Sex-specific effects of anti-fatigue lenses on neck-shoulder muscular patterns during computer work

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ABSTRACT

The aim of this Master's thesis was to study the effects of Anti-Fatigue Lenses (AFL) during a 90-minute computer task, compared to a pair of placebo lenses, on neck/shoulder motor patterns in healthy young adult males and females. Upper body electromyography (EMG) was recorded every 9 minutes during a standardized computer task during two sessions assigned in random order: while wearing AFL, or while wearing placebo lenses. EMG root mean square (RMS), variability (CoV), and normalized mutual information (NMI) were computed. These metrics represent the average and variability of muscle activation amplitude, and the connectivity between two muscles. Results revealed significant increases in Upper Trapezius - Anterior Deltoid connectivity with time in the AFL condition compared to the placebo eyewear. Sex-specific differences were observed in the effects of Eyewear condition on connectivity changes with time for the bilateral Cervical Erector Spinae pair. Additionally, Lower Trapezius muscle activity increased significantly over time in males, however Anterior Deltoid muscle activity was overall greater in females than in males. Lastly, Middle Trapezius amplitude, Left Sternocleidomastoid and Cervical Erector Spinae activation variability, and Middle-Lower Trapezius connectivity, all increased over time. These results reflect potentially healthier muscular responses to computer work with AFL, specifically for females, and provide evidence to consider when considering ergonomic eyewear for occupational use.

RÉSUMÉ

Cette thèse de maîtrise avait pour but d'étudier l'effet des lentilles anti-fatigue pendant un travail informatique de 90 minutes, comparé à une paire de lentilles placebo, sur les schémas moteurs cou/épaule chez de jeunes adultes hommes et femmes en bonne santé. Une électromyographie du haut du corps (EMG) a été enregistrée toutes les 9 minutes au cours d'une tâche informatique standardisée pendant deux sessions assignées dans un ordre aléatoire : pendant le port de lentilles anti-fatigue ou de lentilles placebo. L'EMG a calculé la moyenne quadratique (RMS), la variabilité (CoV) et l'information mutuelle normalisée (NMI). Ces mesures représentent la moyenne et la variabilité de l'amplitude d'activation musculaire, et la connectivité entre deux muscles. Les résultats ont révélé une augmentation significative de la connectivité entre le trapèze supérieur et le deltoïde antérieur avec le temps dans le cas des lentilles anti-fatigue, par rapport aux lunettes placebo. Des différences spécifiques par rapport au sexe furent observées en termes de changements de connectivité avec le temps pour la paire des muscles érecteurs bilatéral cervical du rachis. De plus, l'activité du trapèze inférieur augmentait de manière significative avec le temps chez les hommes, toutefois l'activité musculaire du deltoïde antérieur était supérieure chez les femmes. Enfin, une augmentation de l'amplitude du trapèze moyen, de la variabilité d'activation du sternocléidomastoïdien gauche et de l'érecteur cervical du rachis, ainsi que de la connectivité du trapèze moyen-inférieur furent observées au fil du temps. Ces résultats reflètent un effet potentiel bénéfique des lentilles anti-fatigue sur les réponses musculaires lors de tâches informatiques, et ce particulièrement chez les femmes. Ceci suggère ainsi un avantage potentiel à l'utilisation de lentilles anti-fatigue comme outil ergonomique dans un cadre professionnel.

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INTRODUCTION

The impact of musculoskeletal disease has been widely discussed in the scientific literature to date, with a large disability burden associated with musculoskeletal disorders (MSDs). In the 2017 Global Burden of Disease study, it was found that musculoskeletal conditions were the second highest contributor to global disability, and that around 30% of people live with a painful musculoskeletal condition (James et al. 2017). Further, MSDs remain one of the leading causes of pain and disability in workers in developed countries including Canada (Stock et al., 2011; Bhattacharya, 2014; Safe Work Australia, 2016). Office-related disabilities also have large social and economic implications due to loss of productivity and ability to work, as well as significant costs for treatment. Between 1998 and 2011, prescription medications for musculoskeletal injuries nearly doubled from 201 million prescriptions to 397 million (MEPS, 2011). A recent Canadian study examined the economic burden of chronic pain, estimating the annual cost to manage chronic pain to be $7.2 billion (Hogan et al., 2016). This heavy psychological and economic burden drives research to find preventative solutions, and risk management for MSDs in the workplace.

In Québec, 69% of workers were using computers for the majority of their work, in 2007/2008 (Vézina et al., 2011). Approximately 21% of workers have reported using a computer for work, for 31 hours or more per week (Vézina et al., 2011). Adults exposed to a computer screen for prolonged periods of time have demonstrated an elevated risk of MSDs (Ellahi et al., 2011), believed to be the result of static postures and sustained postural muscle activity (Szeto et al. 2014; Sauter et al., 1991). Specifically, upper limb muscle activity and postural alignment is an area worth evaluating, as the adverse effect of screens in the work setting has been brought forward by various authors (Ellahi et al., 2011; Sauter et al. 1991). In fact, neck/shoulder musculoskeletal disorders (NSMSDs) are the most frequently reported MSDs in office environments (Szeto et al., 2005a).

Although the prevalence of MSDs increases with age, a large population of younger people are affected at the peak of their career (World Health Organization, 2017). Even so, young adults in the university setting spend extensive bouts of time in front of screens. Approximately 50% the student population reported the onset of neck pain and other MDS complaints in association to computer use (Bubric & Hedge, 2016; Kanchanomai et al., 2011). In addition to MSD-related complaints among students, 90% of students aged 18-25 years old reported complaints of computer vision syndrome (CVS), a disorder of the visual system that causes a person to experience ocular complaints as a result of computer use, such as eyestrain and blurry vision (Blehm et al., 2005). Further, women are seen to be at a greater risk of work-related MSDs (Chiu et al., 2002; Madeleine et al., 2013), as well as visual complaints and discomfort (Shantakumari et al., 2014).

Previous research has attempted to link vision and musculoskeletal health, in the context of near vision tasks like computer use (Richter et al. 2010; Zetterberg et al., 2013; Richter et al., 2015; Zetterberg et al., 2015). More specifically, these studies have linked the effects of adverse visual conditions to increases in trapezius muscle activity, measured through electromyography (EMG). EMG has been previously used in research to identify activation patterns that could be indicative of good or bad adaptations to specific interventions (Kumar, 1996). Although some studies have attempted to investigate the mechanistic link between vision and musculoskeletal health (Richter et al., 2010; Domkin et al., 2018; Zetterberg et al., 2013; Zetterberg et al., 2015), it is still a question requiring further investigation.

In recent years, a new eyewear technology has surfaced on the market, in the form of ergonomic computer lenses, designed to accommodate the needs of computer users such as students and office workers, who are continuously using their near viewing systems in front of a computer screen. These lenses contain an increase in optical power which relaxes the ocular muscles at the near viewing distance of the computer. Further testing is required to better understand the impact of ergonomic eyewear on musculoskeletal health indicators. Additionally, their effects on musculoskeletal parameters, taking into account biological sex, is of interest as there is limited to no existing research in this area. The **objective** of this thesis was therefore to quantitatively assess the effect of ergonomic computer eyewear on indicators related to risk of developing neck/shoulder MSD. We hypothesized that the AFL would demonstrate beneficial strategies aiding in the prevention of computer work-related neck/shoulder MSDs. We anticipate that our results will help to gain a better understanding of the onset of symptoms associated with prolonged computer work and will provide appropriate evidence in favour or against the use of these lenses.

LITERATURE REVIEW

1. Impact of Computer Work on MSD and CVS

1.1 Students

Young adults in the university setting spend extensive amounts of time in front of screens. The prevalence of neck pain was assessed in first-year undergraduate students, 46% of which reported the onset of neck pain from baseline to 1-year follow-up, attributable to computer use (Kanchanomai et al., 2011). Another study found that 53.8% of the university students surveyed reported MSD complaints in association with computer use (Bubric & Hedge, 2016). Chang et al., (2007) evaluated daily computer use and how it correlated to MSD symptoms in undergraduate students. They found neck pain to be the highest reported symptom, with 48% of students reporting moderate to high symptoms, followed by the lower back (44%), upper back (40%), and shoulder (37%). In addition, daily duration of computer usage, when greater than 3 hours, was related to 50% higher odds of reporting MSD symptoms, suggesting a relationship between computer use and the risk of MSD development. In 2016, students reported a weekly median of 38.5 hours using their laptops (Hough & Nel, 2016), which equates to more than 7.5 hours per school day. These high rates of MSD-related complaints and significant durations of screen time help depict the relationship between screen use and MSDs among students.

In addition to MSD-related complaints among students, 90% of students aged 18-25 years old reported complaining of computer vision syndrome (CVS) symptoms (Reddy et al., 2013). These symptoms include eyestrain, dry eyes, blurred vision, slowness of focus change, and double vision (Blehm et al., 2005). Mowatt et al. (2018) investigated the effects of ergonomic practices and CVS complaints in university students. They found that severe eyestrain occurred in 63% of those who looked down at a device compared with 21% who kept the device at eye level. According to a study conducted by Koretz and Handelman (1988), at age 20, the youthful lens in the developing adult begins to thicken, leading to more difficulty performing eye-lens accommodation, a vital function of near vision. Further, these studies emphasize the importance of finding both visual and musculoskeletal ergonomic solutions within this screen-dependent age group of 18 to 35 years, as well as prevention strategies as they shift towards careers involving extensive screen time.

1.2 Sex Differences

Women are at a greater risk of suffering from chronic pain than males (Schopflocher et al., 2011). A study by Bubric and Hedge (2016) noted a greater proportion of women reporting NS MSD symptoms, with 43% of women reporting neck discomfort and 24% reporting shoulder discomfort, compared to 28.9% and 8.9%, respectively, in men. Further, women are at a greater risk of work-related MSDs (Côté, 2012). Some arguments highlighting physical (e.g. anthropometrical and strength) differences between males and females are used to explain sex differences in MSD mechanisms. Structurally speaking, females are shorter than males, with shorter limbs. Won et al. (2009) observed that, with the workstation adjusted based on current guidelines, differences in upper extremity force were noted between genders, with females applying significantly greater force. However, differences were greater when subjects were grouped by anthropometry instead of sex. This implies that the workstation design should be scaled to be proportional with the anthropometry and strength of the user, though gender is still to be taken into consideration.

In addition to a larger proportion of females reporting NSMSDs, complaints of eyestrain and visual discomfort have also been reported to a greater extent in women than in men, in a questionnaire that surveyed 1575 female and 1251 male students (Palm et al., 2007). In this questionnaire, 21% of women and 12% of men reported eyestrain. Millodot and Millodot (1989) noted that females have a shorter measured reading distance than men, which could be due to a shorter arm length, requiring a greater correction for near distances for women. As a result, without the appropriate correction, greater strain on the eyes may result in females than in males when reading. With existing evidence that visual complaints do differ between sexes, there is a clear need for ergonomic protection strategies for females working with a computer.

2. Relationship Between Vision and Neck-Shoulder Muscle Activity during Computer Work

An interaction between the visual system, specifically via eye-lens accommodation, and head-stabilizing muscles has been previously investigated (Mork et al., 2016; Richter et al. 2010; Zetterberg et al., 2013). The ciliary muscle is an intraocular muscle that regulates the focal point of the crystalline lens. This muscle adjusts to objects at different distances, contracts to allow for eye-lens accommodation, and allows the eye to focus at near distances. Mork et al. (2016) investigated the relationship between direct glare from behind the screen, previously associated with accommodation response alterations of the crystalline lens (Wolska et al., 1999), eyestrain, and neck-shoulder MSDs (NSMSDs) symptoms during computer work. They showed that direct glare caused increased eyestrain and ocular muscle contraction during a reading task from a computer screen when compared to a standard set up. Additionally, they noted that exposure to direct glare increased trapezius muscle activity over time, suggesting the possibility of an interaction between the visual system, specifically via eye-lens accommodation, and the role of some head-stabilizing muscles (Mork et al., 2016).

