan, 2015). During seated computer work, continuous bouts of sedentary activity and unchanging postures are considered computer work-related risk factors for MSDs, particularly in the upper body (Tittiranonda et al., 1999). Specifically, high levels of muscle activity amplitude of the upper trapezius and low back discomfort during seated computer work (Fedorowich & Côté, 2018) have previously been linked with an elevated risk of MSDs (Grondin et al., 2013).

Individuals who work with a computer for ≥ 3 hours/day are also at an elevated risk of developing visual-related complications (blurred vision and eyestrain) (Blehm et al., 2005).

To reduce risks related to seated computer work, some researchers have suggested using standing computer postures (Callaghan et al., 2015; Nourbakhsh et al., 2001). However, Gao et al. (2017) identified several risk factors associated with prolonged standing computer work, such as more muscle activation and blood pooling in the thighs and legs. Seated and standing computer work postures both possess strengths and inconveniences related to body-region specific MSDs, which could potentially be improved upon by using sit-stand desks and alternating between sitting and standing (Callaghan et al., 2015). Alternating between sitting and standing during computer work possesses several biomechanical advantages, such as reductions in whole-back discomfort and trunk muscle activation, which are factors that have previously been linked to the development of MSDs (Karakolis et al., 2016; Park & Srinivasan, 2021). Pronk et al. (2012) observed similar results (reduced sedentary exposure and low back pain) when participants were given sit-stand desks and longitudinally followed for 4 weeks. However, sex-specific mechanisms underlying potential benefits are still poorly understood and need to be researched.

According to Juul-Kristensen & Jensen (2005), females are more at risk of developing MSDs; however, some studies have observed that males are more susceptible to lower-back injuries while females are more likely to develop injuries to the neck and shoulder region during work-related events (Hooftman et al., 2009). It is believed that males and females could develop these body-region specific MSD-patterns due to sex (biological)- and/or gender (psychosocial)-based mechanisms. Current hypotheses believe that fibre type composition could play a role since females have a greater proportion of type 1 oxidative muscle fibres and a lower proportion of fatigue-resistant type II muscle fibres in the upper body (Kupa et al., 1995; Simoneau & Bouchard, 1989), which would in turn influence how fibres are recruited and activated during activities such as computer work. There could also be differences in how males and females engage the different muscles during the same task, which could in turn provide a reason for sex differences in computer work-related MSDs. For instance, females experience higher levels of electromyography (EMG) activation amplitude in the anterior deltoid while performing seated computer work but lower activation amplitude in the lumbar erector spinae when standing compared to males (Cui et al., 2020). Moreover, female computer users are more at risk of experiencing visual issues such as headaches, tired eyes and burning eye sensations (Shantakumari et al. (2014). However, the interplay between the neuromuscular and visual systems, and how this could impact sex differences in computer work-related MSDs is unclear.

Several studies have examined the different risk factors associated with seated and standing computer work postures, such as muscle activation patterns and musculoskeletal complications. However, no studies to our knowledge, have identified sex-specific responses and/or benefits of alternating computer work postures on electromyographical, discomfort, visual and performance outcomes. The objective of this study was to determine the effects of alternating between sitting and standing during computer work, as opposed to continuous sitting and standing, on the aforementioned health-related outcomes. It was hypothesized that alternating computer work postures would reduce upper body muscle activation amplitude and would increase their variability. Moreover, we hypothesized that females would experience greater muscle activity and musculoskeletal responses during the sitting-standing alternation compared to males.

2. Methods

2.1. Participants

To test our primary outcome (upper trapezius EMG root-mean-square (RMS)) it was determined that a sample size of 24 participants was required (G*Power software, Repeated Measures ANOVA within-between interaction: power = .95, alpha = 0.05, effect size = 0.15 (small to medium), number of groups = 2 (males and females), number of measurements = 36 (3 conditions with 12-time points)). Therefore, 24 young adults (n = 12 females, mean age = 23.33 +/- 2.12 years, mean height = 1.73 +/- 0.10m, mean weight = 70.59 +/- 11.08kg) were recruited as a convenience sample from a university population. Participants were included in the study if they: 1) were cleared by the Physical Activity Readiness Questionnaire for Everyone 2020 (Thomas et al., 1992), 2) were frequent computer users (≥ 6 hours/day or ≥ 40 hours/week), 3) were between the ages of 18 – 29 and 4) willingly provided informed written consent to participate in the study. Participants were excluded from the study if they: 1) had medically diagnosed musculoskeletal or neurological pathologies, 2) consumed alcohol or engaged in exercise ≤ 24 hr before the laboratory visit, 3) consumed caffeine ≤ 12 hours before the laboratory visit, 4) owned or regularly used a standing desk (≥ 1 hour/day), 5) were unable to read or type in English for ≥ 60 minutes and 6) suffered from chronic headaches diagnosed by a doctor or requiring medical attention in the last 3 months. The study was approved by the McGill Research Ethics Board Office (Reference Number: 21-07-018)

2.2. Experimental Protocol

The participant sat or stood in front of a sit-stand desk (Ergonomyx Technologies Canada Inc., Victoria, Canada), adjusted based on Canadian ergonomic guidelines and individualized based on anthropometric measures (Canadian Centre for Occupational Health and Safety, 2016; Occupational Health Clinics for Ontario Workers, 2008). The participant's posture and workstation were adjusted at the beginning of each condition to the previously mentioned guidelines: the top of the laptop screen (12.5 inches × 8 inches) was positioned at eye level on a laptop stand, the elbows were approximately 50 mm above the external keyboard, the screen was positioned 50 – 100cm away from the participant's head, thighs were parallel to the ground when seated, feet were planted on a footstool or the ground and the head position was neutral prior to beginning the task. The participant completed three separate 60-minute computer tasks in a balanced randomized presentation order on the same day. The task involved both reading and typing, in postures of either seated, standing, or alternating between the two (15 minutes of seated computer work followed by 15 minutes of standing computer work, a 1:1 ratio) (Callaghan et al., 2015). Before beginning the first condition, the participant engaged in a 5-minute familiarization task. The participant then performed 12, 5-minute trials of computer work where EMG was recorded during the final 30s of each 5-minute trial. Subsequently, visual analogue scale ratings of discomfort for 3 body regions (visual, low back, and neck/shoulder) and computer performance data were collected. This interruption lasted approximately 15s during which the participant stopped typing. There was also an approximate 15s delay during the alternating condition when transitioning between seated and standing or vice versa. The participant was told at the beginning of each condition and every 20 minutes to type, trying to be as accurate and fast as possible to ensure maximal computer performance. The participant was given 20 minutes to recover after every 60 minutes of computer work to reduce the possibility of residual fatigue from condition to condition (Le & Marras, 2016).

2.3. Instrumentation

2.3.1. Experimental Task, Discomfort and Computer Performance

Pre-determined texts from the Grimm's Fairy Tales collection were randomly selected as the texts for the typing task in the Mavis Beacon Teaches Typing Software (Version 20.0) (Kim et al., 2014; Yoon et al., 2021). The randomly selected texts had similar Flesch-Kincaid grade levels to the texts mentioned in Kim et al. (2014), meaning they could be easily understood by the average twelve-year-old. The text was located at approximately eye level relative to a neutral head posture. Visual analogue scales were used to measure visual, neck/shoulder and lower back discomfort (L4 – L5), while computer performance was measured by the number of words typed per minute with the Mavis Beacon Teaches Typing software, in line with previous studies (Crichton, 2001; Fedorowich & Côté, 2018). The visual analogue scale utilized ratings from "no discomfort" (0mm) to "discomfort as bad as it could be" (100mm). Whenever prompted, the participant marked with a vertical line their current discomfort rating for the above-mentioned measures on a different piece of paper presented each time.

2.3.2. Muscle Activity

Muscle activation amplitude (root mean square, RMS) and coefficient of variation (CoV) were calculated from recordings made using bipolar surface EMG electrodes (Delsys© Trigno™, USA). Before placing the electrodes, the participant's skin was shaved and abraded with rubbing alcohol to minimize signal interference. Electrodes were then placed bilaterally on the cervical erector spinae and unilaterally on the upper/middle trapezius and anterior deltoid of the right side of the body, at specific body landmarks used in applied ergonomics/human factors research and described previously (Fedorowich & Côté; Yoon et al., 2021). All participants were right-hand dominant for mousing. EMG signals were collected via a recording software (Vicon Nexus 2.8.0, VICON Motion Systems Ltd, Oxford, UK) and sampled at 2000Hz with an 80dB common-mode rejection ratio. Kinematic data were recorded and will be reported in a follow-up manuscript.

