Effects of two work postures on musculoskeletal disorder risk associated with computer work

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July, 2014

A thesis submitted to McGill University in partial fulfillment of the requirements for the degree of Master of Science

For my Dido Derow,

who always stressed the importance of education

CONTRIBUTION OF AUTHORS

Larissa Fedorowich, the candidate, was responsible for the research, design, setup, recruitment, data collection, analysis, writing and any other steps related to the completion of the research study and the submission of this thesis as per McGill University requirements.

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Kim Emery, MSc, and David Antle, PhD, assisted with the training of the candidate and provided guidance during the data collection and analysis.

Amanda Farias, MSc candidate, provided assistance during data processing.

ACKNOWLEDGEMENTS

I would firstly like to thank my thesis supervisor, Dr. Julie Côté. I am truly grateful for your unwavering guidance, support and patience throughout this process, as well as the knowledge you have shared in all aspects of this Masters. I am in awe of all the obligations you commit to, but nevertheless your prompt and open communication never faltered. Thank you for giving me this opportunity, it has certainly been a period of growth for me in my life and has opened up new possibilities for me in the future.

Throughout this thesis, many colleagues have contributed at different points and to different degrees, but I couldn't have completed without all of you. David Antle, thank you for introducing me into the lab and integrating me immediately. The training and knowledge you imparted to me have been invaluable. Kim Emery, thank you for your training on equipment and your patience with all my questions. I am grateful you were there to tackle issues with me and guide me to answering my own questions. Hiram Cantu Campos, I'm glad you have been there throughout my entire thesis process; you always seem to have an answer for everything! Thank you for your friendship, positive attitude and all the laughs; I hope we stay in touch even as we start new chapters in our lives. Amanda Farias and Zach Weber, thank you for assisting in the lab with data collection and data processing; you two helped that summer run smoothly. To the other OBEL members who I haven't mentioned, old and new, I thank those of you who have contributed to my project and wish the rest of you good luck in continuing your schooling or future endeavours.

I would like to acknowledge the members of the Jewish Rehabilitation Hospital as well as the Professors and colleagues at the Department of Kinesiology and Physical Education of McGill who contributed to my project in one way or another. To Dr. David Pearsall and Caroline Paquette, who served on my advisory committee, thank you for your insight and feedback to strengthen this project.

To all the friends I have made in Montreal, thank you for encouraging me throughout the thesis process and to those who participated as subjects in my study, thank you for taking interest and agreeing to take part in my study. A special thank you goes to my family in Toronto for continuing to support me. Mom and Dad, thank you for being positive role models in working hard to achieve what you want and also for encouraging me till the end. Vince and Andrew, thank you for your advice and support in what I have been doing, and thank you to my sister Michelle, who took the time to help with editing of this thesis.

Lastly, an important thank you goes to my fiancé Adrien. Adrien you have seen all the good and the bad from these past two years, I couldn't have gotten through it without you. Your encouragement and optimism have always helped me reach the next step; I hope I can return the favour as you complete your own Master's degree later this year. Thank you for believing in me and supporting me in pursuing my goals.

ABSTRACT

The aim of this Master's study was to quantify the effects of modifying computer work posture on neck/shoulder patterns in healthy young adults during a prolonged computer task. In turn, this would serve to provide objective data on a popular computer work intervention: walk-and-work. Upper body muscle activity (EMG) and blood flow (LDF) as well as discomfort and typing performance data were recorded every 9 minutes during a 90-min computer typing task during two sessions of sitting and walking on a treadmill. Results of this study show that discomfort in the neck/shoulder area was higher during sitting and this discomfort increased over time compared to walking. Muscle activity and blood flow patterns were indicative of a lower neck/shoulder load during working while walking, which potentially reflects healthier adaptations to prolonged computer work. This may support that performing computer work in a posture other than sitting may be beneficial in preventing neck/shoulder disorders.