Previous research has investigated this interaction further, suggesting that eye-lens accommodation is connected to neck muscle function and stabilization through a centrally mediated motor command (Richter et al. 2010; Zetterberg et al., 2013; Zetterberg et al., 2015). Richter et al. (2010) manipulated optical lens blur with binocular lenses to induce different levels of oculomotor load during visually strenuous “near” viewing conditions, in healthy, symptom-free subjects and in subjects with a history of both eye disorder and neck disabilities. They simultaneously collected trapezius muscle activity via electromyography (EMG). The amplitude of the EMG signal was calculated by normalizing the root-mean-square (RMS) value of the middle 10 of 15-s reference, submaximal contractions. Subjects were expected to compensate for the blur by adjusting the diopter strength of their crystalline eye-lens, in other words the optic power of the lens. No differences were seen between healthy and symptomatic groups. However, they noted that increasing ciliary muscle tone by placing the optical minus lens in front of the eye leads to an increase in trapezius muscle activity over time; this trend was also seen in a similar study by Zetterberg et al., (2013). Domkin et al. (2018) also investigated the relationship between the activity of the ciliary muscles and the trapezius muscle at various viewing distances which would affect the ocular load. Participants with healthy or corrected vision were recruited to track a moving visual target with a computer mouse on a screen placed, while eye accommodation and bilateral trapezius muscle activity were continuously measured. Results showed that participants who had higher levels of ciliary-muscle contraction force, represented by eye-lens accommodation at the nearest viewing distance, also demonstrated higher levels of trapezius muscle activity than the further viewing distance, a difference of 6.6% of the resting voluntary electrical activity (RVE). The correlation between ciliary-muscle contraction force and dominant side trapezius muscle activity at the "near" distance has been attributed to a centrally generated motor command, in line with Richter et al.'s study (2010). Reflex optic paths originating not only from the ocular muscles but also from the neck and scapular muscles may explain this activation (Richter et al. 2007; Corneil et al. 2002). Richter et al. (2010) and Domkin et al. (2018) theorized that these adjustments of eye-lens accommodation activate stabilization processes linking the eye–neck/scapular area effectors to one another in a common synergy, to hold the visual target in the part of the retina of highest visual acuity. When prompted by strenuous "near" visual work, central efferent command driving the oculomotor system may cross over to motor tracts and drive the visual-musculoskeletal effectors in a synergistic fashion (Richter et al., 2010, Richter 2014, Domkin et al., 2018). Through these synergies, visually demanding work like computer work may increase the likelihood of developing computer work-related MSDs.

3. Neuromuscular Aspects of NSMSDs

The relationship between repetitive tasks like computer work, and musculoskeletal parameters indicative of an increased risk of NSMSDs is often explained by the Cinderella Hypothesis, first brought forward by Hagg (1991). This theory describes how type 1 muscle fibers are the first activated and the last ones deactivated, during a prolonged task. As they remain activated, by-product buildup prevents the further relaxation of the muscle, putting these fibers at a greater risk of overload and damage (Forde et al., 2002), resulting in discomfort and pain. The significant impact of near viewing tasks such as computer work on the elevated activity of trapezius muscle fibers, which have been shown to contain an important proportion of type 1, Cinderella fibers, has previously been highlighted (Zetterberg et al., 2013; Richter et al., 2015; Farias & Cote, 2017). In addition, a lower frequency of relaxation periods has been shown as a predictor of trapezius muscle pain in individuals performing repetitive work (Veiersted et al., 1993), further emphasizing the relationship between uninterrupted work of long duration and the risk of MSD in the trapezius muscle. The trapezius muscle is often a target for NSMSD research, as it plays an active role in maintaining the posture of the neck, the head and its visual platform, and the shoulders during rapid distal upper limb movements associated with computer use. Thus, trapezius muscle activity patterns are worth evaluating to better understand MSDs risk during prolonged computer use in occupational contexts (Farias et al., 2017; Fedorowich et al., 2015; Richter et al., 2010; Mork et al., 2016; Zetterberg et al., 2013).

Motor variability describes variations in muscle activity, movements and postures, that are thought to be controlled by the sensorimotor system (Srinivasan & Mathiassen, 2012). According to these researchers, muscle activity variability may act at the level of recruitment patterns of muscles within or outside the same synergy, different regions within the same muscle or among multiple motor units making up each muscle region. Greater spatio-temporal EMG amplitude variability has been associated with longer endurance times in both sustained and intermittent isometric contractions. As such, variability is interpreted as a strategy preventing MSD symptoms, while keeping the overall motor output constant (Farina et al., 2008; Mathiassen et al., 2008a). Samani et al. (2009b) evaluated the effects of active versus passive pauses during a 90-minute computer task on trapezius motor patterns. Submaximal contractions, in the form of active pauses, led to increases in variability of muscle activation, calculated by taking the standard deviation of the exposure variation analysis (EVA_{SD}). Low EVA(SD) values indicate a broad dispersion of EMG amplitudes and/or a broad range of durations in which EMG remained within the same amplitude class. Therefore, EVA_{SD} values decrease with increasing EMG variation. The active pauses allowed for modifications to the recruitment pattern, and temporarily relaxing of non-recruited fibers. Thus, muscle activity adaptations such as variability may have functional implications for NSMSD prevention among computer users. In a study by Fedorowich et al. (2015), musculoskeletal parameters collected during a walk-while-work condition were compared to those in a standard sitting condition during a 90-minute computer work task. The lower trapezius muscle displayed greater activation variability while walking compared to sitting, which is believed to play a role in shoulder stabilization for typing and a healthy adaptive mechanism to performing a prolonged typing task in a standing position. Variability was calculated by computing coefficients of variation (CoV) for each muscle in each block by dividing the standard deviation of the 30 RMS values by the average RMS value. Other studies previously showed that those expressing lower motor variability may show predispositions and/or may be at a greater risk of future pain or injury (Mathiassen et al. 2003, Madeleine et al. 2008a). However, in a cross-sectional study, a pain-free group demonstrated lower motor variability than the chronic pain group, indicating that the relationship between variability, pain, and MSD is complex (Madeleine et al. 2008b). In relation to computer work, understanding intrinsic motor variability is of great importance and requires further attention.

In order to sustain the effects associated with the Cinderella Hypothesis, the human body has developed various compensatory strategies. Functional reorganization of muscle activity can reflect an ability of the motor system to recruit synergistic muscles to cope with fatigue and pain (Samani et al., 2009a). Relationships between the activation of different muscles has previously been computed using analyses of co-activation. More recently, normalized mutual information (NMI) has been developed as a computational technique that accounts for linear as well as non-linear dependencies between two time series, with values between 0, indicating no connectivity, and 1, indicating complete functional connectivity of the muscle pair (Johansen et al., 2012). An association between pain and functional connectivity has been highlighted previously where subjects have demonstrated higher connectivity with increased ratings of pain (Madeleine et al. 2011). In Samani et al. (2009a)'s study on acute effects of experimental muscle pain on EMG activity of the trapezius muscle with active and passive pauses during a 90-minute computer task, authors noted increases in amplitude in transverse and ascending parts of trapezius under the effects of acute experimental pain, suggesting a functional reorganization in between-muscle strategies. Functional reorganization reflects the ability of the motor system to recruit synergistic muscles, such as the lower trapezius assisting in rotation of the scapula – an action mainly carried out by the upper trapezius (Inman et al., 1996). Additionally, experimental studies have provided evidence that increased co-activation allows for greater protection of the body during a sustained task, by stabilization through muscle pairings. Choi and Vanderby (2000) considered the effects of co-activation on cervical spinal loading in healthy male participants. Their results suggested that antagonistic co-contraction provides stability to the cervical spine around its neutral posture by stiffening the joints. Due to the prolonged nature of computer work, head stabilization may require these antagonistic co-contractions to counter the effects of muscle fatigue. In a study by Fedorowich et al. (2015), increased lumbar erector spinae, anterior deltoid and lower trapezius muscle activation during a 90-minute computer task demonstrated multi-muscle adaptations across those different muscles of the neck, shoulder and back muscles. Further, the increased connectivity that authors also observed may indicate that over a prolonged time and during sitting, the agonist muscle searches for a muscle to partner with to withstand the prolonged task load. This further highlights the role of connectivity as a motor protection mechanism during a sustained task involving postural control. Functional connectivity is, therefore, another important metric that may provide greater insight into factors contributing to the risk of MSD-related symptoms, specifically during computer work.

3.1 Neuromuscular Sex Differences

Though they have not been thoroughly explored, sex differences in motor recruitment patterns may explain the elevated risk of MSDs in females (Côté, 2012). Falla et al. (2008) observed gender differences in muscle activity distribution and reorganization in different parts of the trapezius muscle between pain-induced and control subjects during 60-second-sustained 90 degree shoulder abduction. During the sustained contractions in control subjects, the EMG RMS representing muscle activity amplitude, progressively increased to a greater degree in the cranial than in the caudal region for both men and women. However, this was maintained in men but not in women during the painful condition, demonstrating that in women, muscle pain may differently affect motor adaptations of the trapezius muscle activity. Fedorowich et al., (2013) reported that female subjects with initially high upper trapezius muscle activity variability demonstrated longer endurance times during a repetitive pointing task than females with initially lower variability. This effect of initial variability on endurance time was not observed in males, suggesting gender specificity in the relationship between variability and risk factors towards the development of MSD symptoms. In the context of computer work, research on sex differences in muscle activity variability is scarce. During Farias & Côté's (2017) 90-minute computer task, males demonstrated greater development of trapezius activity variability over time when compared to females. This can be interpreted as a compensatory, injury-preventative strategy to overcome the increased connectivity observed and fatigue experienced within the neck-shoulder muscles, as the UT and AD activity increased over the course of the task. Further, the increased variability in males may be a beneficial muscle strategy in response to fatigue over prolonged computer work. Although the task in Farias and Côté's (2017) study was of low-intensity, fatigue could occur with longer computer use durations, amplifying the muscular patterns observed. These patterns were not observed in females, further demonstrating that females may display some muscular patterns that may be less protective.

Currently, focus on sex differences in functional connectivity is limited, specifically in the context of office work. Johansen et al. (2012) measured activity patterns among subdivisions of the trapezius representing functional connectivity during a repetitive, submaximal box-folding task. Higher functional connectivity between subdivisions of the trapezius was found in women, compared to men which may suggest that females musculature requires greater support from other muscles during a given task, with the risk of fatigue spreading to other muscles. Strategies of low NMI observed in men could represent more efficient strategies of using the neck/shoulder musculature in minimizing the risk that fatigue would pose towards injury risk. Thus, further exploration is required to better understand of the effects of sex and its interaction with other conditions, on functional connectivity.

Lastly, an increase in normalized EMG amplitude can be used as an indication of local muscle fatigue, suggesting that the fatigued muscles are compensating a decrease in force output (Szucs & Molnar (2017). Following Szucs and Molnar's (2017) 60-minute computer task, males demonstrated a significantly greater increase in upper trapezius activation compared to females, suggesting that female muscles are slower to fatigue. This sex difference may be due to differences in morphological and histological traits of the trapezius between males and females (Lindman et al., 1990, Lindman et al., 1991). Although the recent literature shows that sex differences may exist in both structural and functional motor control aspects, further investigation is required to explain how these differences would impact behavior and performance during office work-related tasks.

4. Anti-Fatigue Lenses

In recent years, new ergonomic eyewear technology has surfaced on the market. These lenses are designed to accommodate the needs of office workers who are continuously using their near and intermediate viewing systems when working with a computer (Horgen, 2002). Lens designs that cover viewing distances from near and out to approximately 2 meters work well to improve visual discomfort when using a computer, compared to lens designs trying to cover a greater range of clear vision (Horgen et al., 2004). The magnitude of strength of a lens is measured in diopters (D), or dioptric power, and measures the correction, or focusing power, of the lens (Klein & Mandell, 1995). A simplified version of existing ergonomic eyewear is Anti-Fatigue Lenses (AFL). These lenses act by magnifying the image in the lens to enhance near and intermediate viewing, by adding between +0.5 to +1 Diopter (D) of power in the lower segment of the lenses, with the goal of reducing eyestrain when working at a computer (Blehm et al., 2005). In addition to adding optic power to the lenses, power is specifically added to the lower segment of the lenses, a segment of the lenses associated with near-work tasks. The subject will elevate their chin to look through the lower segment while working at the computer. This allows the subject to view their screen at a more ergonomic angle (Blehm et al., 2005) These lenses are clinically dispensed to younger patients who are considered to be pre-presbyopes and require small magnification to ease their accommodation systems as they work at their laptops for long durations. Enhancing near vision offers the potential to optimize neck-shoulder muscle activity during computer work through mechanistic relationships between vision and neck/shoulder neuromuscular control. This synergistic pathway links the eye–neck/scapular area effectors to one another, to hold the visual target in the part of the retina of highest visual acuity. Further, studying the impact of the use of these lenses could offer greater understanding of the mechanisms coupling the visual system and the musculoskeletal to one another, thereby better explaining MSD risk in the occupational setting.