2.4. Maximal Voluntary and Sub-Maximal Isometric Contractions

The participant completed a series of maximal and sub-maximal voluntary isometric contractions (MVICs/sMVICs) for all the previously mentioned muscles. For the cervical erector spinae muscles, the participant lay prone with their neck extended off a treatment table, and held the weight of their head, with a neutral neck posture. For the upper trapezius, the participant was seated in a neutral position and held their arm by having their shoulder abducted 90^{o}. Similarly, for the anterior deltoid, the participant held their arm in a shoulder flexed posture with a 90^{o} angle. Finally, for the middle trapezius, the participant maximally abducted their scapula to 90^{o} while their forearms rested on an adjustable table in a seated neutral position (Yoon et al., 2021). SVICs were conducted for all the muscles except the middle trapezius which was normalized using an MVIC. Two ramp-up, ramp-down five-second trials were performed for each muscle, with verbal encouragement for the maximal efforts, and instructions to maintain a static angle for the sub-maximal efforts. Approximately one minute of rest was given between each trial.

2.5. Data Analysis

The EMG recordings were full-wave rectified, band-pass filtered, and smoothed using a 4th order Butterworth filter with a frequency range between 10 – 450Hz. The signals were normalized to the peak amplitude calculated from the MVICs/sMVICs recordings. EMG amplitude values recorded during the experimental task were calculated by taking the average of the RMS values calculated over 30 1-s non- overlapping timeframes, representing the muscle's mean amplitude value from each time trial. Moreover, EMG amplitude variability (CoV) was measured by dividing the standard deviation of the 30 RMS timeframe values by the mean RMS value at each time level (Fedorowich & Côté, 2018; Yoon et al., 2021).

2.6. Statistical Analysis

Mean and standard deviation for both males and females were determined for Age, Weight and Height using Independent-Samples T-Tests between sexes. A p-value < 0.05 indicated a significant sex difference for variables with equal variances.

Computer performance (words/min), Visual analogue ratings of discomfort (eye strain, neck/shoulder, lower back) and EMG (RMS, CoV) data were statistically analyzed using generalized estimating equations (GEE; Zeger & Liang, 1986) in SPSS (v23, IBM Corporation), via the Ballinger et al. (2004) methods. Time (12 levels for 12 trials during the task) and Condition (seated vs. standing vs. alternating postures) were modelled as within-subjects factors and Sex (Males, Females) was modelled as a between-subjects factor. Sequential Bonferroni corrections were performed if statistically significant effects were observed using pairwise comparisons (Wald X2).

3. Results

Participant characteristics are presented in Table 1. Males were significantly taller ($p < 0.001$) and heavier ($p = 0.005$) than their female counterparts, however, they did not differ significantly in terms of age.

Table 1 Mean and standard deviation (SD) of male and female participants. Independent-Samples T-Tests were performed with equal variances for age, height, and weight. A p-value of < 0.05 indicates a significant sex difference.

Characteristic	Males	Females	p-value
Age (years)	22.75 (2.1)	23.92 (2.07)	= 0.18
Height (m)	1.82 (0.043)	1.64 (0.06)	**< 0.001**
Weight (kg)	76.63 (8.98)	64.54 (9.80)	**= 0.005**

3.1. Computer Performance

For computer performance, a significant interaction effect of Sex × Condition × Time ($X^2 = 242.73$, $p < 0.001$) was determined, however, pairwise comparisons revealed no significant comparisons. Generally, computer performance was greater in females than it was in males (Fig.

1-A). There was a decrease in the alternating condition until the 30-minute mark from approximately 48 words/min to 46 words/min where it plateaued (Fig. 1-B).

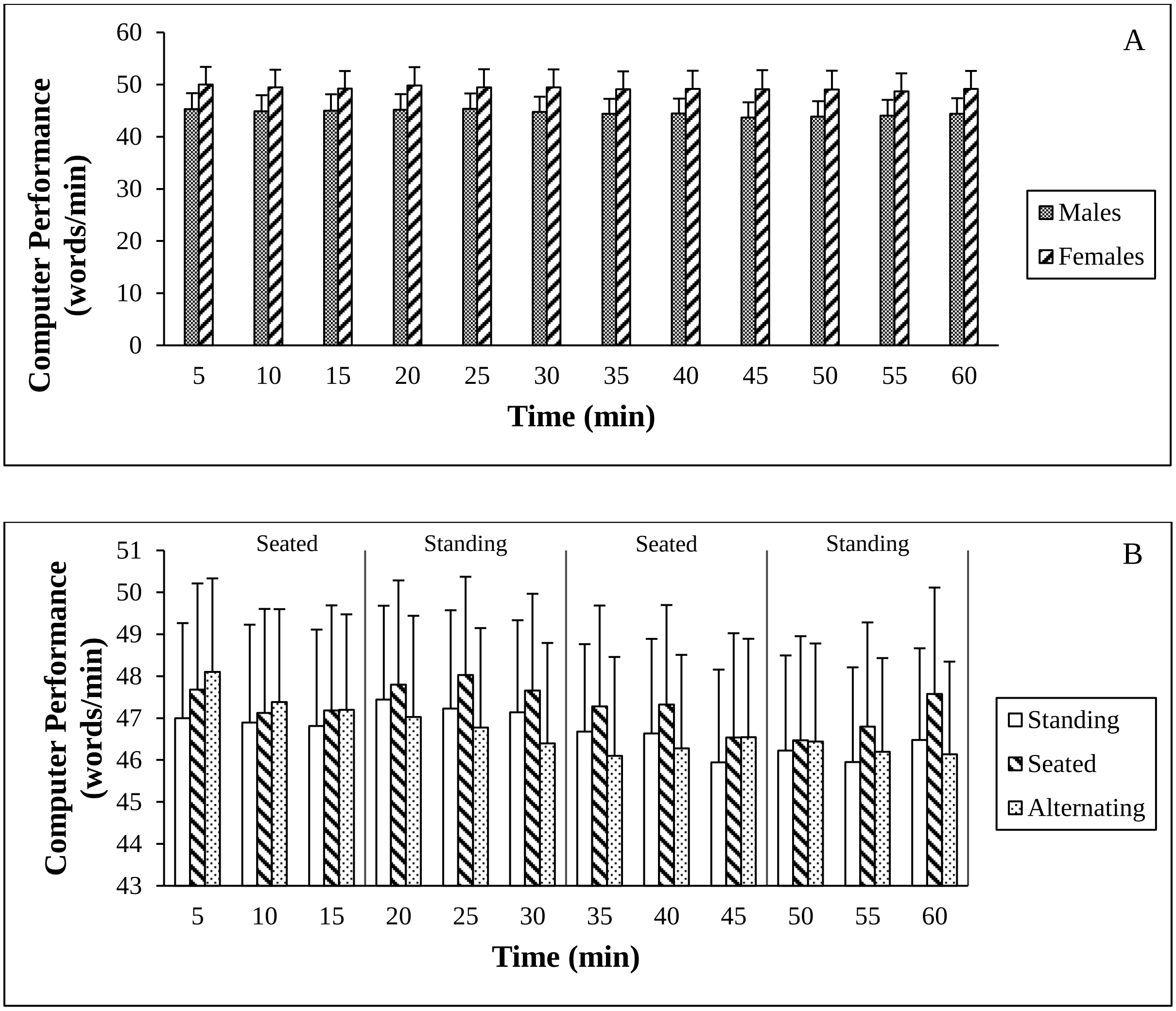


Figure 1. Typing performance measure (words per minute) as a function of condition, time, and sex. There was a significant interaction effect of Sex × Condition × Time for computer performance ($p < 0.001$).

3.2. Eye Strain and Discomfort

For eye strain, a significant interaction effect of Sex × Condition × Time ($X^2 = 1898.82$, $p < 0.001$) was found. Eye strain appeared to increase throughout time, with females demonstrating higher levels of eye strain than males, with a sex difference that varied over time (Fig. 2-A). Moreover, throughout time, eye strain varied between the conditions, with the alternating condition demonstrating similar levels to the standing condition up until the 25-minute mark when it began to elicit higher levels of eye strain (Fig. 2-B).