RÉSUMÉ

L'objectif de ce projet de recherche était de quantifier les effets de changer la posture de travail sur les patrons de la région cou/épaules durant un travail prolongé sur ordinateur chez des jeunes adultes en santé. De cela, en découleraient des données objectives à propos d'interventions devenant communes en milieu de travail à l'ordinateur : marcher-et-travailler. L'activité musculaire du haut du corps (EMG), le débit sanguin (LDF), la perception de l'inconfort ainsi que la performance à l'ordinateur ont été enregistrés toutes les 9 minutes pendant une période de 90 min alors que les sujets reproduisaient un texte à l'ordinateur, ceci pendant deux sessions, une étant assis et l'autre en marchant sur un tapis roulant. Les résultats de cette étude confirment l'état d'inconfort au niveau du cou et des épaules étant plus élevé à la position assise comparativement à la marche. D'autres résultats de cette étude nous montrent un modèle d'activité musculaire durant la marche, qui reflète potentiellement une adaptation bénéfique à un travail informatique de longue durée. Les différents mécanismes observés lors des deux postures pourraient soutenir l'idée de travailler sur un ordinateur avec une posture autre que celle assise, avec pour but de prévenir les troubles musculaires dans la région des épaules et du cou.

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INTRODUCTION

Industrialization in societies has brought about new styles of working, where people assume much more fine movements and static postures like that of computer work. Along with this evolving work style, new and more specific types of musculoskeletal disorders (MSDs) are emerging. A large percentage of the population is affected by MSD but not solely the individual is impacted, there are social and financial implications in the form of health care costs and absenteeism as well (Vezina, 2011). A more specific definition arising from occupational exposures is work-related musculoskeletal disorders (WRMSD) which can be defined as reoccurring musculoskeletal symptoms affecting an individual's activities, that can develop progressively and that are perceived to be partly or entirely related to a person's main work (Stock et al. 2011). Recent Quebec statistics show that approximately 1 in 5 workers is impeded by work-related symptoms (Stock et al. 2011) and approximately 25% of diagnoses affect cervical structures (Madeleine et al. 1999; Hagberg 1996). The neck/shoulder area is generally affected as a unit (Visser and van Dieen, 2006). It has been shown that neck/shoulder MSDs typically develop from highly repetitive work, forceful exertions, high and/or prolonged static loads, and static or extreme postures (Larsson et al. 2007).

The development of musculoskeletal symptoms may increase with the growing number of people using computers on a more regular basis. Studies have shown that the number of jobs which require the computer for the bulk of their work has increased from 30% in 1989 to 50% in 2000, and more recently Quebec statistics have shown this number to increase to 69% in 2007/2008 with greater than 30% using a computer for 20 hours per week (Vezina et al. 2011). Recent Quebec statistics found that nearly 30% of the population reported suffering from an MSD severe enough to impact their daily lives within the previous year (ISQ, 2010). This statistic taken with the high number of workers now using a computer daily makes it quite plausible that computer work may be playing a part in the development of MSD symptoms.

According to the National Research Council (2001), evidence points to an increased risk of upper-extremity disorders among computer users. The neck/shoulder structure may be a cause for concern during computer work, as this work is generally typified as repetitive and static. The idea of repetition in work as being harmful to the body can be explained by repetitive modelling constructs (Armstrong et al. 1993) in which each exposure poses risk of tissue micro-trauma, and over time these repeated micro-traumas can eventually lead to impairments (Forde et al. 2002). Repetition may interact with many other factors such as exposure, intensity, duration, loading and so on, so that it is much more complex to identify just one causal mechanism. Repetitive upper limb work is characteristic of computer work, so while neck pain is the most common risk among office workers, the forearm is the other region most affected (Berglund et al. 2008; Samani et al. 2011). During computer work, the neck/shoulder and forearm body areas are where symptoms are most often reported, suggesting some commonalities in the injury mechanisms of both regions, although this is not clear yet.