To our knowledge, no current study exists evaluating the effects of ergonomic eyewear specifically within populations likely to suffer from CVS and are pre-presbyopic, such as university students and female workers. Evaluating experimental effects of AFL in this specific population is required to lead to greater generalizability of their effects and would also bring forward potential preventative mechanisms in populations working with computers. No studies have extensively explored sex differences in terms of neck/shoulder muscular parameters with the use of AFL. As well, precise experimental techniques such as those using EMG to capture muscle activity may be more sensitive to small but important effects of visual interventions on neck/shoulder motor patterns. Lastly, no known studies to date have used measures of motor variability and NMI to describe the sex-specific effects of ergonomic lens wear on the neck-shoulder muscles.

RESEARCH ARTICLE

Sex-specific effects of anti-fatigue lenses on neck-shoulder muscular patterns during computer work

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Abstract

The effects of Anti-Fatigue Lens (AFL) and sex during a 90-minute computer task on motor patterns were investigated in healthy university students. Neck-Shoulder Musculoskeletal Disorders (NSMSDs) and visual complaints are closely linked, and are prevalent in university students working with computers, as well as females. AFL have emerged as ergonomic eyewear meant to reduce visual complaints, with the potential to act on the visuo-musculoskeletal pathway, playing a role in NSMSD risk prevention. It was hypothesized that the AFL would lead to decreased muscle activity, variability, and functional connectivity, compared to placebo lenses. Further, these effects would be more pronounced in females. Twenty-three healthy student participants (mean age: 23 years; 12 males) completed a 90-minute computer task while wearing AFL or placebo lenses. Electromyography (EMG) from eight upper body muscles was recorded throughout the task to obtain the following dependent variables of interest: EMG amplitude (RMS), variability (CoV), and normalized mutual information (NMI). A three-way repeated measures ANOVA was used to analyze the effects of eyewear condition, time and sex on the dependent variables. Significant increases with time were seen in the AFL condition in Upper Trapezius and Anterior Deltoid (AD) NMI ($p = 0.049$) compared to the placebo eyewear. Sex-specific differences were observed during AFL use on NMI changes with time for the Right-Left Cervical Erector Spinae pair ($p = 0.032$). Additionally, Lower Trapezius RMS ($p = 0.003$) increased significantly over time in males, however AD RMS ($p = 0.002$) was greater in females. Results showing increases in functional connectivity in the AFL condition and in females suggest that AFL may allow healthier muscular responses during computer work, specifically for females. This provides evidence to consider when implementing ergonomic eyewear for occupational use.

1. Background

Adults exposed to a computer screen for prolonged periods of time are at an elevated risk of MSDs attributed to sustained postural muscle activity (Ellahi et al., 2011; Szeto et al. 2014). In 2016, students reported spending a daily average of over 7.5 hours interacting with a computer (Hough & Nel, 2016), with 50% of the student population reporting musculoskeletal symptoms associated to prolonged computer use (Kanchanomai et al., 2011), especially in the neck-shoulder (NS) area (Chang et al., 2007). Additionally, a majority of students report complaints of computer vision syndrome (CVS), a disorder of the visual system that causes a person to experience ocular complaints, such as eyestrain and blurry vision, as a result of computer use (Blehm et al., 2005).

A higher prevalence of women typically report complaints of neck-shoulder discomfort than men (Bubric and Hedge, 2016) as well as visual discomfort (Palm et al. 2007; Shantakumari et al., 2014), in association to their use of computers. Anthropometrical and strength differences have been previously brought forward to explain sex differences in mechanisms of musculoskeletal disorders (MSD). Won et al. (2009) showed that females produced more relative keyboard typing force than males, suggesting an injury mechanism whereby females produce overall greater work, relative to their maximal capacity. As well, sex differences in visual system characteristics can explain the larger proportion of women reporting visual complaints. For instance, females have a shorter measured reading distance than males, requiring a greater near distance correction (Millodot & Millodot, 1989), placing greater visual strain in females than in males, without appropriate correction.

An interaction between the visual system, specifically via eye-lens accommodation, and head-stabilizing muscles has been previously investigated. Mork et al. (2016) investigated the relationship between direct glare emitted from behind a computer screen, associated with eye-lens accommodation responses (Wolska et al., 1999), and eyestrain complaints, as well as neck/shoulder MSD (NSMSDs). Results demonstrated that direct glare leads to increases in eyestrain, ocular muscle contraction and trapezius muscle activity over time. Richter et al. (2010) induced different levels of oculomotor load during visually strenuous “near” viewing conditions. Increasing ciliary muscle tone lead to an increase in trapezius muscle activity over time; a trend that was also observed in other studies (Zetterberg et al., 2013; Domkin et al., 2018). These investigations demonstrated the possibility of a synergy between muscles of the visual and skeletal systems, through a centrally-mediated motor command, activated to achieve gaze stabilization. These adjustments of eye-lens accommodation to activate stabilization processes would link the eye–neck-scapular area effectors to one another, to hold the visual target in the region of highest visual acuity of the retina (Richter et al., 2010; Domkin et al. 2018).

Various studies have highlighted the significant impact of near viewing tasks such as computer work on the elevation of trapezius muscle activity (Zetterberg et al., 2013; Farias & Cote, 2017), a muscle that is often a target for NSMSD research, as it plays an active role in postural tasks. Motor variability describes the variations in muscle activity, muscle patterns and postures, controlled by the sensorimotor system (Srinivasan & Mathiassen, 2012). Previous studies have shown that those expressing lower motor variability may be at a greater risk of pain or injury, and results to suggest that higher motor variability may be a form of MSD symptom prevention (Mathiassen et al. 2003**,** Madeleine et al. 2008a). Indeed, varying activation patterns may be an effective motor control strategy to reduce overloading vulnerable fibers by recruiting other fibers while keeping the overall force level constant (Farina et al., 2008), however this remains to be proven physiologically. Another muscular control strategy frequently studied is muscle co-activation. Experimental and modeling studies suggests that during a sustained task, increasing cervical coactivation may provide greater protection of the body (Choi and Vanderby, 2000). Authors investigated the effects of co-activation on cervical spinal loading in healthy male participants, and showed results suggesting that co-contractions stiffen the spinal joints, providing stability and protection to the neutral cervical spine. The normalized mutual information (NMI) of the time series-based electromyographical signals between two muscles represents their functional connectivity. Previous studies have demonstrated an association between muscle pain and between-muscle functional connectivity, with subjects showing higher connectivity with increased ratings of pain (Madeleine et al. 2011). The recruitment of other muscles may have an added cost – increased fatigue of neighbouring muscles. From a functional perspective, decreased NMI may be a strategy of avoiding propagating fatigue to neighboring muscles (Johansen et al., 2012), creating a paradox between the protection of joints and the development of muscle fatigue. Functional connectivity is therefore another important metric to use to gain greater insight into MSD-related symptoms.

Ergonomic eyewear is a recent commercial development targeting those loading their near and intermediate viewing systems due to extensive computer screen use (Horgen, 2002). In comparison to lens designs attempting to cover a greater range of clear vision, ergonomic eyewear covers viewing distances from near and to around 2 meters out, to reduce visual discomfort during computer use (Horgen et al., 2004). Anti-Fatigue Lenses (AFL), a form of ergonomic eyewear, act on magnifying the image in the lens to enhance near and intermediate viewing (Blehm et al., 2005), adding +0.5D to +1D of power to the lens. By enhancing near vision, these lenses may optimize neck/shoulder muscle activity during computer work, through the synergetic pathways previously described. However, their effects on muscle activity has never been studied. Additionally, no research has evaluated the effects of ergonomic eyewear between sexes during computer work.

The objective of the present study was to study the sex-specific effects of AFL on neck/shoulder muscle activity amplitude, muscle activity variability, and functional connectivity between muscle pairs during a 90-minute computer task in university students. We hypothesized that the AFL would be associated to decreases in muscle activity, variability, and functional connectivity, compared to placebo lenses, effects of which would be more pronounced in females.

2. Methods

2.1 Participants

A convenience sample of 23 healthy young adults (11 females, 12 males; mean age 23 years; mean height 173.5 cm; mean mass 73.5 kg) was recruited within all Montreal university communities. This sample size was similar to that of Farias and Côté (2017) and Fedorowich et al. (2015) studies who recruited 27 and 20 participants, respectively, yielding significant statistical power. A form was given to screen for our selection criteria. These included a requirement for average daily laptop use >6 hours and an age range of 18 to 35 years old. Volunteers with current, diagnosed, chronic musculoskeletal impairments or migraines were screened using a Par-Q Health Questionnaire (Warburton et al., 2011) and excluded from the study. Lastly, subjects were required to have overall healthy vision. Wearing glasses or contacts were part of the exclusion criteria, while previous eye surgery correction was deemed acceptable for inclusion. Data collection took place at McGill University, Montreal, Canada. All subjects completed informed, written consent forms, approved by the McGill Research Ethics Board Office.

2.2 Instrumentation

Participants were instrumented with surface electromyography (EMG) equipment (Trigno Avanti, Delsys Incorporated, MA, USA), using wireless surface electrodes placed on eight muscle sites (Figure 1). EMG signals were sampled at 2000 Hz. The SENIAM guideline was the exemplary model for our electrode placement (Hermens et al., 2000). Electrode locations were landmarked with washable eyeliner based on the SENIAM guidelines. The electrode placement remained consistent between both sessions due to the specific landmarking. Electrode placement consisted of the unilateral dominant (right or left) upper, middle and lower trapezius (UT, MT, LT) and anterior deltoid (AD), and bilateral placement on the right and left sternocleidomastoid (RSCM and LSCM) and right and left cervical erector spinae (RCES and LCES). A small portion of skin over the respective muscle, where the electrode would be placed, was shaven and sterilized with rubbing alcohol to minimize electrical impedance. Electrodes were fixed on the muscle bellies, with their orientation parallel to the underlying muscle fibers. Electrodes were taped down with medical tape to minimize their movement.

2.3 Initial Measures

The subject completed an Office Ergonomic Assessment questionnaire to provide information on their computer work habits and computer workstations. This questionnaire specifically asked about lighting, chair and desk conditions, monitor type and configuration, as well as noise conditions, based off of the Guideline of Office Ergonomics (Canadian Standards Association, 2000). Participant demographics (age, height, weight), room conditions (brightness level, weather) and participant state (hours of sleep, physical activity prior to protocol) were recorded.

The participant then completed a series of maximum voluntary isometric contractions (MVIC). An MVIC of the UT was obtained by having the participant abduct their dominant shoulder at 90 °, with their palms facing downward, pushing up against manual resistance applied by the researcher (Mathiassen et al. 1995). For the AD, the participant flexed their dominant arm at 90 ° against manual upper arm resistance applied by the researcher (Fischer, Belbeck, & Dickerson, 2010). For the MT, the participant performed scapular adduction with 45 ° arm flexion. An MIVC for the LT consisted of lying supine on an athletic therapy table and lifting the dominant arm at a 45 ° abduction angle above the horizontal in the sagittal plane (Ekstrom et al. 2003). To obtain MVIC values for the RSCM and LSCM, participants sat upright in a chair and performed anterolateral neck flexion against manual resistance applied on the temporal region of the head (Kendall, McCreary, & Provance, 1993). Finally, to obtain MIVCs for the RCES and LCES, subjects laid prone on a table with their head unsupported and performed neck extension against manual resistance applied on the posterior aspect of the head (Fedorowich et al., 2015). Two five-second trials were performed for each muscle with verbal encouragement to contract their muscles and push against the resistance as hard as possible, with one minute of rest between each trial.

Following the MVICs, kinematic markers were placed on the participants' head, chest and shoulder (Figure 1). Kinematic analyses of the head, and shoulder were not analyzed as part of this study. The participant was then seated at an adjustable desk and in a chair with lumbar support, but no arm rests. The laptop and chair were adjusted according to the individual's posture and standard ergonomic recommendations (Occupational Health Clinics for Ontario Workers, 2008; Workers' Compensation Board- Alberta, 2007) for both sessions (AFL and placebo), which were assigned in random order and spaced two to seven days apart. A 13" laptop (Dell, 2013) with a trackpad to operate mouse functions was used for the task, with consistent screen brightness.

Figure 1. Participant set up.

2.4 Computer Task

The experimental computer task consisted of highlighting spelling mistakes in a Microsoft Word document during a 90-minute period. This task duration represents a typical work bout uninterrupted by a meal or a break and has been used by various researchers as the standard computer testing time frame (Seghers & Spaepen, 2003; Farias & Cote, 2017; Strøm et al., 2009). The participant used their dominant arm for trackpad scrolling while performing the task and were instructed to keep their arms on the desk at all times. Participants were told their editing speed would be measured, calculated by lines/minute. Measurements were taken every 10 minutes throughout the task. EMG measurements were recorded in 30s bouts at the end of each 10-minute block. During recordings, the research team sat quietly behind the participant, and movement/noise in the laboratory was controlled to avoid distracting the participant. Subjects started both sessions at the same point in the text, and the text was different but remained the same level of difficulty between sessions.