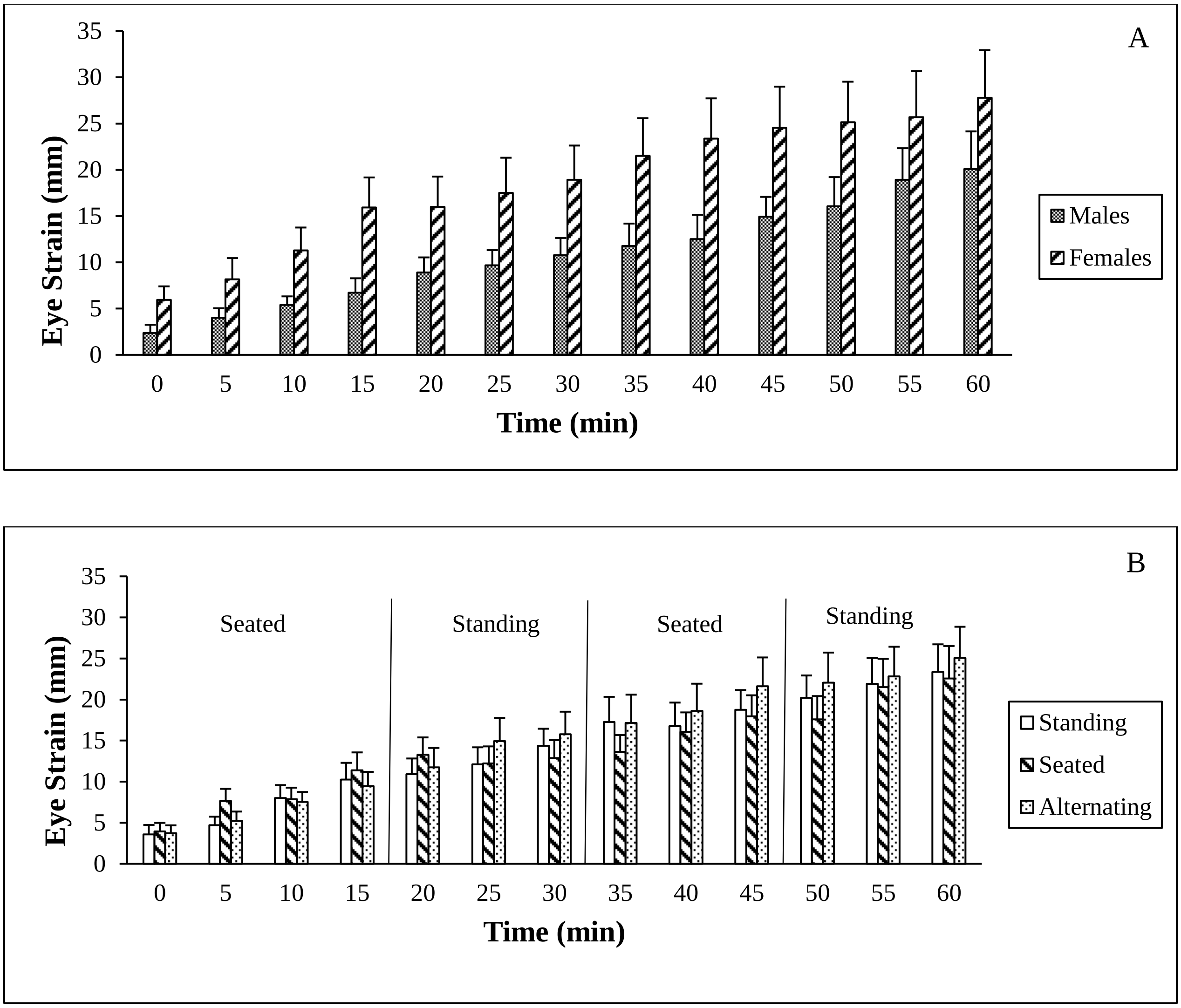
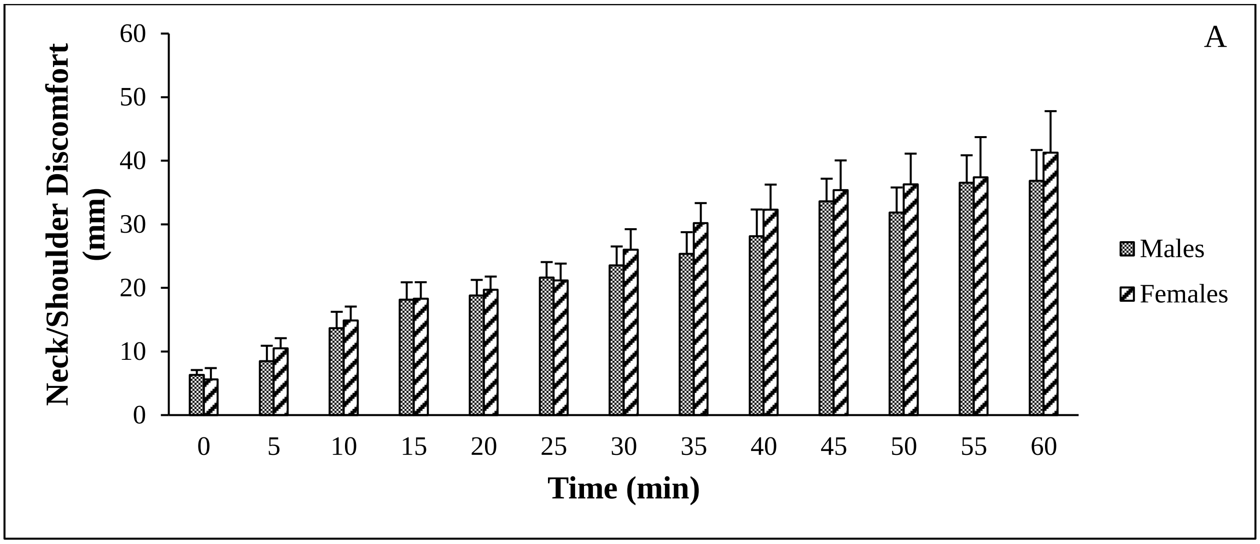


Figure 2. Eye strain (measured on a 0-100 mm visual analogue scale) reported during the computer task. A significant interaction effect of Sex × Condition × Time for eye strain ($p < 0.001$) is identified.

For neck/shoulder discomfort, a significant interaction effect of Sex × Condition × Time ($X^2 = 442.12$, $p < 0.001$) was determined. Throughout time, the standing condition appeared to demonstrate the lowest levels of neck/shoulder discomfort, with the alternating condition having similar levels to the seated condition during the seated phase and similar levels to the standing condition during the standing phase. Moreover, the differences between conditions seemed to diminish with time, with no post-hoc significant differences in discomfort between conditions towards the end of the task (Fig. 3-B). Generally, females also demonstrated higher levels of discomfort, this sex difference varied over time (Fig. 3-A).



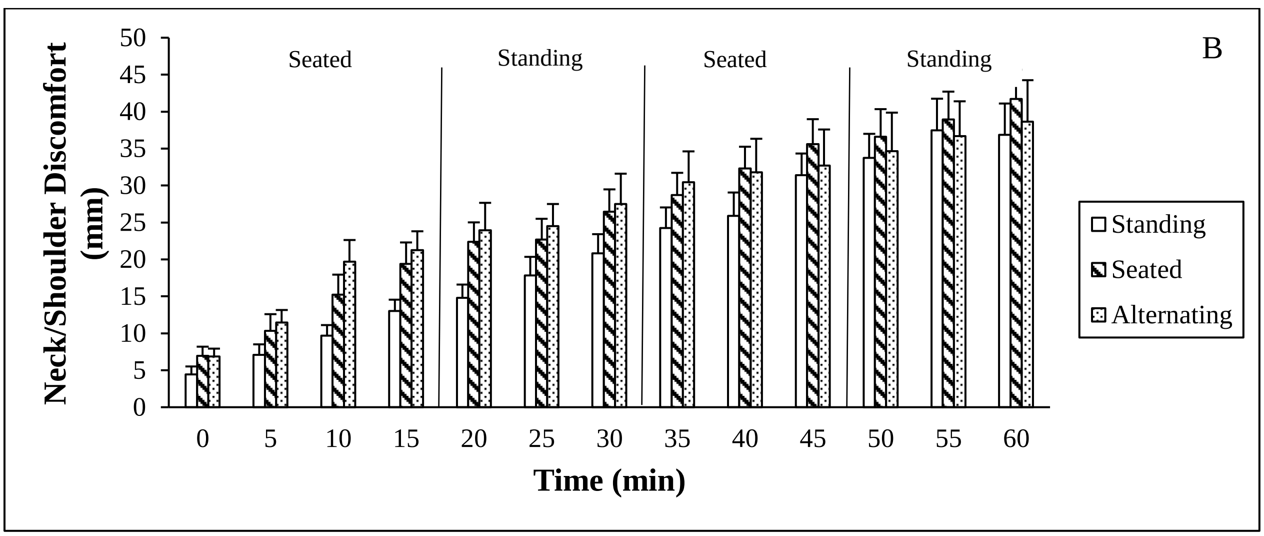


Figure 3. Neck/shoulder discomfort (measured on a 0-100 mm visual analogue scale) reported during the computer task. A significant interaction effect of Sex × Condition × Time for neck/shoulder discomfort ($p < 0.001$) is identified.