Research so far has attempted to implement prevention strategies for workers who are at the most risk for developing MSD, but despite the high prevalence of reported disorders, there are still many unknowns about which intervention methods are most effective. A recent trend is walk-and-work computer workstations which are being considered as an alternative to seated computer work, in that they may help to decrease sedentary time and increase daily physical activity (Koepp et al. 2013). However little is known about the real impact of this type of intervention on musculoskeletal health indicators. The **objective** of this thesis was to quantitatively assess the effect of modifying computer work posture on indicators related to risk of developing neck/shoulder MSD. We recruited subjects to perform an extended computer-typing task while sitting, standing and walking on a treadmill (although only the results pertaining to the seated and walking tasks were analyzed for this thesis). We hypothesized that walking while working would display strategies that could be interpreted as advantageous towards the prevention of computer work-related neck/shoulder MSDs. We expected that our results would help to gain a better perspective on the onset of symptoms associated with prolonged computer work, and would provide much needed evidence to support (or not) the use of alternating computer work postures.

LITERATURE REVIEW

Recent research has helped us gain a better understanding of the pathophysiological mechanisms which could be associated or lead to neck/shoulder MSD. In light of the various references, we have identified three important injury pathways to neck/shoulder MSD: a neuromuscular, a postural and a vascular one, which will be detailed below. These factors may work independently or interact to affect symptom development. The current study focuses on gathering precise data illustrating each pathway during a protocol of computer work under different postural conditions.

Muscular Mechanisms

A part of the neck/shoulder injury mechanism may be related to patterns of muscle activation. The most influential hypothesis of muscular mechanisms for neck/shoulder MSD associated with low-force tasks is the Cinderella Hypothesis (Hagg, 1991). This hypothesis looks to the behaviour of the low-threshold motor units and their associated Type 1 fibers as a central aspect of the mechanism of injury associated with sustained, low-intensity efforts (Visser and van Dieen, 2006). The type 1 muscle fibers, which are the slow, fatigue-resistant fibers, are the first to be recruited according to Henneman's 'size principle' (1965). As such, during low-intensity efforts, these fibers are consistently activated and sustained for the longest period of time, and therefore overload may occur. As the muscle is prevented from relaxing, this overload increases the content of Ca^{2+} resulting in a build-up (Gissel, 2000). In turn, this accumulation would have harmful effects on the membranes of the muscle fibers creating structural damage, and muscle injury may result (Hagg and Astrom, 1997; Lexell, 1993; Visser and van Dieen, 2006). A further component of this injury process may be related to impairments in blood flow and insufficient muscle tissue oxygenation (Shiro et al. 2012; Van Galen et al. 2002), but the role of blood flow will be expanded on later. Support for this model can be found in some biopsy studies (Hagg, 1991; Lindman et al. 1990; Hagg, 2000) which are some of the few linking experimental evidence with tissue damage mechanisms.

The neck/shoulder region has been shown to be affected by computer office work although the injury pathways are likely quite multifactorial. Muscle activity in the neck/shoulder area is found to be quite low during computer work according to some studies using surface EMG, observing activity values below 10% of maximum contractions (Johansson et al. 1999; Roe and Knardahl, 2002; Blangsted et al. 2004). Although this may be the case, this could be sufficient to maintain the Cinderella fibers active over prolonged periods of time, and therefore the possibility that muscle-fiber activity plays a part in symptom development cannot entirely be disregarded. Some studies have quantified the muscular load of healthy, asymptomatic subjects during computer work and have observed increased levels of muscle activity with time, concluding that greater levels of muscle activity could indeed indicate higher risks for developing symptoms (Cooper and Straker, 1998; Aaras et al. 1997; Kleine et al. 1999). In support of this, a recent systematic review by Eijckelhof et al. (2013) concluded that simulated workplace stressors also resulted in increased activity in both the neck/shoulder and forearm regions; since stress has also been associated with WMSD, this supports the role of muscle activity in the development of WMSD, through direct (mechanical) or indirect pathways. Another study on the activity of the upper trapezius of symptomatic and asymptomatic secretaries observed more frequent EMG gaps in the healthy workers (Hagg and Astrom, 1997). The authors allude to the lack of muscle relaxation as a risk factor for developing neck/shoulder disorders which is supported by findings in similar studies (Jensen et al. 1999; Veiersted et al. 1993). Szeto et al. (2005a) conducted a study of office workers performing a prolonged computer task and observed asymptomatic subjects to display more symmetrical activity of their neck/shoulder muscles, while symptomatic subjects displayed higher activity on their right side. Furthermore the Szeto group found high levels of discomfort with high unilateral muscle activity in the upper trapezius for the symptomatic group. These findings point to the possibility that various types of muscle activity alterations could lead to discomfort and symptom development. Moreover, a recent computer-typing study with healthy individuals found that continuous computer work led to increases in muscle activity of the upper trapezius (Park et al. 2013). These studies taken together, point to sustained muscle activity in the neck/shoulder region during computer work, as a potential pathway for developing MSDs.