2.5 Data Analysis

EMG recordings were full-wave rectified, band-pass filtered between 10 Hz and 450 Hz, and smoothed using a 2nd order Butterworth filter with a low-pass cut-off frequency of 6 Hz, creating a linear envelope. A reference heartbeat in one trial was identified, and then correlated to the other signals to eliminate heartbeats from all 8 muscle signals. The signals from the linear envelope were normalized to the mean amplitude of MVICs. RMS values were calculated over 30 1-s non- overlapping windows for each collection block and the average of the 30 RMS values was taken to represent the mean amplitude value for each muscle from each time trial. Variability was calculated by computing each muscle's coefficients of variation (CoV) of each time block by dividing the standard deviation of the 30 RMS values by the average RMS value. Functional connectivity represented by Normalized Mutual Information (NMI) between pairs of adjacent muscles was calculated using the EMG time series from each block. The following pairs were studied: UT-MT, UT-AD, AD-RCES, MT-LT, RSCM-LSCM, RSCM-RCES, RCES, LCES, and UT-MT. NMI is based on calculating the Entropy of the EMG time series, ranging from 0, demonstrating no muscle pair connectivity to 1, demonstrating complete muscle pair connectivity (Jeong et al., 2001). NMI was calculated over a 500-ms window for each trial, for all the possible pairs in this study. The median value was taken to represent the trial. Further details can be found in Johansen et al. (2012).

2.6 Statistical Analysis

A three-way repeated measures ANOVA was computed for within-subject conditions of Eyewear (AFL, Placebo) and Time (9 times, each 10 minutes) and between-subject conditions of Sex. This statistical test was used to analyze main and interaction effects on RMS and CoV for each muscle, and NMI for muscle pair combinations, as well as task speed. Patterns of RMS, CoV and NMI changes over Time in both types of Eyewear conditions between Sex were calculated with a three-way repeated measures ANOVA for Eyewear * Time * Sex, Eyewear * Time, Eyewear * Sex, and Time * Sex. Bonferroni corrections were run for any significant results, with an alpha set to 0.05. Effect size was calculated using partial eta squared ($\eta^2_{partial}$) which measures the proportion of the variation in our dependent variables (RMS, CoV, and NMI) associated with the independent variables (eyewear, time, and sex). $\eta^2_{partial}$ values of 0.01, 0.06, and 0.14 represent small, medium and large proportions, respectively (Watson, 2019).

3. Results

Task performance showed no significant differences between eyewear, but a significant main Time effect [$F(8,160)= 2.45$, $p = .016$], effect size ($\eta^2_{partial}$): 0.10) as well as a Sex x Time interaction [$F(8,160)= 2.50$, $p = .014$], effect size ($\eta^2_{partial}$): 0.11). The Sex x Time interaction revealed increases in speed in males ($Mean_{Time1} = 11.73$, $Mean_{Time9} = 12.30$, but none in females ($Mean_{Time1} = 11.39$, $Mean_{Time9} = 10.49$).

Analysis of EMG RMS revealed few significant effects. No significant main or interaction effects involving Eyewear on RMS were found in any of the neck/shoulder muscles. A significant Time x Sex interaction was found for LT RMS ($Mean_{females} = 1.34$, $Mean_{males} = 1.99$), with an increase seen over time in males but none in females [$F(8,168)= 3.04$, $p = .003$], effect size ($\eta^2_{partial}$): 0.13) (Figures 2-4). In addition, a significant main Sex effect was found for AD RMS ($Mean_{females} = 0.88$, $Mean_{males} = 0.33$), with greater RMS in females than in males ([$F(1,21) = 12.51$,

p = .002], effect size ($\eta^2_{partial}$): 0.37) (Figure 5). As well, a significant main Time effect was noted in MT RMS ([F(8, 168) = 3.01, p = .004], effect size ($\eta^2_{partial}$): 0.13). No other significant effects were found with respect to RMS (Table 1).

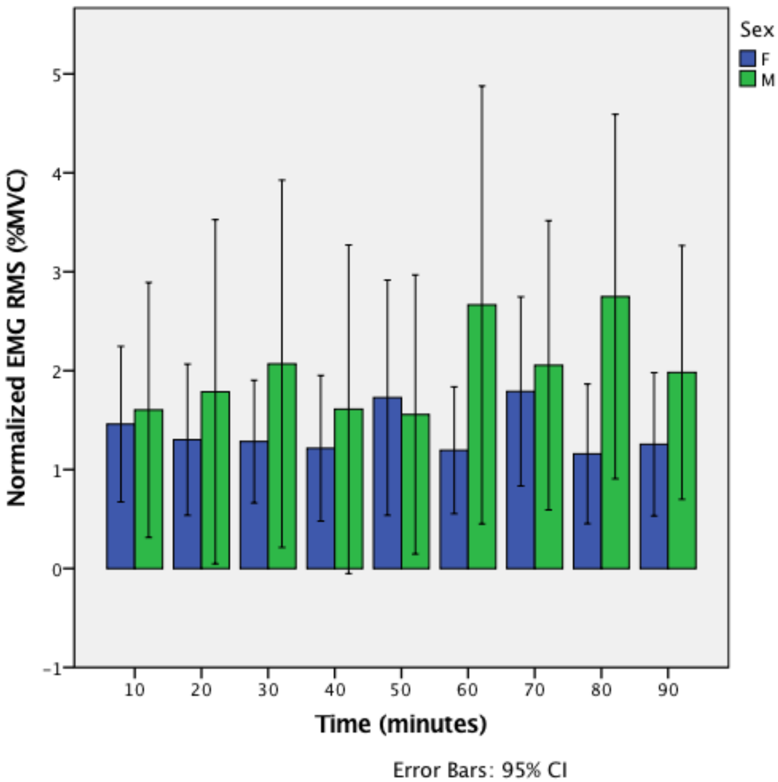

Figure 2. LT EMG RMS during the 90-minute computer task. A significant interaction was found for Time by Sex, with greater increases in LT RMS in males over time ($p < 0.05$).

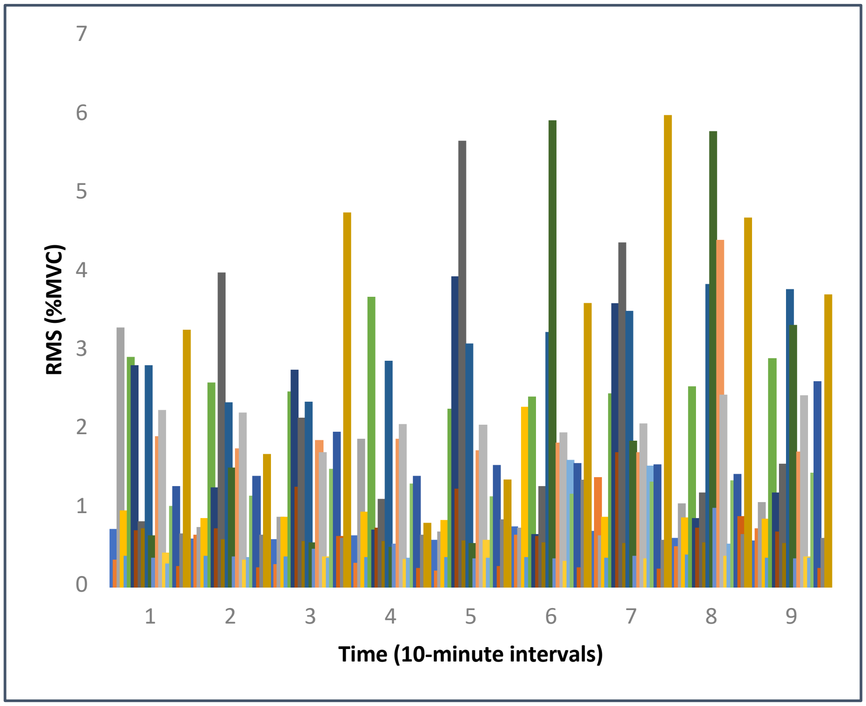

Figure 3. LT EMG RMS of all subjects during the 90-minute computer task, in the AFL condition.

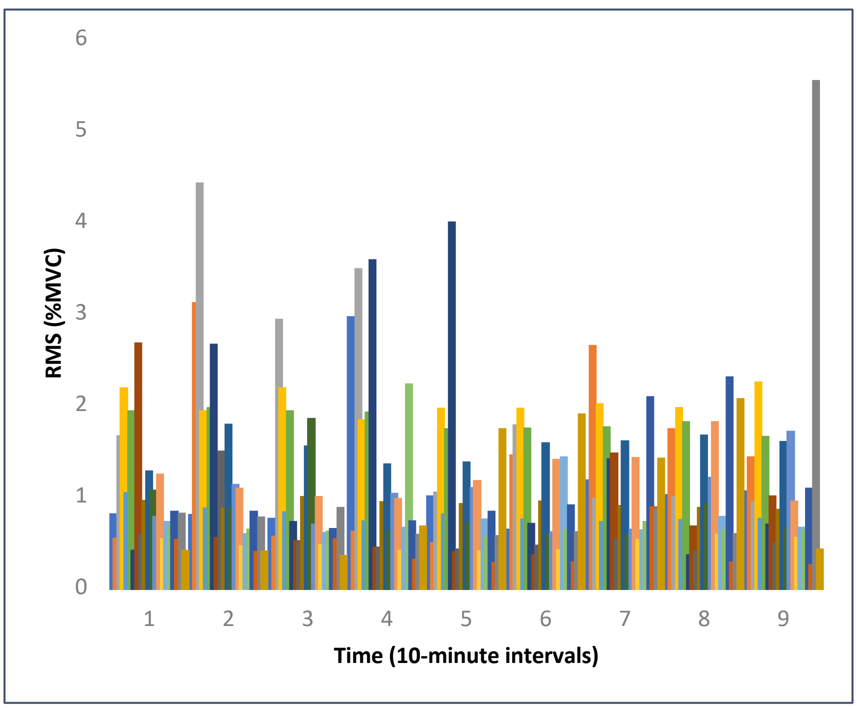

Figure 4. LT EMG RMS of all subjects during the 90-minute computer task, in the placebo condition.

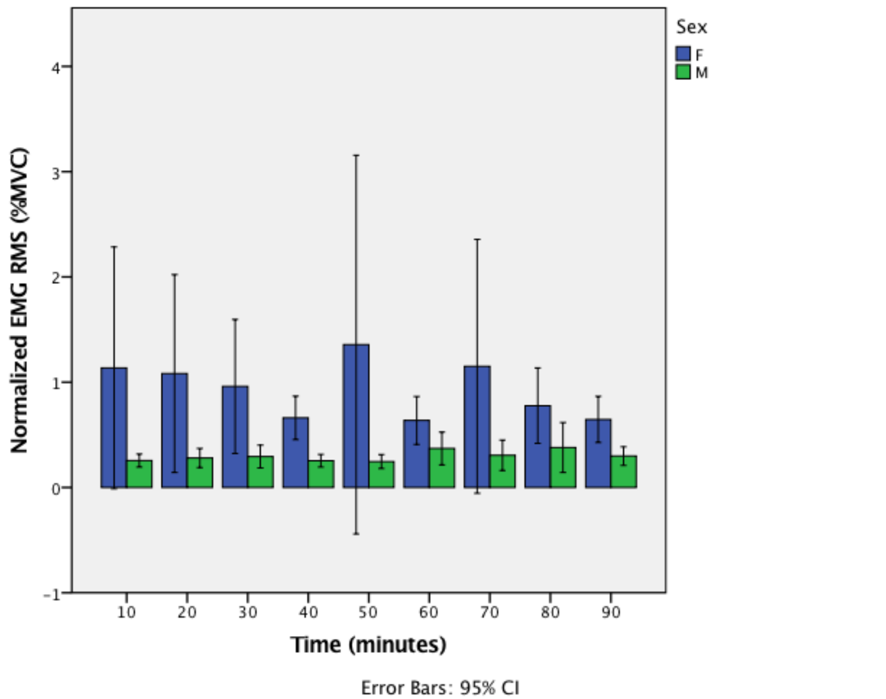

Figure 5. AD EMG RMS during the 90-minute computer task. A significant main effect was found for Sex, with greater AD RMS in females ($p < 0.05$).