For low back discomfort, a significant interaction effect of Sex × Condition × Time ($X^2 = 6.41 \times 10^{10}$, $p < 0.001$) was found. Generally, females experienced higher levels of low back discomfort than males throughout time, with a sex difference varying at different time points (Fig. 4-A). Moreover, although discomfort was higher in females in all 3 conditions, the sex difference was greatest in the standing condition. In addition, the seated condition demonstrated the highest levels of discomfort throughout time, with the standing and alternating condition demonstrating similar lower ratings of discomfort (Fig. 4-B).

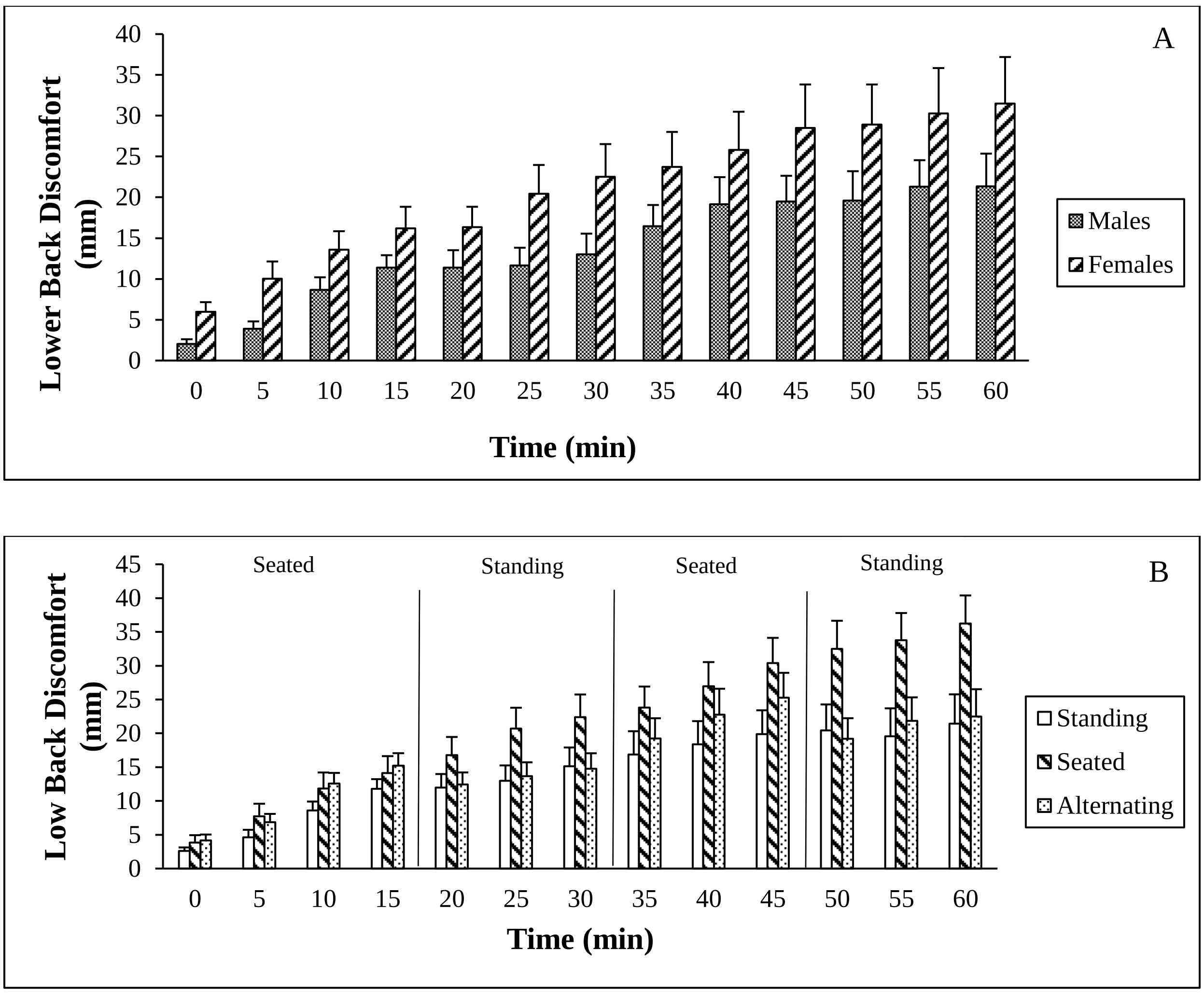


Figure 4. Low back discomfort (measured on a 0-100 mm visual analogue scale) was reported during the computer task. A significant interaction effect of Sex × Condition × Time for low back discomfort ($p < 0.001$) is identified.

3.3. Muscle Activation Amplitude (RMS)

Table 2 Test of model effects (main and interaction), Wald Chi-Square and p-values for muscle activation amplitude of all the tested muscles using generalized estimated equations. A p-value of < 0.05 indicates a significant effect.

Muscle	Test of Model Effects	Wald Chi-Square	p-value
Upper Trapezius			
	Sex × Condition × Time	737.94	**< 0.001**
	Sex × Condition	1.23	= 0.54
	Sex × Time	37.70	**< 0.001**
	Condition × Time	972.20	**< 0.001**
	Sex	0.70	= 0.413
	Condition	8.84	**= 0.012**
	Time	8.59	= 0.66
Middle Trapezius			
	Sex × Condition × Time	3138.18	**< 0.001**
	Sex × Condition	10.38	**= 0.006**
	Sex × Time	167.81	**< 0.001**
	Condition × Time	48865.62	**< 0.001**
	Sex	0.65	= 0.42
	Condition	46.06	**< 0.001**
	Time	526.62	**< 0.001**
Anterior Deltoid			
	Sex × Condition × Time	25585.94	**< 0.001**
	Sex × Condition	7.38	**= 0.025**
	Sex × Time	22.80	**= 0.019**
	Condition × Time	3733.35	**< 0.001**
	Sex	0.44	= 0.51
	Condition	0.51	= 0.51
	Time	65.35	**< 0.001**
Right Cervical Erector Spinae			
	Sex × Condition × Time	6955.93	**< 0.001**
	Sex × Condition	6.00	**= 0.05**
	Sex × Time	50.21	**< 0.001**
	Condition × Time	34734.04	**< 0.001**
	Sex	0.87	= 0.35
	Condition	6.09	**= 0.048**
	Time	126.51	**< 0.001**
Left Cervical Erector Spinae			
	Sex × Condition × Time	1583.17	**< 0.001**
	Sex × Condition	2.32	= 0.31
	Sex × Time	75.00	**< 0.001**
	Condition × Time	25426.74	**< 0.001**
	Sex	0.15	= 0.70

Condition	2.62	= 0.27
Time	146.68	**< 0.001**

Significant and non-significant p-values are presented in Table 2 for all the muscles tested. A significant interaction effect of Sex × Condition × Time was determined for all five muscles on activation amplitude: upper trapezius ($X^2 = 737.94$, $p < 0.001$), middle trapezius ($X^2 = 3138.18$, $p < 0.001$), anterior deltoid ($X^2 = 25585.94$, $p < 0.001$), right cervical erector spinae ($X^2 = 6955.93$, $p < 0.001$), and left cervical erector spinae ($X^2 = 1583.17$, $p < 0.001$). Post-hoc analyses revealed significant comparisons for the upper trapezius when comparing the seated vs. standing conditions. Similarly, the middle trapezius revealed significant differences when comparing the seated vs. standing conditions and the standing vs. alternating conditions. Further, there were significant comparisons over Time for the right cervical erector spinae. In terms of sex differences, all muscles generally showed similar trends. Over time females appeared to demonstrate higher levels of muscle activation amplitude, except for the left cervical erector spinae where males demonstrated higher levels (Fig. 5-A). Moreover, all muscles seemed to demonstrate that the standing condition elicited the lowest levels of muscle activation amplitude over time compared to the seated condition. However, the alternating condition appeared to increase and decrease over time depending on whether the participant was seated or standing, the participant would vary muscle activation amplitude consistently every 15-minutes (Fig. 5-B). The anterior deltoid and left cervical erector spinae muscles demonstrated higher activation amplitudes during the seated portion of the alternating condition when compared to the seated and standing conditions.