As mentioned earlier, the high prevalence of reported neck/shoulder and forearm pain may indicate that these two areas share common injury mechanisms. Support for this hypothesis can be seen in a study of subjects with and without elbow pain. Berglund et al. (2008) found that when provocation tests were performed on participants' cervical spine as well as a neurodynamic test of the radial nerve, the pain response was significantly higher in the elbow pain group. Furthermore in another study during computer mouse work, experimental pain was induced in the trapezius and exercise was performed to produce delayed onset muscle soreness (DOMS) in the wrist extensors. The authors found that pain in the trapezius affected the muscle activity of the wrist extensors, as well as altered coordination patterns of the forearm muscles in the presence of delayed onset muscle soreness (Samani et al. 2011). In another computer work study, Strom et al. (2009a) found that the trapezius and forearm extensor displayed similar muscle activity increases with time, and although the authors hypothesized a possible role of blood flow, this was not measured to verify this link. One possible explanation for this link may be the involvement of the radial nerve (Vincenzino and Wright, 1996), in that pain in the neck may travel the length of the radial nerve and irritate the forearm. Yaxley and Jull (1993) provided clinical evidence for this, as they found that subjects with symptoms of unilateral tennis elbow were affected by adverse tension in neural tissue during glenohumeral abduction. Therefore, investigating the effects of computer work on both neck/shoulder and forearm areas may help us better understand the mechanisms that could explain why both regions are highly affected by computer work.

A way to prevent overload of muscle fibers may be to take advantage of the concept of variability, which has been defined as the variation of behavioral outcomes over repetitions or time (Latash et al., 2002). Variability has been previously quantified using standard deviation, coefficient of variation, median absolute deviation, or inter-quartile range (Madeleine et al. 2010; Mathiassen et al. 2003; Skurvydas et al. 2010). In one study where upper trapezius activity was analyzed during a repetitive pointing task to fatigue, Fuller et al. (2011) found variability of the muscle activity to increase with fatigue. The authors suggest that increasing variability may be a way to explore healthy fatigue-adaptation mechanisms. Studies focusing on muscle activity variability during isokinetic knee extensions (Skurvydas et al. 2010) and isometric trunk extension (Vandieen et al. 1993), found high muscle activity and force variability with high endurance which may point to high variability as an effective mechanism in prolonging the performance of a task. In accord with this, it is hypothesized that high motor variability may prevent the development of chronic symptoms and conversely, that those with less variable motor patterns do not fully benefit from the redundancy of the motor system and therefore are at greater risk of injury (Mathiassen et al. 2003; Madeleine et al. 2008a). Support for these interpretations is found in one study where lower motor variability of the shoulder muscles was seen in workers with pain performing a meat cutting task (Madeleine et al. 2008b). As well, another study of seated arm flexion/extension observed larger activity variability of the deltoid muscles in pain-free workers (compared to workers with pain) which may be associated with increasing recovery from pain (Moseley and Hodges, 2006). Variability has been hypothesized to be a possible compensation strategy, where one study looking at shoulder muscles during a repetitive reaching task, observed low variability at the injured joint, but high variability at other joints, interpreted as a way to make up for functional deficits at the injured area (Lomond and Côté, 2010, 2011). Additionally, we have previously shown that during the performance of a repetitive pointing task to exhaustion, in healthy subjects, supraspinatus activity variability increased with fatigue (Fedorowich et al. 2013) and was higher compared to symptomatic subjects (Lomond and Côté, 2010), which may reflect a healthy beneficial strategy to prolong task performance. Fedorowich et al. (2013) also observed that initially high variability in the neck/shoulder area was a predictor of task endurance, although that relationship was only significant in the female subgroup. The recent review paper by Srinivasan and Mathiassen (2012) on motor variability suggests that this is a promising area of study to better understand the development of MSD.