Table 1. EMG RMS (%MVC) *p*-values

	Eyewear Main	Time Main	Sex Main	Eyewear x Time	Eyewear x Sex	Time x Sex	Eyewear x Time x Sex
UT	0.50	0.13	0.46	0.97	0.31	0.19	0.25
MT	0.98	0.004*	0.69	0.08	0.34	1.00	0.57
LT	0.92	0.85	0.37	0.22	0.97	0.003*	0.75
AD	0.92	0.71	0.002*	0.69	0.41	0.73	0.57
RSCM	0.38	0.16	0.60	0.87	0.08	0.22	0.70
LSCM	0.65	0.36	0.26	0.97	0.58	0.07	0.25
RCES	0.90	0.85	0.16	0.08	0.36	0.24	0.55
LCES	0.53	0.39	0.72	0.59	0.91	0.16	0.71

LSCM CoV ($Mean_{Time1}$ = 0.333, $Mean_{Time2}$= 0.338) and LCES CoV ($Mean_{Time1}$ = 0.246, $Mean_{Time2}$ = 0.329) significantly increased over time, demonstrating significant main Time effects (LSCM [$F(8, 168)= 2.02$, $p = .047$], effect size ($\eta^2_{partial}$): 0.09 (Figure 6); LCES [$F(8, 168)= 2.91$, $p = .005$], effect size ($\eta^2_{partial}$): 0.12 (Figure 7)). No other significant effects were found with respect to variability (Table 2).

Table 2. EMG CoV *p* values

	Eyewear Main	Time Main	Sex Main	Eyewear x Time	Eyewear x Sex	Time x Sex	Eyewear x Time x Sex
UT	0.85	0.84	0.13	0.85	0.50	1.00	0.60
MT	0.97	0.36	0.62	0.67	0.48	0.80	0.92
LT	0.91	0.65	0.97	0.78	0.91	0.22	0.89
AD	0.21	0.28	0.52	0.59	0.76	0.65	0.68
RSCM	0.28	0.52	0.74	0.40	0.35	0.29	0.52
LSCM	0.90	0.047*	0.98	0.49	0.96	0.25	0.93
RCES	0.89	0.55	0.90	0.94	0.26	0.71	0.56
LCES	0.27	0.005*	0.81	0.92	0.62	0.25	0.74

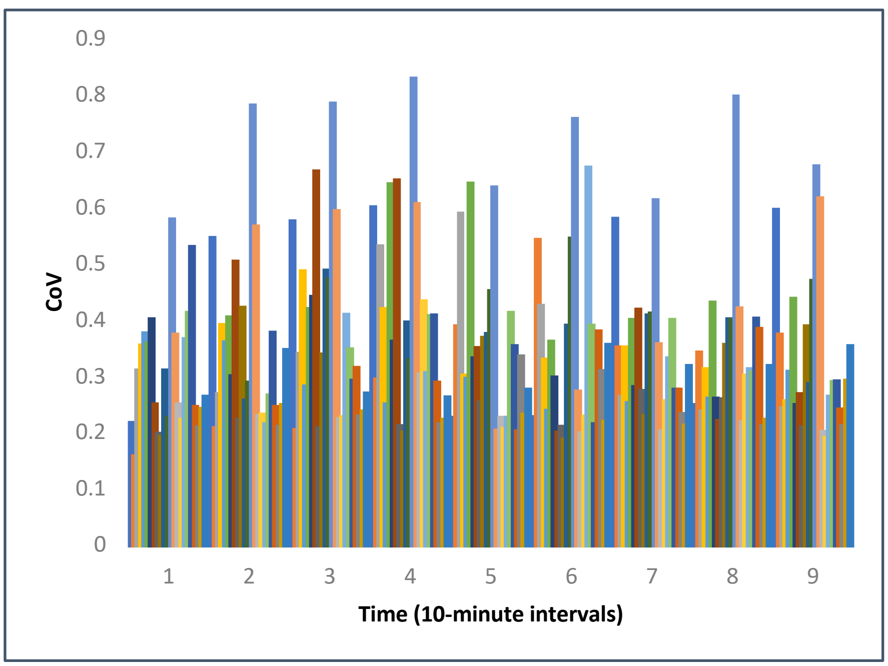

Figure 6. LCES CoV of all subjects during the 90-minute computer task, in the AFL condition. A significant main effect was found for Time, with increases in CoV over time ($p < 0.05$)

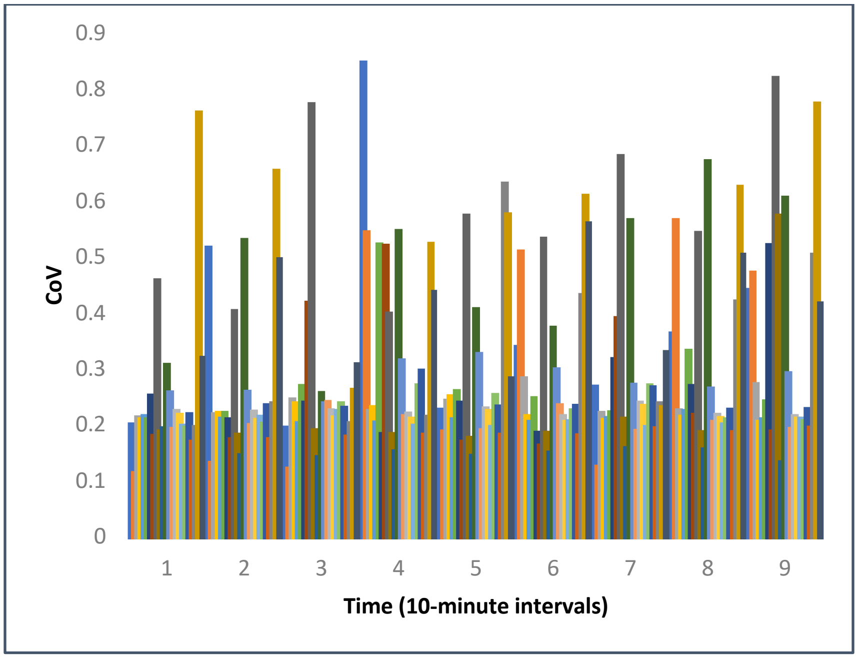

Figure 7. LSCM CoV of all subjects during the 90-minute computer task, in the AFL condition. A significant main effect was found for Time, with increases in CoV over time ($p < 0.05$)

NMI of the UT-AD demonstrated a significant Eyewear by Time interaction effect, with the NMI increasing significantly over time during the AFL condition (Mean = 0.378) compared to the placebo lenses (Mean = 0.375) ([$F(8, 168)= 2.01$, $p = .049$], effect size ($\eta^2_{partial}$): 0.09) (Figure 8). Further, there was a significant Eyewear by Time by Sex interaction for RCES-LCES ([$F(8,168) = 2.17$), $p = .032$], effect size ($\eta^2_{partial}$): 0.09). Sex-specific differences were observed in the effects of Eyewear condition on NMI changes in the temporal domain. In females, the AFL RCES-LCES NMI ($Mean_{female} = 0.380$) decreased until the hour mark and then returned to near the initial value, while in the placebo lenses condition, RCES-LCES NMI ($Mean_{female} = 0.378$) demonstrated an inverse trajectory through time (Figure 9). In males, the RCES-LCES NMI ($Mean_{male} = 0.378$) slowly increased with the AFL condition during the task, while in the placebo lenses condition, RCES-LCES NMI ($Mean_{male} = 0.375$) stayed fairly constant (Figure 10). Lastly, a significant main Time effect was noted for the MT-LT pairing (Mean = 0.384), with increases in NMI over time ([$F(8,168) = 2.76$, $p = 0.01$], effect size ($\eta^2_{partial}$): 0.007). No other significant effects were found with respect to NMI (Table 3).

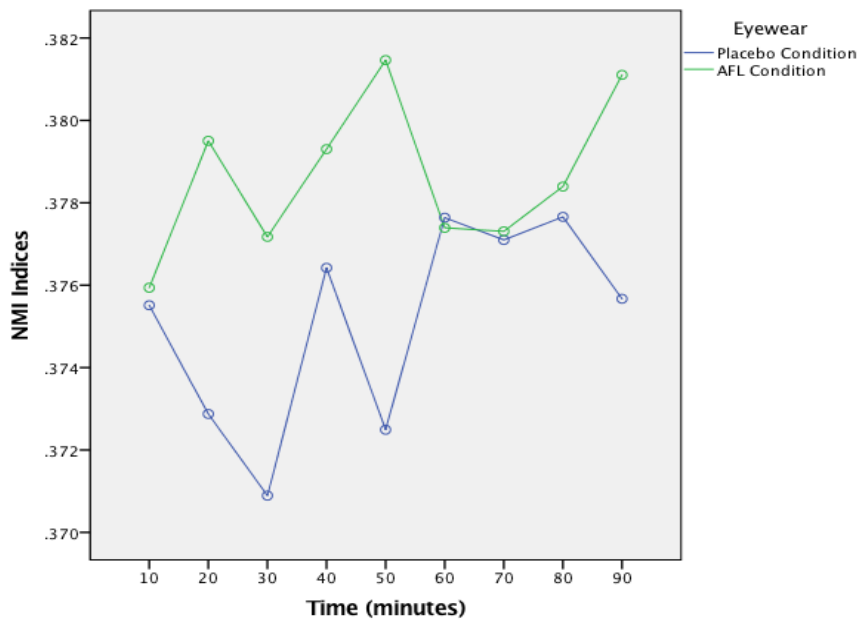

Figure 8. UT-AD NMI during the 90-minute computer task. A significant Eyewear by Time interaction was found, with greater UT-AD NMI in AFL over time ($p < 0.05$).

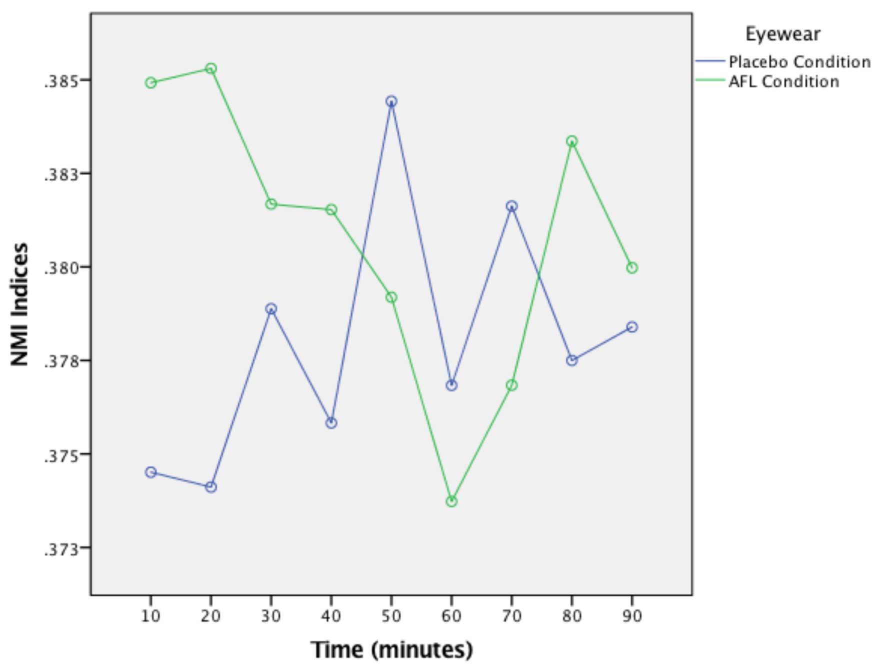

Figure 9. Female RCES-LCES NMI during the 90-minute computer task. A significant Eyewear by Time by Sex interaction was found, with the Eyewear condition leading to varying patterns in NMI between both sexes, over time ($p < 0.05$).

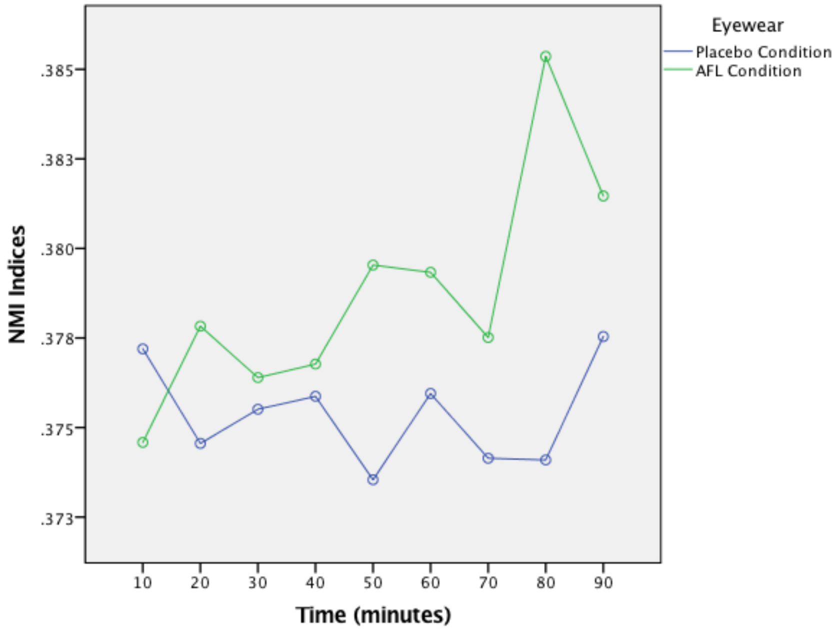

Figure 10. Male RCES-LCES NMI during the 90-minute computer task. A significant Eyewear by Time by Sex interaction was found, with the Eyewear condition leading to varying patterns in NMI between both sexes, over time ($p < 0.05$).