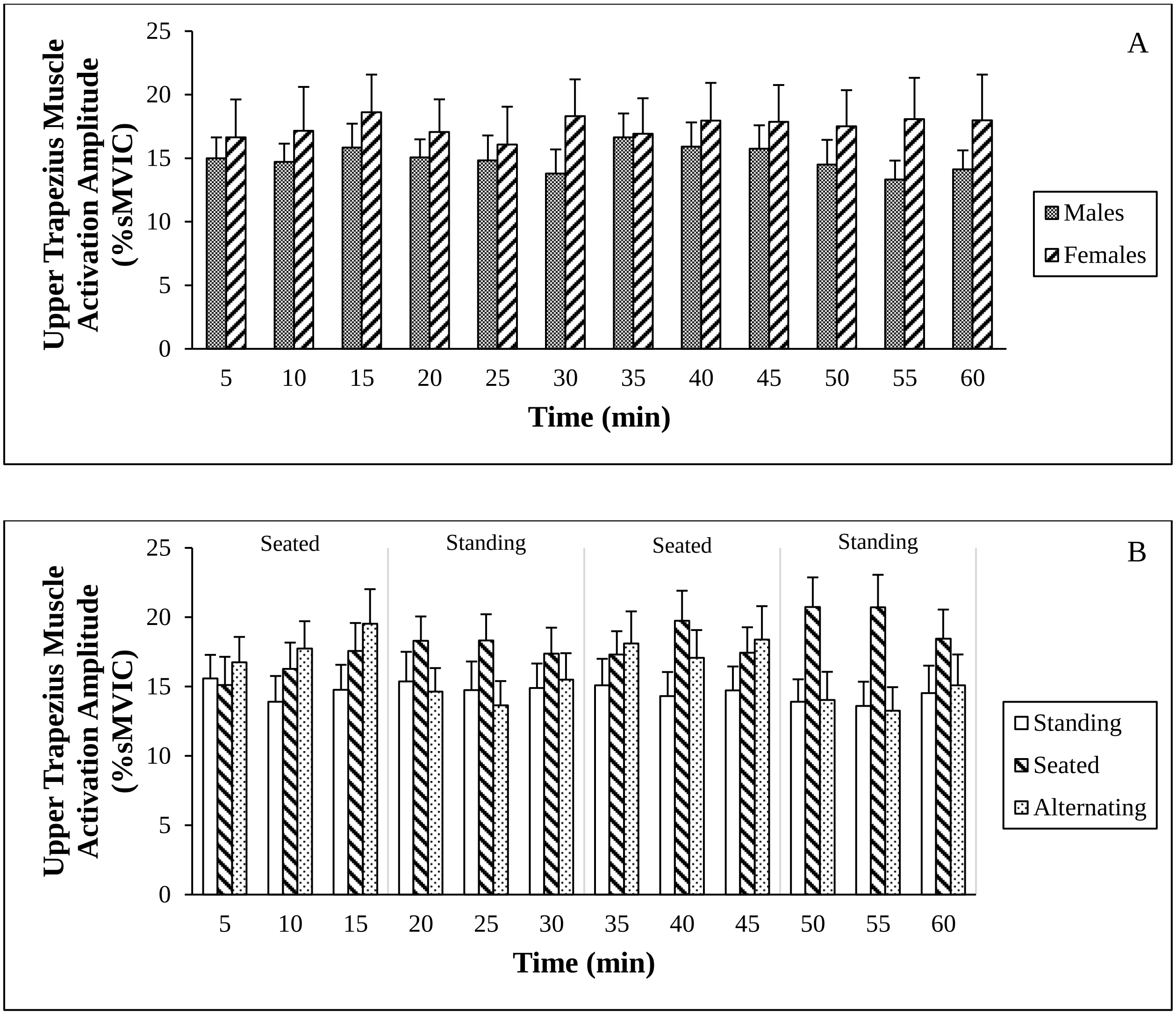


Figure 5. Muscle activation amplitude of the upper trapezius (group average values, error bars indicate SEs) recorded throughout the typing task. A significant interaction effect of Sex × Condition × Time for upper trapezius activation amplitude ($p < 0.001$) was found.

3.4. Muscle Activation Variability (CoV)

Table 3 Test of model effects (main and interaction), Wald Chi-Square and p-values for muscle activation variability of all the tested muscles using generalized estimated equations. A p-value of < 0.05 indicates a significant effect.

Muscle	Test of Model Effects	Wald Chi-Square	p-value
Upper Trapezius			
	Sex × Condition × Time	1638.02	**< 0.001**
	Sex × Condition	2.65	= 0.27
	Sex × Time	48.18	**< 0.001**

	Condition × Time	1605.91	**< 0.001**
	Sex	0.64	= 0.42
	Condition	0.13	= 0.94
	Time	120.98	**< 0.001**
Middle Trapezius			
	Sex × Condition × Time	15392.62	**< 0.001**
	Sex × Condition	1.61	= 0.45
	Sex × Time	8.59	= 0.66
	Condition × Time	1.46×10^{11}	**< 0.001**
	Sex	0.39	= 0.53
	Condition	1.6	= 0.50
	Time	73.84	**< 0.001**
Anterior Deltoid			
	Sex × Condition × Time	474843.85	**< 0.001**
	Sex × Condition	0.08	= 0.961
	Sex × Time	18.38	= 0.073
	Condition × Time	3801.77	**< 0.001**
	Sex	4.32	**= 0.038**
	Condition	11.48	**= 0.003**
	Time	29.42	**= 0.002**
Right Cervical Erector Spinae			
	Sex × Condition × Time	2828.14	**< 0.001**
	Sex × Condition	0.74	= 0.691
	Sex × Time	95.27	**< 0.001**
	Condition × Time	692.16	**< 0.001**
	Sex	3.32	= 0.068
	Condition	25.51	**< 0.001**
	Time	60.55	**< 0.001**
Left Cervical Erector Spinae			
	Sex × Condition × Time	1456.16	**< 0.001**
	Sex × Condition	6.18	**= 0.045**
	Sex × Time	45.38	**< 0.001**
	Condition × Time	1107.25	**< 0.001**
	Sex	9.85	**= 0.002**
	Condition	5.24	= 0.73
	Time	82.95	**< 0.001**

Significant and non-significant p-values are presented in Table 3 for all the muscles tested. A significant interaction effect of Sex × Condition × Time was found for all five muscles on activation variability: upper trapezius (X^2 = 1638.02, p < 0.001), middle trapezius (X^2 = 15392.62, p < 0.001), anterior deltoid (X^2 = 474843.85, p < 0.001), right cervical erector spinae (X^2 =

2828.14, $p < 0.001$), and left cervical erector spinae ($X^2 = 1456.16$, $p < 0.001$). Post-hoc analyses revealed significant comparisons in the anterior deltoid and right cervical erector spinae when comparing the seated vs. standing conditions. Generally, females demonstrated higher activation variability for all muscles, which appeared to increase throughout time (Fig. 6-A). Moreover, there appeared to be similar muscle activation variability for the first 30 minutes of the task. However, in the final 30 minutes, standing generally elicited the highest levels of muscle activation variability, followed by the alternating, and then seated conditions (Fig. 6-B).