Another characteristic of muscle activity which has been recently studied in association with MSD risk is observing patterns of two muscles working together. A statistical method to quantify this inter-muscle coordination is Mutual Information (MI), which can be defined as shared activation or functional connectivity. This method accounts for both linear and non-linear relationships as it quantifies shared activation patterns of two muscles' electromyographic time series (Jeong et al. 2001; Kojadinovic, 2005). One group used this technique to measure activity patterns among subdivisions of the trapezius during a repetitive, submaximal box-folding task. There was no effect of time, but higher functional connectivity between subdivisions of the trapezius was found in women, compared to men (Johansen et al. 2013). In another study of a fatiguing task of eccentric contractions at 100% MVC, Madeleine et al. (2011) found that within-trapezius functional connectivity was shown to increase with muscle fatigue and delayed onset muscle soreness (DOMS), although this study only included male subjects. Contrasting results were seen in another study of a repetitive task to fatigue, where initial low mutual information was a predictor of higher endurance in subdivisions of the trapezius, but only in males (Fedorowich et al., 2013). The differing results from these studies may be attributed to the variances in procedures or to the level of fatigue which was induced. In a recent study by Svendsen et al. (2013) individuals with sub-acute low back pain exhibited lower functional connectivity between muscle pairs, specifically the left and right sides erector spinae and external abdominal oblique. The authors suggest that the lower mutual information may signify that muscle recruitment is not properly coordinated, which could lead to lumbar instability or a lack of bodily awareness. Although muscle sharing could seem like an advantageous strategy, at this time, the literature suggests that high mutual information is not necessarily beneficial; however, more experimental data needs to be provided to support this early interpretation. Less adaptable within- (variability) and between- (coordination) muscle patterns could play an important part in the mechanisms of neck/shoulder MSD.

Vascular Aspects

Another pathway in which MSD symptoms could develop in the neck/shoulder may be related to vascular mechanisms. As addressed in the Cinderella hypothesis, when there is an imbalance between muscle damage and repair mechanisms, muscle injury is likely to result. Blood flow plays an important role in supply to, and regeneration of the working muscles, although the specific mechanisms linking blood flow dynamics and muscle injury are somewhat unclear. Some hypotheses related to blood supply in symptom development include impeding circulation or decreases in muscle oxygenation (Carayon et al. 1999; Van Galen et al. 2002). Keller et al. (1998) suggest that an anterior displacement of the head and shoulder girdle, like the round shoulder posture seen often after extended periods of time at the computer, would limit the thoracic circulatory area and compress the brachial artery, therefore compromising the amount of blood flow to more distal structures. When we look to clinical studies comparing symptomatic and asymptomatic workers, Larsson et al. (1999) observed lower blood flow at the surface of the painful muscle in symptomatic subjects. Conversely, another study of a prolonged computer work task found no difference between symptomatic and asymptomatic subjects, but observed blood flow to peak earlier for symptomatic people (15 min compared to 30 min) (Strom et al. 2009b). This finding may suggest insufficient recovery mechanisms in the symptomatic subjects, compared to healthy subjects, although the causality of this relationship is less clear. When looking to healthy subjects, there is an association between changes in symptoms with blood flux but not muscle activity, suggesting a predominant role of blood flow in response to prolonged work (Strom et al. 2009a).