Table 3. EMG NMI *p* values

	Eyewear Main	Time Main	Sex Main	Eyewear x Time	Eyewear x Sex	Time x Sex	Eyewear x Time x Sex
UT-MT	0.68	0.27	0.50	0.81	0.34	0.90	0.46
UT-AD	0.17	0.34	0.14	0.049*	0.06	0.29	0.66
AD-RCES	0.67	0.08	0.07	0.96	0.09	0.75	0.74
MT-LT	0.23	0.01*	0.25	0.29	0.23	0.15	0.28
RSCM-LSCM	0.21	0.13	0.15	0.23	0.07	0.93	0.83
RSCM-RCES	0.14	0.65	0.16	0.22	0.10	0.87	0.29
RCES-LCES	0.58	0.77	0.73	0.24	0.95	0.64	0.032*
UT-MT	0.68	0.27	0.50	0.81	0.34	0.90	0.46

4. Discussion

The purpose of this study was to quantify the sex-specific effects of anti-fatigue lenses on neck/shoulder muscular patterns during a prolonged, 90-minute computer work task. We hypothesized that the AFL condition would lead to lower neck/shoulder muscle activity, variability, and functional connectivity, compared to the placebo lenses condition, in both sexes, suggesting a protective effect of the lenses on the NS region. Further, we hypothesized that these effects would be more pronounced in females than males.

4.1 Performance Measures

Task performance, represented by speed (lines/minute), was not affected by condition (AFL and placebo), but there was a significant main Time effect as well as an interaction between Time and Sex. The Sex by Time interaction showed that males improved in speed while females did not. Together, these sex-specific effects on performance may at least partly explain any sex differences in EMG patterns, although other factors such as kinematics (e.g. posture) could also affect effects on EMG measures, either independently or in relation to sex effects on typing speed. Follow-up analyses on kinematic patterns may help shed light on this issue.

4.2 Eyewear Effects on EMG characteristics

With regards to the main aim of this study, AFL saw greater increases in functional connectivity over time compared to the placebo lenses, specifically between the UT-AD pairing. During a repetitive task to fatigue, initial low connectivity was seen as a predictor of higher endurance in subdivisions of the trapezius (Fedorowich et al., 2013), and the development of high connectivity a form of muscular protection (Farias et al., 2017). Svendsen et al. (2013) studied a cohort with low back pain symptoms and demonstrated lower functional connectivity between muscle pairs including bilateral erector spinae, compared to controls. Similarly, Madeleine et al. (2016) studied a cohort with chronic neck-shoulder pain and also saw lower muscle functional connectivity compared to healthy subjects in the LT-UT pairing. As such, the lower connectivity may suggest that muscle recruitment is not effectively coordinated, resulting in potential spinal instability. With greater connectivity, improved muscle coordination and postural muscle stability may also result. Therefore, if increases in functional connectivity are seen as a protective and stabilizing mechanism, then the AFL condition would indicate a strategy of activation of supporting muscular compensatory strategies as the task progresses. Further, increases in UT-AD connectivity in the AFL condition over time mirror the increased MT muscle activity over time, in our current study. Thus, AFL can be seen as beneficial, helping stabilize and protect the musculature as muscle activity increases over time.

Interestingly, both eyewear conditions saw variations in left-right cervical erector spinae functional connectivity patterns overtime, between females and males. The AFL experienced a decrease in connectivity during the task in females, while a constant increase in connectivity over time was seen in males. Contrarily, the placebo condition saw an increase in connectivity over time in females, and no overall change in connectivity over time in males. Previously, Johansen et al. 2012 have shown that females experience greater levels of functional connectivity than males. However, in the AFL condition of our current study, females experienced connectivity decreases over time, while males saw increases in connectivity over time. Therefore, AFL appear to be more effective at sustaining muscular endurance and reducing the necessity for activation of compensatory strategies in females, a population at greater risk of NSMSDs. Further research is required to better understand the effects of the lenses and time on functional connectivity in females.

Various explanations exist as to why no significant main Eyewear effects were observed, beginning with the design of the AFL. The lenses used were not custom fit to our participants, therefore they may not have been as effective as they are capable of being. A standard pair of lenses with a +.5D in each eye was used. Future studies should take into account pupil distance and participant prescription, regardless of their claims of being free of obvious visual impairments. As well, a magnification of +0.5D was found in the bottom segment of the lenses, a feature of the "anti-fatigue" portion of the lenses. For this anti-fatigue component to be effective, participants are required to use the bottom portion of the lenses for their computer work. Although the laptop is located in the lower part of their field of view, participants were not accustomed to looking through the lower segment of their lenses, and may use the upper segments, tilting their head downward. In this study, participants were not instructed to look through a particular region of the lenses, leading to a potentially reduced effect of the anti-fatigue properties, a limitation of this study. Additionally, subjects were not accustomed to wearing lenses in general, which may have altered their levels of discomfort or focus on the task. Thus, with more appropriate instruction and fitting of the AFL, more significant results may be observed in future studies.

4.3 Sex Effects on EMG characteristics

Our results showed some significant main Sex effects, where females demonstrated greater AD RMS than males, suggesting that females have overall greater shoulder muscle activity during computer work than males. Similar to these findings, muscle activity has been shown to be higher during repetitive work in females (Nordander et al., 2008; Farias & Côté, 2017). Moreover, during a computer task, Won et al. (2009) reported that females applied more relative force (%MVC) of the shoulder and arm muscles compared to males on the keys, supporting the idea that females typically produce work at a greater capacity of their maximal strength. Similarly, Wahlstrom et al. (2000) observed that women used higher relative forces (%MVC) and more non-neutral postures than men when operating a computer mouse. Moreover, increased levels of prolonged postural muscle activity of low intensity have shown to lead to a higher risk of muscle fiber damage (Hagg, 1991). Because females have been seen to sustain higher levels of postural muscle activity for the same task as males, as seen in our study, this could partially explain why they are at a greater risk of NSMSDs. That being said, as the task progressed, males demonstrated greater shoulder stabilizer muscle activity increases, as LT RMS saw significant Time x Sex interactions. Interestingly, Farias and Côté (2017) noted similar findings, although in their study on the effects of working with a dual monitor setup, it was instead the activity of other neck/shoulder (UT and AD) muscles that increased over time in males only, suggesting a task- specific sex difference in the muscular response. Contrasting the overall greater shoulder muscle activity seen in women regardless of task duration, this muscular response activated in males highlights a complex sex difference in musculoskeletal mechanisms. Overall, our results are consistent with previous findings that overall females tend to work at higher levels of muscle activity when compared to males (Won et al., 2009; Yang et al., 2012; Nordander et al., 2008), however males may see increases in muscle activity as the task progresses (Farias & Côté, 2017). In sum, sex differences in muscular response require further investigation and understanding.

It should be noted that during the current study, few sex differences were noted for muscle activity, and none for muscle activity variability, nor functional connectivity. Interestingly, Won et al. (2009) observed significant differences in normalized keyboard force, forearm muscle activity and shoulder postural measures across groups of individuals when grouped by gender and by anthropometry, during a computer task. However, differences were more pronounced when groups were defined by anthropometry than by gender, with higher keyboard force, muscle activity and shoulder postural measures for the smaller computer operators. Because anthropometric differences are often used to rationalize sex differences, grouping subjects based on anthropometry in addition to sex may reveal more significant differences with regards to muscle activity, variability, and functional connectivity.

4.4 Time effects on EMG characteristics

Our findings showed a main Time effect for MT RMS, demonstrating that as the 90-minute computer task progressed, muscle activity increased. This time-dependent change was seen regardless of the Eyewear condition and Sex. Research has shown increases in NS muscle amplitude in symptomatic office workers with chronic neck and upper limb pain (Szeto et al., 2005a, 2009). Farias and Côté (2017) also noticed significant time-dependent changes in RMS during their 90-minute computer task, in addition to other studies with long-sustaining computer work tasks (Richter at al., 2015). The increase in muscle activity appears to be a response to the long-sustaining posture. As the Cinderella Hypothesis brings forward, tasks of long duration and low intensity demonstrating prolonged increases in muscle activity such as postural support and computer work are thought to lead to a greater risk of NSMSDs (Hagg, 1991). Determining appropriate work-rest regimens for static muscular work in occupational settings may be an efficient way to reduce this risk. However, there is no current consensus on intensity and duration thresholds to represent increased risk in the experimental research literature. Our task duration lasted 90 minutes, representing a typical work bout without breaks, however identifying a threshold value for workers, of various groups, and under different conditions should be included in future studies.

Muscle activity variability has also been shown to increase during the progression of a long-sustaining task, often interpreted as a compensatory strategy. This mechanism is thought to relieve the developing muscle load by changing muscle coordination characteristics of movement, such as by alternating patterns of muscle recruitment and increasing degrees of freedom in movement (Fuller et al., 2009; Fuller at al., 2011). As such, Mathiassen et al. (2003) have previously suggested that subjects displaying less variability may be at a higher risk of developing musculoskeletal injuries. In our current study, we saw significant increases in variability over time in the LSCM and LCES. The higher variability seen at the end of the session in both neck muscles may suggest that they are actively recruited in the development of fatigue and injury avoidance patterns during the computer task. Further, this supports the argument that greater variability indicates an adaptive strategy in sustaining posture during a computer task, in line with previous findings (Farina et al., 2008; Fedorowich et al., 2015). The reason why this is observed to occur in muscles on the left side are unclear and could be due to postural stability requirements for unilateral track pad scrolling with the right arm. Indeed, Szeto et al. (2009) evaluated cervical postural muscle loads and discomfort in symptomatic and asymptomatic female office workers across bilateral (typing) and unilateral (mousing) conditions. The symptomatic participants saw higher activity in the left (contralateral) upper trapezius during mousing, suggesting a global motor response, which can be interpreted as a compensation mechanism for unilateral track pad scrolling, and further explain our unilateral loading of the left cervical muscles.

A time-dependent effect was also noted for MT-LT functional connectivity in our study. Increases in MT-LT connectivity over time, in both females and males, could indicate another protective mechanism developed during a long-sustaining task. Similar to our findings, when functional connectivity was measured during computer work for the CES-AD pair and for the CES-LT pair, a time-dependent effect on connectivity was seen in another computer task (Fedorowich et al., 2015). Moreover, Madeleine et al. (2011) also found that within-trapezius functional connectivity was shown to increase with muscle fatigue and delayed onset muscle soreness during shoulder elevations, however only in male subjects. This highlights how increased functional connectivity could reflect an elevated risk of MSDs, specifically in the NS muscle region during computer work.

4.5 Limitations

Results from this investigation may be limited to laptop use, and to the simple, low-stress task used in our study, which does not always reflect academic or occupational conditions. Our chosen editing task may indeed not be representative of all work that students and office workers perform. However, tasks such as reading and scanning text on a computer screen can isolate forces such as convergence and accommodation of the eye (Collier et al., 2011), which were of interest in our study. Another limitation of the study is the signal to noise ratio versus the sources of error.

Our RMS values were very small (%MVC), and any errors due to our EMG collection procedure may be larger than the effect sizes found in our present study. A greater signal to noise ratio (ie. larger %MVC values) would have been more sound in our design. Additionally, the computer task was restricted to 90-minutes, limiting the generalizability of the results to employees who work for longer sustained bouts, such as the typical 8-hour work day. Results from this investigation are also limited to healthy populations with no pre-existing musculoskeletal complaints or injuries, limiting the generalizability of our results to patient populations. As well, the two sessions required participants to visit the lab on separate occasions and therefore EMG electrode placement could be slightly altered from one visit to the next. Finally, because subjects came in for two sessions, the time of day, weather, and any hormonal changes were not tightly controlled for between each session.