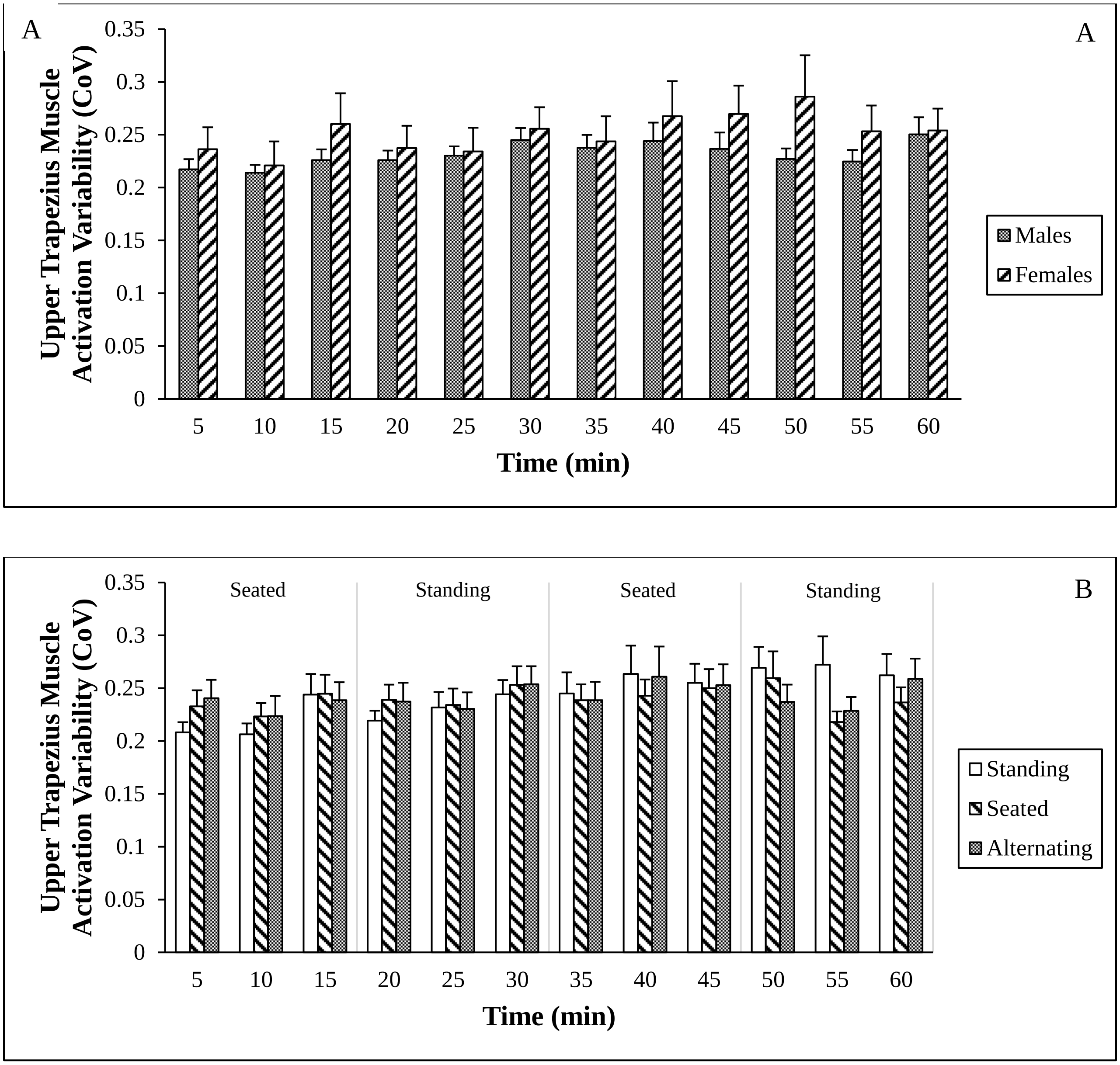


Figure 6. Muscle activation variability of the upper trapezius (group average values, error bars indicate SEs) recorded throughout the typing task. A significant interaction effect of Sex × Condition × Time for upper trapezius activation amplitude ($p < 0.001$) was found.

4. Discussion

The current study examined the sex-specific effects of alternating between sitting and standing during computer work on computer performance, eye strain, musculoskeletal discomfort, and EMG outcomes. Results show that the alternating condition was not beneficial, compared to the other postures, in terms of computer performance or eye strain. However, significant interaction effects indicate a quicker levelling off of neck/shoulder discomfort with time in the alternating posture, especially in males. Conversely, Sex × Condition interaction results suggest a more beneficial effect of the alternating posture on low back discomfort in females. Moreover, the several interaction effects on EMG RMS generally showed less of an increase in time in the standing condition, and as expected, more modulation of the EMG RMS in the alternating condition. Finally, the three-way interactions on CoV showed more EMG variability in the standing condition compared to the alternating and seated conditions, especially in the last 30 minutes, and especially, in females.

4.1. Computer performance

For the computer performance measure (words/min), alternating between sitting and standing seemed to only be beneficial for the first few minutes of the experimental task until performance plateaued, with the best performance observed mainly in the seated condition afterwards. These results are somewhat different from those of Karakolis et al. (2016) who found no statistical difference in total keystrokes between three 60-minute computer tasks (seated, standing, and alternating between sitting and standing at a 15:5min ratio). These differences in results could be attributed to the fact that Karakolis et al. (2016) utilized a different sit-stand ratio, with quicker changes than in our protocol and seated time three times longer than the standing time and did not allow a 20-minute recovery period between conditions, as recommended by Le & Marras (2016). However, there is some similarity in the results of our two studies, in that neither study shows a benefit of the alternating posture on performance. Karakolis et al. (2016) argue that this could be due to a trade-off between impacts on discomfort and performance. Our results are consistent with this interpretation, in that as seen below, the different impacts of the alternating condition on low back and neck/shoulder discomfort that are also sex-specific may cancel out, for only a marginal impact on performance. Moreover, the results of the current study are also different from those of Fedorowich & Côté (2018), who found a significant Time × Condition interaction effect for words typed per minute between the sitting and standing conditions and observed a significant increase with time in computer performance, but during the standing condition. The difference in results from Fedorowich & Côté (2018) could be due to several factors. For instance, Fedorowich & Côté (2018) assessed sitting and standing on different days as opposed to the current study which assessed all three conditions on the same day. Fedorowich & Côté (2018) also reported that computer performance benefits during standing occurred in the latter half of their 90-minute task, while the current study's task was only 60-minutes in duration; therefore, observation of any benefits past the 60-minute mark was not possible. In addition, Haynes & Williams (2008) observed that increases in upper extremity discomfort were linked to a reduction in typing speed, which is in line with our findings. Computer performance decreased over time starting at approximately the 30-minute mark during the alternating condition, which could be attributed to the increase in reported eye strain and musculoskeletal discomfort. Overall, it appears that alternating between sitting and standing could be beneficial in improving computer performance up until participants experience some upper-extremity discomfort, which in the current study seemed to occur halfway through the task.

4.2. Eye Strain and Discomfort

The current study observed that over time, females experienced higher levels of eye strain compared to males. This finding is in line with Shantakumari et al. (2014) who found that females experienced tired eyes and burning eye sensations to a greater extent during computer work than males. Rempel et al. (2007) observed associations between the development with time of visual discomfort and forward head posture during seated computer work. The current study also observed a higher level of upper trapezius muscle activation amplitude during seated computer work compared to standing. Therefore, the link between the visual and musculoskeletal systems could play a role in why females experience elevated levels of eye strain during seated computer work compared to males throughout the entire task and regardless of condition. Moreover, according to Haefeli & Elfering (2006) pain scores below 20% of maximal value may not be valid in indicating any significant sensation of discomfort. As a result, even though eye strain increased with time in both males and females, it is uncertain whether males experienced significant levels eye strain during the protocol. However, our results support that females did experience eye strain, at least starting at the 30min mark.

The standing condition produced the lowest levels of neck/shoulder discomfort, with the alternating condition demonstrating similar levels to the seated condition over time. These findings are similar to Fedorowich & Côté (2018) who also observed that standing during computer work demonstrated lower levels of neck/shoulder discomfort compared to sitting over time. This lower amount of neck/shoulder discomfort while standing could be associated with an increase in postural variability and a more neutral neck posture (Babski-Reeves & Calhoun, 2016; Ghemasty et al., 2016). Moreover, Barbieri et al. (2019) observed that alternating between sitting and standing increased neck postural variability which could potentially be another mechanism contributing to the reduction in neck/shoulder discomfort. Neck postural variability will be validated in a follow-up manuscript where kinematic data is reported.