In light of these studies, it is conceivable that strategies that would augment blood flow to working muscles would also be beneficial in reducing symptoms of the neck/shoulder region. In support of this, Cagnie et al. (2007) found that being physically active decreased the likelihood of developing neck pain (odds ratio = 1.85). Furthermore, a few studies have observed that cycling with relaxed upper limbs resulted in increased oxygenation to the forearm and shoulder (Andersen et al. 2010; Green et al. 2002; Tanaka et al. 2006) which indicates a positive effect of exercise on blood flow. This may also strengthen support for various types of exercise as a means of intervention to decrease neck/shoulder MSD, especially considering that another benefit of exercise is inducing an analgesic response for people in pain (Cote and Bement, 2010). However, thus far, no studies have evaluated the relationship between work posture and blood flow to the upper extremities during computer work. Considering that the seated posture is static, sedentary and does not engage the lower limbs, it is plausible that blood flow is not being sufficiently directed to the working upper limbs during standard, seated computer work. Therefore the upper limb muscles may be lacking in blood supply, which could play a part in the work-related neck/shoulder injury mechanism. Therefore, one good strategy would be to look for ways to increase blood flow to the working upper limb muscles.

Postural Aspects

Aside from female gender, posture appears to be one of the most important injury risk factors in association with MSD (Cagnie 2007). One aspect of static postures may be their influence in creating muscular imbalances, whereby hypertrophy would occur in overused muscles and underused muscles would experience weakening (Mackinnon and Novak, 1994; Higgs and Mackinnon, 1995). Mechanically disadvantageous postures may lead to risks of injury; over time, an increasingly flexed neck posture may be adopted, creating a non-neutral posture for a prolonged period, which may place pressure on or stretch peripheral nerves (Forde et al. 2002) and thereby lead to pain (Cagnie et al. 2007; Strom et al. 2009a). In a study of office workers with a 1-year prevalence of neck pain, Cagnie et al. (2007) found that the likelihood of having neck pain is increased by two times with a forward bent neck posture for a prolonged time (OR = 2.01). More research on computer workers performing prolonged computer tasks found symptomatic workers to display postural deviations, left-right asymmetric posture (Szeto et al. 2005b), increased neck flexion angles and elevated muscle activity (Szeto et al. 2005a). These studies suggest that there is a link between neck posture and overload of neck postural muscle fibers. However these studies were conducted only on female workers, so that it is difficult to make inferences for both sexes. More specifically, sitting, working postures may also be a risk factor for MSD as neck pain has been significantly associated to prolonged sitting (OR =

2.06) (Cagnie et al. 2007), is higher in seated jobs (Ariens et al. 2001), increases over time (Skov et al. 1996), and is higher when sitting >5 hours a day (Kamwendo et al. 1991). Stationary standing is also a common posture in the workplace and in some settings it is an alternative solution to sitting. Two studies comparing neck/shoulder muscle activity of cashiers while sitting and standing observed lower neck/shoulder muscle activity and postural deviations during standing (Lehman et al. 2001; Lannersten and Harmsringdahl, 1990). This may point to lower risks of injury in the upper body with standing work, compared to while sitting. However, some research has previously found stationary standing work to be associated with discomfort in the lower limbs (Reid et al. 2010), vascular disorders (Raffetto and Khalil, 2008; Tuchsen et al. 2005), and low-back pain and musculoskeletal disorders (Messing et al. 2009; Tissot et al. 2009). In a stationary standing box-folding task, Antle and Côté (2013) found that prolonged standing can lead to blood pooling in the lower limbs as well as low-back discomfort. Furthermore, the development of low-back pain during standing may be related to co-activation patterns of the trunk and hips as some studies found that these patterns preceded the onset of muscle pain (Nelson-Wong et al. 2008; Nelson-Wong and Callahan, 2010). These studies taken together suggest that prolonged standing work may lead to different symptoms from sitting work, and therefore may not be a viable solution.