5. Conclusion

We sought to investigate the effects of AFL on muscular outcomes during a standardized 90-minute computer task. Few eyewear effects were noted, however AFL saw greater increases in functional connectivity over time compared to the placebo lenses, in one muscle pairing (UT-AD). Both Eyewear conditions saw variations in functional connectivity patterns overtime, between females and males. Thus, AFL can be seen as beneficial, helping protect neck/shoulder musculature as muscle activity increases over time, however AFL also appear to be more effective at sustaining muscular endurance and reducing the necessity for activation of compensatory strategies in females. With regards to sex differences, females not only experienced greater increases in NS muscle activity as the computer task progresses, but greater neck/shoulder muscle activity than males overall, regardless of task duration. That being said, few sex differences were noted for muscle activity, and none for muscle activity variability, nor functional connectivity during the present study. Lastly, our findings demonstrated that as the 90-minute computer task progressed, muscle activity and functional connectivity increased, highlighting the development of a protective mechanism during the task. Further studies should be designed with better ecological validity, such as with longer, more realistic work tasks, in more populations more likely to be fitted with AFLs such as older workers.

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Competing Interests

The authors declare there are no competing interests.

CONCLUSION

Results from the current study provide better understanding of the effects of anti-fatigue lenses on muscular outcomes and sex differences therein. Overall, few eyewear effects were noted, however lens wear saw greater increases in functional connectivity over time compared to the placebo lenses, between neck and shoulder muscle pairs. Both Eyewear conditions saw variations in functional connectivity patterns overtime, with differences in both females and males. With the lenses, females experienced a decrease in functional connectivity over time, while males saw increases in connectivity over time. AFL can thus be seen as beneficial, helping protect neck-shoulder musculature as muscle activity increases over time, however these lenses also appear to be more effective at sustaining muscular endurance and reducing the necessity for activation of compensatory strategies in females. Regardless of eyewear, females experienced overall greater shoulder muscle activity during the typing tasks normalized to reference contractions, while males saw greater increases in shoulder-stabilizer muscle activity, demonstrating that sex differences remain complex, with respect to NSMSD risk. Additionally, the 90-minute computer task used for this investigation elicited a significant increase in NS muscle activity amplitude, variability, and functional connectivity, regardless of eyewear or sex. This suggests that although AFL may provide certain musculoskeletal benefits, specifically in females, prolonged computer work remains a risk factor for the onset of NSMSDs. Further studies should be designed with better ecological validity, including longer, more realistic work tasks, in more populations more likely to be fitted with, and benefit from, AFL, such as older workers. As well, a longitudinal study highlighting the long-term outcomes of ergonomic eyewear would be of interest for future evaluations attempting to understand their effects.

BIBLIOGRAPHY

(CSA), C. S. A. (2000). A Guideline on Office Ergonomics. Retrieved from Toronto: Canadian Standards Association.

Australia, S. W. (2016). Statistics on Work-Related Musculoskeletal Disorders. SafeWork, Safety Science, 120, 146-156.

Bhattacharya, A. (2014). Costs of occupational musculoskeletal disorders (M SDs) in the United States. International Journal of Industrial Ergonomics, 44(3), 448-454. doi:https://doi.org/10.1016/j.ergon.2014.01.008

Blehm, C., Vishnu, S., Khattak, A., Mitra, S., & Yee, R. W. (2005). Computer Vision Syndrome: A Review. Survey of Ophthalmology, 50(3), 253-262. doi:10.1016/j.survophthal.2005.02.008

Bubric, K., & Hedge, A. (2016). Differential patterns of laptop use and associated musculoskeletal discomfort in male and female college students. Work, 55, 663-671. doi:10.3233/WOR-162419

Chang, C. H., Amick, B. C., 3rd, Menendez, C. C., Katz, J. N., Johnson, P. W., Robertson, M., & Dennerlein, J. T. (2007). Daily computer usage correlated with undergraduate students' musculoskeletal symptoms. American Journal of Industrial Medicine, 50(6), 481-488. doi:10.1002/ajim.20461

Chiu, T. T. W., Ku, W. Y., Lee, M. H., Sum, W. K., Wan, M. P., Wong, C. Y., & Yuen, C. K. (2002). A Study on the Prevalence of and Risk Factors for Neck Pain Among University Academic Staff in Hong Kong. Journal of Occupational Rehabilitation, 12(2), 77-91. doi:10.1023/A:1015008513575

Choi, H., & Vanderby, R., Jr. (2000). Muscle forces and spinal loads at C4/5 level during isometric voluntary efforts. Medicine & Science in Sports & Exercise, 32(4), 830-838. doi:10.1097/00005768-200004000-00016

Collier, J. D., & Rosenfield, M. (2011). Accommodation and convergence during sustained computer work. Optometry - Journal of the American Optometric Association, 82(7), 434-440. doi:https://doi.org/10.1016/j.optm.2010.10.013

Corneil, B. D., Olivier, E., & Munoz, D. P. (2002). Neck Muscle Responses to Stimulation of Monkey Superior Colliculus. II. Gaze Shift Initiation and Volitional Head Movements. Journal of Neurophysiology, 88(4), 2000-2018. doi:10.1152/jn.2002.88.4.2000

Côte, J. N. (2012). A critical review on physical factors and functional characteristics that may explain a sex/gender difference in work-related neck/shoulder disorders. Ergonomics, 55(2), 173-182. doi:10.1080/00140139.2011.586061

Domkin, D., Forsman, M., & Richter, H. O. (2018). Effect of ciliary-muscle contraction force on trapezius muscle activity during computer mouse work. European Journal of Applied Physiology, 119(2), 389-397. doi:10.1007/s00421-018-4031-8

Ekstrom, R. A., Donatelli, R. A., & Soderberg, G. L. (2003). Surface Electromyographic Analysis of Exercises for the Trapezius and Serratus Anterior Muscles. Journal of Orthopaedic & Sports Physical Therapy, 33(5), 247-258. doi:10.2519/jospt.2003.33.5.247

Ellahi, A., Khalil, M.S. (2011). Computer users at risk: Health disorders associated with prolonged computer use. Journal of Business Management and Economics, 2(4), 171-182.

Falla, D., Arendt-Nielsen, L., & Farina, D. (2008). Gender-specific adaptations of upper trapezius muscle activity to acute nociceptive stimulation. Pain, 138(1), 217-225. doi:https://doi.org/10.1016/j.pain.2008.04.004

Farias Zuniga, A. M., & Cote, J. N. (2017). Effects of Dual Monitor Computer Work Versus Laptop Work on Cervical Muscular and Proprioceptive Characteristics of Males and Females. Human Factors, 59(4), 546-563. doi:10.1177/0018720816684690

Farina, D., Leclerc, F., Arendt-Nielsen, L., Buttelli, O., & Madeleine, P. (2008). The change in spatial distribution of upper trapezius muscle activity is correlated to contraction duration. Journal of Electromyography and Kinesiology, 18(1), 16-25. doi:https://doi.org/10.1016/j.jelekin.2006.08.005

Fedorowich, L., Emery, K., Gervasi, B., & Côté, J. N. (2013). Gender differences in neck/shoulder muscular patterns in response to repetitive motion induced fatigue. Journal of Electromyography and Kinesiology, 23(5), 1183-1189. doi:10.1016/j.jelekin.2013.06.005

Fedorowich, L. M., Emery, K., & Côté, J. N. (2015). The effect of walking while typing on neck/shoulder patterns. European Journal of Applied Physiology, 115(8), 1813-1823. doi:10.1007/s00421-015-3163-3

Fischer, S. L., Belbeck, A. L., & Dickerson, C. R. (2010). The influence of providing feedback on force production and within-participant reproducibility during maximal voluntary exertions for the anterior deltoid, middle deltoid, and infraspinatus. Journal of Electromyography and Kinesiology, 20(1), 68-75. doi:10.1016/j.jelekin.2009.01.007

Forde, M. S., Punnett, L., & Wegman, D. H. (2002). Pathomechanisms of work-related musculoskeletal disorders: conceptual issues. Ergonomics, 45(9), 619-630. doi:10.1080/00140130210153487

Fuller, J. R., Fung, J., & Côté, J. N. (2011). Time-dependent adaptations to posture and movement characteristics during the development of repetitive reaching induced fatigue. Experimental Brain Research, 211(1), 133-143. doi:10.1007/s00221-011-2661-8

Fuller, J. R., Lomond, K. V., Fung, J., & Côté, J. N. (2009). Posture-movement changes following repetitive motion-induced shoulder muscle fatigue. Journal of Electromyography and Kinesiology, 19(6), 1043-1052. doi:10.1016/j.jelekin.2008.10.009

GBD 2017 Disease Injury, I. P., Collaborators. (2018). Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet (London, England), 392(10159), 1789-1858. doi:10.1016/S0140-6736(18)32279-7

Hagg, G. M. (1991). Static work and occupational myalgia – a new explanation model. In Electromyographical kinesiology (pp. 159-165). Amsterdam: Elsevier Science.

Hermens, H. J., Freriks, B., Disselhorst-Klug, C., & Rau, G. (2000). Development of recommendations for SEMG sensors and sensor placement procedures. Journal of Electromyography and Kinesiology, 10(5), 361-374. doi:https://doi.org/10.1016/S1050-6411(00)00027-4

Hogan, M. E., Taddio, A., Katz, J., Shah, V., & Krahn, M. (2016). Incremental health care costs for chronic pain in Ontario, Canada: a population-based matched cohort study of adolescents and adults using administrative data. Pain, 157(8), 1626-1633. doi:10.1097/j.pain.0000000000000561

Horgen, G., Aaras, A., Kaiser, H., & Thoresen, M. (2002). Do specially designed visual display unit lenses create increased postural load compared with single-vision lenses during visual display unit work? Optometry and Vision Sci, 79(2), 112-120. doi:10.1097/00006324-200202000-00013

Horgen, G., Aaras, A., & Thoresen, M. (2004). Will Visual Discomfort among Visual Display Unit (VDU) Users Change in Development When Moving from Single Vision Lenses to Specially Designed VDU Progressive Lenses? Optometry and Vision Science, 81(5), 341-349. doi:10.1097/01.opx.0000134908.44145.49

Hough, R., & Nel, M. (2016). Time and space dimensions of computer laptop use amongst third year students of the University of the Free State. South African Journal of Occupational Therapy, 46, 27-32. Retrieved from http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2310-38332016000100007&nrm=iso

Inman, V. T., Saunders, J. B. d. M., & Abbott, L. C. (1996). Observations of the Function of the Shoulder Joint. A Publication of The Association of Bone and Joint Surgeons, 330. Retrieved from https://journals.lww.com/clinorthop/Fulltext/1996/09000/Observations_of_the_Function_of_the_Shoulder_Joint.2.aspx

Jeong, J., Gore, J. C., & Peterson, B. S. (2001). Mutual information analysis of the EEG in patients with Alzheimer's disease. Clinical Neurophysiology, 112(5), 827-835. doi:10.1016/s1388-2457(01)00513-2

Johansen, T. I., Samani, A., Antle, D. M., Cote, J. N., & Madeleine, P. (2012). Gender effects on the coordination of subdivisions of the trapezius muscle during a repetitive box-folding task. European Journal of Applied Physiology, 113(1), 175-182. doi:10.1007/s00421-012-2425-6

Kanchanomai, S., Janwantanakul, P., Pensri, P., & Jiamjarasrangsi, W. (2011). Risk factors for the onset and persistence of neck pain in undergraduate students: 1-year prospective cohort study. BMC Public Health, 11, 566. doi:10.1186/1471-2458-11-566

Kendall, F. P., McCreary, E.K. and Provance, P.G. (1993). Muscle Testing and Function (4th ed.). Philadelphia: Lippincott, Williams and Wilkins.

Klein, S. A. & Mandell, R. B. (1995). Shape and Refractive Powers in Corneal Topography. Investigative Ophthamology and Visual Science, 36(10), 2096-2109.

Koretz, J. F., & Handelman, G. H. (1988). How the human eye focuses. Scientific American, 259(1), 92-99. doi:10.1038/scientificamerican0788-92

Kumar, S. (1996). Electromyography in ergonomics. London: Taylor and Francis.