The current study also demonstrated some contradictory results to Karakolis et al. (2016) results on whole-body discomfort, and to Park & Srinivasan (2021)'s results on low-back discomfort, with both finding that the sit-stand condition elicited the lowest levels of discomfort. This was also demonstrated in our study in the low back, but only in females. Combined with the higher increase in low back discomfort with time in females, this suggests that females could potentially benefit the most from the alternating condition. However, of the three postures tested in our study, the one that produced the least low back discomfort in males was the standing posture. This contrasts with Karakolis et al. (2016), who observed that males experienced higher levels of discomfort during standing, but with discomfort measures averaged across the entire body and not specific to the low back. These differences in results could also be impacted by other methodological differences, such as the current study's decision to include a 20-minute recovery period between conditions, the current study's use of a typing only software as seen in Fedorowich & Côté (2018), as opposed to typing and mousing or the difference in the computers used (laptop in our study vs. desktop in Karakolis et al. (2016)).

Overall, the literature suggests that prolonged seated computer work elicits the highest level of low back discomfort compared to either prolonged standing or alternating between sitting and standing (Karakolis et al., 2016; Park & Srinivasan, 2021), which was also confirmed by our findings. As a result, the general theme that prolonged seated computer work should be avoided remains true. Novel findings from the current study demonstrate that regardless of condition, females are always at a greater risk of developing low back discomfort, with our results suggesting that they have the most potential to benefit from the alternating condition as it regards low back symptoms. Conversely, males potentially benefit the most from the alternating posture in terms of the perspective of neck/shoulder discomfort. Together, these contrasting findings suggest a need to consider sex-specificity in results when looking to implement the alternating posture in the workplace, especially in workers at risk of developing, or who are recovering from, injuries to the low back, or the neck/shoulder.

4.3. Muscle Activation Amplitude (RMS) and Variability (CoV)

For all neck and shoulder muscles investigated, their activation amplitude during the alternating condition generally varied over time depending on whether the participant was sitting or standing. The lowest levels of muscle activation amplitude were generally seen during standing compared to sitting. Moreover, females appeared to demonstrate higher muscle activation amplitude in all muscles, except for the left cervical erector spinae. These findings are similar to Babski-Reeves & Calhoun (2016) who found that seated computer work resulted in higher levels of upper trapezius muscle activity compared to standing. Similarly, Fedorowich & Côté (2018) observed generally higher levels of lower trapezius muscle activity during a seated computer work task compared to standing. According to Lin et al. (2017), individuals adopt a less neutral shoulder posture when sitting, which results in greater shoulder muscle activity. Barbieri et al. (2019) also observed higher levels of neck postural variability when alternating between sitting and standing compared to a seated condition. Previous studies have also found that females work at muscle activation intensities closer to their maximum. This higher intensity, sustained over prolonged periods of work, could explain why they are more susceptible to upper-body injuries (Nordander et al., 2008; Wahlstrom et al., 2000). Similarly, our study showed greater muscle activation variability in females during standing for all reported muscles compared to the alternating condition and then the seated condition, especially in the final 30-minutes. Standing or alternating between sitting and standing could allow the individual to adopt a more variable and non-static posture during computer work, which could increase muscle activation variability compared to sedentary sitting. Increased muscle activation variability over time, especially in females, could support an injury prevention mechanism associated with the standing and alternating conditions. Moreover, females generally demonstrated higher muscle activation amplitude and variability during standing compared to sitting. These sex-specific responses to computer work could be associated with differences in fibre-type composition since females have a lower proportion of fatigue-resistant type II fibres in the upper body (Kupa et al., 1995). The greater muscle activation variability seen in females throughout the entire task could be a strategy to mitigate the need to develop and sustain higher muscle activation amplitude and the fact that females work at intensities closer to their maximum. Therefore, it could be beneficial for individuals, especially females, to adopt postures other than sitting when performing computer-based tasks to reduce the risk of fatiguing and developing MSDs.

4.4. Limitations

The results of the current study should be interpreted by taking into consideration that participants were conveniently sampled from a young and healthy population. Although many laboratory-based studies recruit from similar samples (Fedorowich & Côté, 2018; Karakolis et al., 2016; Yoon et al., 2021), future studies testing an older diverse population should be conducted. Moreover, similarly to Karakolis et al. (2016), all three experimental conditions were performed on the same day. However, residual fatigue from condition to condition was minimized in this study by allowing participants a 20-minute recovery period (Le & Marras, 2016). In addition, the 15s transition delay unique to the alternating condition could have created a bias in the results of this one condition. The current study also did not assess kinematic data, which will be reported in a follow-up manuscript. Finally, no lower body outcomes were assessed (muscle activity and/or discomfort). Future studies should consider testing both the upper and lower limbs during standing, seated and alternating conditions since standing has been associated with high muscle activity levels and blood pooling in the thigh and leg muscles which are associated with MSD development (Gao et al., 2017).

5. Conclusion

Findings from the current study suggest sex-specific responses to alternating between sitting and standing during a 60-minute computer work task. As shown by the computer performance and EMG variability results, it might take a 30-minute period of adjustment to observe the benefits of the alternating posture. These specific benefits appear to depend on sex, with females gaining more in terms of low back discomfort and muscle activation variability, and males gaining more in terms of neck/shoulder discomfort and muscle activation amplitude. As a result, females should take extra care at minimizing prolonged levels of seated computer work to reduce exposure to risk factors linked to developing MSDs such as eye strain, low back discomfort and muscle activation amplitude. The alternating condition should be recommended based on the computer worker's signs and symptoms; importantly, the observed sex differences reinforce the notion that the same recommendations should not necessarily be made for all males and all females. The extent to which our findings can be used to understand workplace injury mechanisms should be considered with caution given the differences between our experimental and the real-life conditions. Future studies should look to test the upper and lower body simultaneously in a diverse population to ensure that the benefits of alternating between sitting and standing during computer work are not restricted to the upper body.

CONCLUSION

Although several studies have assessed discomfort and health outcomes during standing and seated computer postures, no studies to our knowledge have identified the sex-specific impacts of alternating between sitting and standing on performance, eye strain, discomfort, and EMG outcomes during a computer task. Results of this thesis showed that the alternating condition, compared to the other conditions, was not beneficial regarding computer performance or eye strain. However, males did show a quicker levelling off of neck/shoulder discomfort in time during the alternating condition. Moreover, during the alternating condition, females generally showed a more beneficial effect on low back discomfort. Several interaction effects on EMG RMS in time were also observed, with the greatest modulation occurring during the alternating condition and less of an increase during the standing condition. Finally, in the final 30-minutes of the task, CoV showed the greatest responses during the standing condition compared to the other two conditions, especially in females. Therefore, it could take 30 minutes to adjust and observe the benefits of the alternating posture. Our findings suggest that recommendations in terms of alternating between sitting and standing should be made based on an individual's computer work symptoms and in a sex-specific manner. In addition, to avoid risk factors associated with upper-body MSDs such as eye strain, low back discomfort and muscle activation amplitude in females over time, prolonged periods of seated computer work should be avoided. However, these findings should be interpreted within the scope of several limitations: 1) participants were sampled from a young and healthy population, 2) all three experimental tasks were performed on the same day with a 20-minute recovery period between each task, 3) the 15s transition delay during the alternating condition, 4) kinematic data was not assessed and 5) outcomes were only assessed in the upper body. As a result, future studies should consider analyzing data from both the upper and lower body in a diverse population to further assess the benefits of alternating between sitting and standing during computer work. Considering these delimitations may prevent and/or reduce the potential for the development of MSDs in the workplace for both male and female computer users.

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APPENDICES

Appendix A

Version Date: 10 – 08 – 2021 REB File #: 21-07-018

Do you want to experience what research in Kinesiology and Biomechanics is all about? Are you interested in contributing to science of computer work ergonomics?

You have the opportunity to take part in a study that could help prevent musculoskeletal injuries in university students and adults who use computers often.

WE NEED YOU!

Criteria:

- You use a computer for ≥ 6 hours/day or ≥ 40 hours/week and are able to type for 90 minutes in English
- You should be between 18 and 29 years of age and in general good health, with no known musculoskeletal or neurological conditions of the upper or lower body in the past year
- You have not consumed alcohol or engaged in resistance training 24 hours leading up to the visit
- You have not been diagnosed with chronic headaches over the past 3 months
- You do not own or regularly use a standing desk

Objectives:

- Evaluate the effects of alternating computer postures in male and female young adults who use computers regularly.

Procedures:

- Several instruments (muscle activity sensors, motion capture sensors, blood flow sensors, and visual analogue scales) are used to non-invasively measure muscle activity, posture, blood flow and discomfort during a computer task.
- Pictures will be taken during the experiment and will be used by researchers only if you provide your consent.