Computer/Office work and posture

Computer work is traditionally performed while sitting, but as mentioned above, this may not be the ideal posture to perform this work. The aforementioned issues propel us to search for alternate postures to promote neck/shoulder health. A study by Ebara et al. (2008) measured speed and accuracy of a 150-minute computer task during 3 variations of working posture: seated on a regular chair, seated on a high chair, and a sit/stand alternation. The authors found computer performance to not be affected by the sitting variations. Another study by Husemann et al. (2009) also found no effect on data entry performance during a sit/stand condition, although physical and psychological well-being was increased during the sit/stand condition compared to the seated condition.

A new trend in the workplace is experimenting with 'active' workstations, for instance incorporating cycling or walking (Straker et al. 2009; Funk e al. 2012; Thompson and Levine, 2011; John et al. 2009). Adopting more active working postures is thought to help alter sedentary behaviour and improve health (Straker et al. 2013; Ben-Ner et al. 2014). Some studies have investigated walking while working and have focused on cardiovascular and metabolic outcomes with results showing benefits to cardiovascular health risk factors (Thompson et al. 2008; Levine and Miller, 2007). However, some research has found impairments in work performance while walking (John et al. 2009; Straker et al. 2009). Specifically, one study investigated work-related aspects and found worse computer performance while walking in terms of mistakes, for example a 6-11% decrease in typing math problem solving, mousing and typing performance, although the subjects of that study were not given an acclimation period (John et al. 2009). However another study varied treadmill walking speeds and found similar decreases in performance at 1.6km/h and 3.2km/h, although they discovered an optimal speed at 2.25km/h which found no effect on typing performance when compared to the seated condition (Funk et al. 2012). Another concern of performing a task while walking is the consequence of cognitive distraction and altered mechanical demands. Schabrun et al. (2014) found that while participants read or typed text on a cell phone, they maintained a flexed neck position and had greater head range of motion in global space. The authors explained that head movement closely resembled phone movement, which was most likely a strategy to enable steadiness of the head relative to the hand, although this prioritizing may compromise the control of the head and impact postural stability. The impact of dual-tasking on performance is known to vary from person to person, and those who are better apt, may exhibit better overall performance than those who perform poorly at dual-tasks (Watson and Strayer, 2010). Therefore, dual-tasking may be an explanation for computer work performance deficits while walking, although a proposed theory from Yogev-Seligmann et al. (2012) suggests that cognitive tasks are ordered based on postural reserve, expertise and task complexity. Conversely, walking may actually aid in performing cognitive tasks as aerobic exercise training has been shown to help mediate stress, increase hippocampal volume and improve memory function (Erickson et al. 2011). Furthermore, a 12 month-long study with treadmill workstations in a work setting found an initial decline in overall performance over the first 24 weeks, although over time, all aspects of performance (quantity, quality, interaction quality) actually exceeded the initial performance measures (Ben-Ner et al. 2014). These studies indicate that there are physical and psychological benefits with the use of a treadmill workstation, especially when proper walking speed and acclimation are incorporated into the study design, but nevertheless, it still remains unclear whether walking while working on a computer impacts musculoskeletal health. Since this is an increasingly popular work method incorporated into some of the biggest worldwide companies, there is a need for objective data to inform the use of these new computer workstations.

RESEARCH ARTICLE

The effect of walking while typing on neck/shoulder patterns

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In preparation, for submission to European Journal of Applied Physiology