Lindman, R., Eriksson, A., & Thornell, L. (1990). Fiber type composition of the human male trapezius muscle: Enzyme-histochemical characteristics. American Journal of Anatomy, 189(3), 236-244. https://doi.org/10.1002/aja.1001890306

Lindman, R., Eriksson, A., & Thornell, L. (1991). Fiber type composition of the human female trapezius muscle: Enzyme-histochemical characteristics. American Journal of Anatomy, 190(4), 385-392. https://doi.org/10.1002/aja.1001900406

Madeleine, P., Mathiassen, S. E., & Arendt-Nielsen, L. (2008b). Changes in the degree of motor variability associated with experimental and chronic neck-shoulder pain during a standardised repetitive arm movement. Experimental Brain Research, 185(4), 689-698. doi:10.1007/s00221-007-1199-2

Madeleine, P., Samani, A., Binderup, A. T., & Stensdotter, A. K. (2011). Changes in the spatio-temporal organization of the trapezius muscle activity in response to eccentric contractions. Scand J Med Sci Sports, 21(2), 277-286. doi:10.1111/j.1600-0838.2009.01037.x

Madeleine, P., Vangsgaard, S., Hviid Andersen, J., Ge, H.-Y., & Arendt-Nielsen, L. (2013). Computer work and self-reported variables on anthropometrics, computer usage, work ability, productivity, pain, and physical activity. BMC Musculoskeletal Disorders, 14(1), 226. doi:10.1186/1471-2474-14-226

Madeleine, P., Voigt, M., & Mathiassen, S. E. (2008a). The size of cycle-to-cycle variability in biomechanical exposure among butchers performing a standardised cutting task. Ergonomics, 51(7), 1078-1095. doi:10.1080/00140130801958659

Mathiassen, S. E., Moller, T., & Forsman, M. (2003). Variability in mechanical exposure within and between individuals performing a highly constrained industrial work task. Ergonomics, 46(8), 800-824. doi:10.1080/0014013031000090125

Mathiassen, S. E., Winkel, J., & Hägg, G. M. (1995). Normalization of surface EMG amplitude from the upper trapezius muscle in ergonomic studies — A review. Journal of Electromyography and Kinesiology, 5(4), 197-226. doi:https://doi.org/10.1016/1050-6411(94)00014-X

Millodot, M., & Millodot, S. (1989). Presbyopia correction and the accommodation in reserve. Ophthalmic and Physiological Optics, 9(2), 126-132. doi:10.1111/j.1475-1313.1989.tb00831.x

Mork, R., Bruenech, J. R., & Thorud, H. M. S. (2016). Effect of Direct Glare on Orbicularis Oculi and Trapezius During Computer Reading. Optometry and Vision Science, 93(7), 738-749. doi:10.1097/opx.0000000000000855

Mowatt, L, Gordon, C, Santosh, ABR, Jones, T. Computer vision syndrome and ergonomic practices among undergraduate university students. International Journal of Clinical Practice. 2018; 72. https://doi.org/10.1111/ijcp.13035

Nordander, C., Ohlsson, K., Balogh, I., Hansson, G.-Å., Axmon, A., Persson, R., & Skerfving, S. (2008). Gender differences in workers with identical repetitive industrial tasks: exposure and musculoskeletal disorders. International Archives of Occupational and Environmental Health, 81(8), 939-947. doi:10.1007/s00420-007-0286-9

Organization, W. H. (2018). Musculoskeletal conditions. Retrieved from https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions

Palm, P., Hansson Risberg, E., Mortimer, M., Palmerud, G., Toomingas, A., & Wigaeus Tornqvist, E. (2007). Computer use, neck and upper-extremity symptoms, eyestrain and headache among female and male upper secondary school students. SJWEH Supplements(3), 33-41. Retrieved from https://www.sjweh.fi/show_abstract.php?abstract_id=1180

Reddy, S. C., Low, C. K., Lim, Y. P., Low, L. L., Mardina, F., & Nursaleha, M. P. (2013). Computer vision syndrome: a study of knowledge and practices in university students. Nepalese Journal of Ophthalmology, 5(2), 161-168. doi:10.3126/nepjoph.v5i2.8707

Richter, H. O. (2014). Neck pain brought into focus. Work, 47(3), 413-418. doi:10.3233/WOR-131776

Richter, H. O., Banziger, T., Abdi, S., & Forsman, M. (2010). Stabilization of gaze: a relationship between ciliary muscle contraction and trapezius muscle activity. Vision Res, 50(23), 2559-2569. doi:10.1016/j.visres.2010.08.021

Richter, H. O., Crenshaw, A., & Lyskov, E. (2007). Low-levels sustained accommodative/vergence loads, eyestrain and neck-shoulder discomfort. http://urn.kb.se/resolve?urn=urn:nbn:se:hig:diva-899

Richter, H. O., Zetterberg, C., & Forsman, M. (2015). Trapezius muscle activity increases during near work activity regardless of accommodation/vergence demand level. European Journal of Applied Physiology, 115(7):1501-1512. doi:10.1007/s00421-015-3125-9.

Samani, A., Holtermann, A., Søgaard, K., & Madeleine, P. (2009a). Experimental pain leads to reorganisation of trapezius electromyography during computer work with active and passive pauses. European Journal of Applied Physiology, 106(6), 857-866. doi:10.1007/s00421-009-1083-9

Samani, A., Holtermann, A., Søgaard, K., & Madeleine, P. (2009b). Active pauses induce more variable electromyographic pattern of the trapezius muscle activity during computer work. Journal of Electromyography and Kinesiology, 19(6), e430-e437. doi:https://doi.org/10.1016/j.jelekin.2008.11.011

Sauter, S. L., Schleifer, L. M., & Knutson, S. J. (1991). Work Posture, Workstation Design, and Musculoskeletal Discomfort in a VDT Data Entry Task. Human Factors, 33(2), 151-167. doi:10.1177/001872089103300203

Schopflocher, D., Taenzer, P., & Jovey, R. (2011). The prevalence of chronic pain in Canada. Pain research & management, 16(6), 445-450. doi:10.1155/2011/876306

Seghers, J., Jochem, A., & Spaepen, A. (2003). Posture, muscle activity and muscle fatigue in prolonged VDT work at different screen height settings. Ergonomics, 46(7), 714-730. doi:10.1080/0014013031000090107

Services, U. S. D. o. H. a. H. (1996-2011). Medical Expenditures Panel Survey (MEPS). Retrieved from http://meps.ahrq.gov/mepsweb/

Shantakumari, N., Eldeeb, R., Sreedharan, J., & Gopal, K. (2014). Computer use and vision-related problems among university students in ajman, United arab emirate. Annals of Medical and Health Science Research, 4(2), 258-263. doi:10.4103/2141-9248.129058

Srinivasan, D., & Mathiassen, S. E. (2012). Motor variability in occupational health and performance. Clinical Biomechanics (Bristol, Avon), 27(10), 979-993. doi:10.1016/j.clinbiomech.2012.08.007

Strøm, V., Roe, C., & Knardahl, S. (2009). Work-induced pain, trapezius blood flux, and muscle activity in workers with chronic shoulder and neck pain. Pain, 144(1-2), 147-155. doi:10.1016/j.pain.2009.04.002

Svendsen, J. H., & Madeleine, P. (2010). Amount and structure of force variability during short, ramp and sustained contractions in males and females. Human Movement Sciences, 29(1), 35-47. doi:10.1016/j.humov.2009.09.001

Szeto, G., Chan, C., Chan, S., Lai, H., & Lau, E. . (2014). The effects of using a single display screen versus dual screens on neck-shoulder muscle activity during computer tasks. International Journal of Industrial Ergonomics, 44(3), 460-465.

Szeto, G. P., Straker, L. M., & O'Sullivan, P. B. (2005a). A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work--1: neck and shoulder muscle recruitment patterns. Manual Therapy, 10(4), 270-280. doi:10.1016/j.math.2005.01.004

Szeto, G. P. Y., Straker, L. M., & O'Sullivan, P. B. (2009). During computing tasks symptomatic female office workers demonstrate a trend towards higher cervical postural muscle load than asymptomatic office workers: an experimental study. Australian Journal of Physiotherapy, 55(4), 257-262. doi:https://doi.org/10.1016/S0004-9514(09)70005-4

Szucs, K. A., & Molnar, M. (2017). Differences in the activation and Co-activation ratios of the four subdivisions of trapezius between genders following a computer typing task. Human Movement Science, 52, 181-190. https://doi.org/10.1016/j.humov.2017.02.001

Veiersted, K. B., Westgaard, R. H., & Andersen, P. (1993). Electromyographic evaluation of muscular work pattern as a predictor of trapezius myalgia. Scandinavian Journal of Work, Environment & Health, 19(4), 284-290. Retrieved from www.jstor.org/stable/40966147

Vézina, M. C., Stock, S., Lippel, K., Fortin, É., Delisle, A., St-Vincent, M., & al., e. (2011). Québec Survey on Working and Employment Conditions and Occupational Health and Safety (EQCOTESST).

Wahlström, J., Svensson, J., Hagberg, M., & Johnson, P. (2000). Differences between work methods and gender in computer mouse use. Scandinavian Journal of Work, Environment & Health*, 26*(5), 390-397. Retrieved April 28, 2020, from www.jstor.org/stable/40967080

Warburton DER, J. V., Bredin SSD, and Gledhill N (2011). The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada, 4(2), 3-23.

Peter Watson. (2019, October 30). Effect Size - Cognition and Brain Science Unit. University of Cambridge - CBU wiki farm. Retrieved July 1, 2020, from https://imaging.mrc-cbu.cam.ac.uk/statswiki/FAQ/effectSize

Wolska, A., & Switula, M. (1999). Luminance of the surround and visual fatigue of VDT operators. International Journal of Occupational Safety and Ergonomics, 5(4), 553-581. doi:10.1080/10803548.1999.11076438

Won, E. J., Johnson, P. W., Punnett, L., & Dennerlein, J. T. (2009). Upper extremity biomechanics in computer tasks differ by gender. Journal of Electromyography and Kinesiology, 19(3), 428-436. doi:10.1016/j.jelekin.2007.11.012

Yang, J.-F., & Cho, C.-Y. (2012). Comparison of posture and muscle control pattern between male and female computer users with musculoskeletal symptoms. Applied Ergonomics, 43(4), 785-791. doi:https://doi.org/10.1016/j.apergo.2011.11.013

Zetterberg, C., Forsman, M., & Richter, H. O. (2013). Effects of visually demanding near work on trapezius muscle activity. Journal of Electromyograohy and Kinesiology, 23(5), 1190-1198. doi:10.1016/j.jelekin.2013.06.003

Zetterberg, C., Richter, H. O., & Forsman, M. (2015). Temporal Co-Variation between Eye Lens Accommodation and Trapezius Muscle Activity during a Dynamic Near-Far Visual Task. PLOS ONE, 10(5), e0126578. doi:10.1371/journal.pone.0126578

APPENDIX

McGill | Faculty of Education | Department of Kinesiology and Physical Education

Version Date: ______ REB File #: _____

Participant Informed Consent form

Researcher

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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

Impact of Ergonomic lenses on neck/shoulder discomfort, vision, and musculoskeletal mechanisms

Sponsor

This project is funded by Mitacs and by IRSST (student fellowship).

Preamble/Introduction

You are invited to participate in a study on the sex-specific effects of computer lenses on neck/shoulder posture and eye strain during text typing in young adults who frequently use a computer. 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 describe the effects of computer lenses on vision, muscle activity, postural alignment, and neck-shoulder discomfort during text typing. This project also aims to assess sex differences in these capacities. 22 healthy subjects will be recruited and will perform a typing task at a desk, in our laboratory. The long-term objective of this project is to better understand how computer lenses work as an ergonomic solution for men and women working in front of a computer screen for prolonged periods of time, and implement changes in the workplace based on findings. This research will provide the knowledge and tools to identify, treat and prevent computer work-related vision syndrome and neck musculoskeletal injury. Results from this project will be disseminated in the forms of a M.Sc. Thesis, conference presentations, and a manuscript.

Nature and duration of your participation

This research project aims at understanding how computer lenses influence neck-shoulder muscular activity, posture, discomfort, and vision, while working in front of a laptop screen. The study takes place at McGill University, Currie Gymnasium in Montreal. You are asked to participate in two experimental sessions that will last from two to three 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).

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During Phase 1, locations of surface electrodes and markers will be marked on your skin using a make-up pen. Sensors will be applied on the skin over your neck and shoulder muscles in order 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 computer 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 procedure. We will offer you a few neck and shoulder stretches to relieve any tension or discomfort.

Voluntary participation

Participation in this research study is fully voluntary. You have the right to decline to answer any questions and the right to withdraw from the study for five years, after which the data will be de-identified. If you withdraw from the study within the five year period, all documents of your participation will be destroyed.

Potential benefits associated with your participation

You will not benefit from any advantage by 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. The lenses may cause you to have a mild headache, if you are not used to wearing eye wear. Also, you may experience some fatigue towards the end of the typing protocol, which may cause some tenderness, stiffness and/or pain in the neck-shoulder region.

Monetary compensation

There are two, two and-a-half hour sessions and you will be compensated at a rate of $4/hr for a total of $20.

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 this five-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.

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 Genevieve Gill, 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 lynda.mcneil@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: ______________

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