Duration:

- You must be able to attend three experimental sessions of approximately 2.5 hours in duration each

Location:

- Currie Gym, McGill University, 475 Pine avenue West, Montreal, QC.

For more information, please contact: Samuel Lamanuzzi (samuel.lamanuzzi@mail.mcgill.ca)
Supervisor: Dr. Julie Côté (julie.cote2@mcgill.ca)

Appendix B

Version Date: 17 – 08 - 2021 REB File #: 21-07-018

Participant Informed Consent form

Researcher

Samuel Lamanuzzi, M.Sc. Candidate, Department of Kinesiology and Physical Education, McGill University, (514) 398-4455 ext. 0583 or 0783

Supervisor

Julie Côté, Ph.D., Associate Professor, Department of Kinesiology and Physical Education, McGill University, (514) 398-4184 ext. 0539, (450) 688-9550, ext. 4813

Title of project

The Sex-Specific Effects of Alternating Computer Work Postures in Young Adults

Funding

- Natural Science and Engineering Research Council (NSERC) of Canada, student fellowship
- MITACS Accelerate Fellowship (with operating budget)

Preamble/Introduction

You are invited to participate in a study on the sex-specific effects of alternating computer work postures on the physical, physiological, and biomechanical outcomes during computer work in young adults. Before agreeing to participate in this project, please take the time to consider the following information.

This consent form explains the aim of this study, the procedures, advantages, risks and drawbacks, as well as the persons to contact, if necessary.

We invite you to ask any questions that you deem useful to the researchers and other members of the staff assigned to the study. You can ask them to explain anything that is not clear to you.

Project description, objectives, and planned dissemination

The objectives of this research are to uncover the sex-specific effects of alternating computer work postures. 28 young adults will be recruited and will perform a computer task at a desk, in our laboratory. Participants will be included if they: 1. are between the ages of 18 and 29 years old 2. have no musculoskeletal or neurological pathologies to the upper or lower body and cleared by the PAR-Q 3. are frequent computer users (≥ 6 hours/day or ≥ 40 hours/week) who do not use a standing desk 4. willingly provide informed written consent to participate in the study. Participants will be excluded if they: 1. consume alcohol or engage in resistance training ≤ 24 hr prior to the laboratory visit 2. consume caffeine 12 hours prior to the laboratory visit 3. are unable to type seated or standing at an ergonomically standardized desk for 60 minutes continuously 4. are unable to read and type in English 5. suffer from chronic headaches diagnosed by a doctor or requiring medical attention in the last 3 months.

The long-term objective of this project is to better understand the effects of sit-stand computer workstations on the underlying physiological mechanisms, which will ultimately serve to improve evidence-based ergonomic interventions in the workplace for both male and female computer users, such as the optimal sit to stand ratio. Results from this project will be disseminated in the forms of a M.Sc. Thesis, conference presentations, and a peer-reviewed manuscript.

Nature and duration of your participation

This research project aims at understanding how alternative computer work postures influence physiological mechanisms, while working in front of a computer screen. The study takes place at McGill University, Currie Gymnasium in Montreal. You are asked to participate in three experimental sessions that will last from two to two and a half hours. The session involves four phases: Phase 1: preparation (30 minutes), Phase 2: pre-fatigue tests (20 minutes), Phase 3: typing procedure (90 minutes), Phase 4: recovery (10 minutes).

During Phase 1, locations of surface electrodes, blood flow sensors and kinematic markers will be marked on your skin using a make-up pen. Sensors will be applied on the skin over several muscles of your upper body to measure their activity and your head-neck posture. None of these procedures are invasive.

During Phase 2, You will be asked to fill out questionnaires and complete baseline reference efforts, and a baseline strength measure.

During Phase 3, You will be asked to complete a typing protocol 90 minutes. You will be asked your perceived level of neck-shoulder discomfort and eyestrain every 10 minutes, on a visual scale.

During Phase 4, You will relax and recover from the typing procedure. You will be offered a few neck and shoulder stretches to relieve any tension or discomfort.

Voluntary participation

Participation in this research study is fully voluntary. If you choose to withdraw during or right after the study, all information obtained up until that point will be destroyed unless you specify otherwise at the time of withdrawal. Once data have been combined for publication, it may not be possible to withdraw your data in its entirety. We can only remove your dataset from further analysis and from use in future publications. Identifiable data will be kept for 5 years, once data is anonymized, it can no longer be withdrawn.

Potential benefits associated with your participation

There are no benefits from participating in this study. However, you will contribute to the advancement of knowledge on human movement and musculoskeletal injury.

Potential risks associated with your participation

None of the techniques used are invasive. Your participation in this project does not put you at any medical risk.

Personal inconvenience

Some small regions (8, 3x3 cm each) of the skin over your neck and shoulder muscles must be shaven before placing the electrodes. This might be an inconvenience for you. Although it is hypo-allergenic, the adhesive tape used to fix the electrodes on your skin may occasionally produce some slight skin irritation. Should this happen, a hypo-allergic lotion will be applied on your skin to relieve skin irritation. Also, you may experience some fatigue towards the end of the typing protocol, which may cause some tenderness, stiffness and/or pain in your upper body.

Monetary compensation

As a token of appreciation for your time and participation in this study, you will be compensated with $20 in cash. In the event of withdrawal from the study, this will not affect compensation and you will still receive the full amount for which you are entitled.

Confidentiality

All your data will be securely stored in password protected files on a password protected computer. Your identifiable information will be kept separate in a locked filing cabinet in the Supervisor's office or lab. Only the people involved in the project will have access to this information. If the results of this research project are presented or published, nothing will allow your identification. After a seven-year period, identifiable data will be destroyed. The de-identifiable data will be kept for a total of seven years following publication, according to University Policy.

The researchers may wish to photograph you during the study with a digital camera. All photographs are de-identified and may be used in presentations and publications. Consenting to camera photography is optional for this study. Images will not contain facial features, or other potentially identifiable features such as tattoos, scars, piercings.

Yes: ___ *No:* _____ You consent to camera photography. Photography will be taken of your upper body (above your waist). Images will not contain any of your facial features.

Questions concerning the study

The researchers present during the testing should answer your questions in a satisfactory manner. You can ask questions at any time.

Contact persons

If you need to ask questions about the project, signal an adverse effect and/or an incident, you can contact at any time Julie Côté, Ph.D., or Samuel Lamanuzzi, at the numbers indicated on the 1st page.

If you have any questions or concerns regarding your rights or welfare as a participant in this research study, you can contact the McGill Ethics Officer at 514-398-6831 or georgia.kalavritinos@mcgill.ca.

Please sign below if you have read the above information and consent to participate in this study. Agreeing to participate in this study does not waive any of your rights or release the researchers from their responsibilities. A copy of this consent form will be given to you and the researcher will keep a copy.

Participant's Name: (please print) ____

Participant's Signature: ______________________Date: ______________

New Version Date : 2021-08-17

Appendix C

Version Date: 17 – 08 – 2021 REB File #: 21-07-018

Participant Debrief

Please find below a detailed summary of the study's objectives and hypotheses. The participant will now have the opportunity to ask any questions they may have about the study that the Researcher is permitted to answer. In addition, a lay article summarizing the results of the study, which will be written in collaboration with the MITACS industry partner, will be sent to the participant once all the study's data is processed and analyzed.

Objective	Hypothesis
To assess the effects of condition (sitting, standing, or alternating), time, and sex on neck flexion.	With time, people will have a more forward head posture and flexed neck, this will be worse in females, but it should be lessened in standing and in sitting-standing, compared to sitting.
To assess the effects of condition, time, and sex on neck/shoulder (upper trapezius) muscle activity.	With time, people who sit during computer work will have the highest levels of upper trapezius muscle activity, then people who stand, then people who alternate postures, with females experiencing the highest levels of muscle activity.
To assess the effects of condition, time, and sex on levels of low back discomfort.	With time, levels of low back discomfort will be similar in seated and standing with people experiencing decreased levels of discomfort when they alternate postures and females experiencing greater levels compared to males.
To assess the effects of condition, time, and sex on levels of eye strain.	With time, levels of eye strain will be similar in seated and standing with people experiencing decreased levels of eye strain when they alternate postures and females experiencing greater levels compared to males.
To assess the effects of condition, time, and sex on computer work performance.	Time, condition, and sex will have no effect on computer work performance.