ABSTRACT

This project was designed to quantify the effects of modifying computer work posture on neck/shoulder patterns during a prolonged computer typing task. Twenty healthy, participants completed a 90-minute computer typing task while sitting or walking on a treadmill. Electromyography (EMG) was recorded from eight muscles of the right upper body and Laser-Doppler Flowmetry (LDF) from two upper body sites. EMG amplitude (RMS), variability (CoV), normalized mutual information (NMI) and blood flow (LDF) were computed over time and across the two postures. Upper limb discomfort and computer performance (speed, errors) were also recorded. Upper limb discomfort was higher during sitting ($p < .0001$) and increased with time ($p < .0001$). Significant interaction effects showed that lumbar erector spinae (LES) ($p = .004$) and wrist extensor ($p = .008$) activity decreased over time in walking, but increased over time in sitting. Significant interaction effects showed higher LES CoV during walking compared to sitting ($p = .019$) in the beginning but not the end of the 90min task, and higher neck/shoulder NMI ($p = .050$) towards the end of the 90min task during sitting compared to walking. When seated, high increases in shoulder blood flow through time correlated with high increases in work speed ($r = .548$). In walking, high increases through time in MT EMG correlated with lower shoulder blood flow ($r = -.835$) and more typing errors ($r = .638$). Results suggest that walking while performing computer work may be effective in employing healthier muscular patterns possibly explaining the lower level of discomfort compared to sitting. This may support that performing computer work in a posture other than sitting may be beneficial in reducing or preventing neck/shoulder MSD.

1. Introduction

Work-related musculoskeletal disorders (WRMSD) are chronic musculoskeletal symptoms which interfere with ones' activities, can develop over time and can be partly or entirely related to a person's main work (Stock et al. 2011). With the growing number of people requiring the use of a computer for their main work, it is quite plausible that computer work may be playing a part in the increasing diagnoses of musculoskeletal disorders (MSDs), especially in the neck/shoulder region. Larsson et al. (2007) identified neck/shoulder MSDs to typically develop from repetitive work, forceful exertions, high-prolonged static loads, and static or extreme postures. Many of these factors characterize traditional seated computer work, and despite the high prevalence of reported disorders, there are still many unknowns about which intervention methods are most effective. The reasons for this could be that there is still some uncertainty about the specific neck/shoulder injury pathomechanisms in relation to computer work, although previous literature has identified elements to support the presence of three injury pathways: a neuromuscular, a postural and a vascular one (Forde et al. 2002; Strom et al. 2009b). In addition, the forearm has displayed similar muscle activity increases over time as the trapezius during computer work (Strom et al. 2009a) and pain in the trapezius has been seen to affect activity of the wrist extensors (Samani et al. 2011) which suggests that these two areas may be functionally connected during computer work. However, the specific pathways linking the two areas during work have not been clearly identified yet.

One part of the computer work-related neck/shoulder injury mechanism may be related to patterns of muscle activation. Although the activity load during computer work is quite low, with EMG values below 10% of maximum contractions (Johansson et al. 1999; Roe and Knardahl, 2002; Blangsted et al. 2004), increases in activity over time may still pose a risk for developing MSDs (Cooper and Straker, 1998; Aaras et al. 1997; Kleine et al. 1999). However previous studies do not show a clear association between trapezius muscle activity amplitude and neck symptoms during computer work (Strom et al. 2009a), such that other measures of muscle activity may be better predictors of symptoms. One such measure may be muscle activity variability which is the variation of behavioral outcomes over repetitions or time (Latash et al. 2002). Variability of the supraspinatus has been previously observed to increase with fatigue (Fedorowich et al. 2013), and greater variability of shoulder muscles has been seen in pain-free workers compared to those with pain (Madeleine et al. 2008b; Moseley and Hodges, 2006) suggesting that higher variability may be beneficial and those who display lower variability may be at higher risk of developing injuries. In addition, observing patterns of two muscles working together is another part of muscle activity which has been studied lately. Mutual Information (MI) is a statistical method which accounts for both linear and non-linear relationships as it quantifies shared activation patterns of two muscles' electromyographic time series (Jeong et al. 2001; Kojadinovic, 2005). Research has shown MI to increase with muscle fatigue and delayed onset muscle soreness in males (Madeleine et al. 2011) whereas another study found that initial low MI was a predictor of higher endurance in the trapezius of males (Fedorowich et al. 2013). Literature right now suggests that high MI is not beneficial; however more experimental data needs to be gathered to relate MI to better understood patterns associated with neck/shoulder work.

Another pathway in which symptoms could develop may be related to vascular mechanisms in that an imbalance between muscle damage and repair mechanisms may lead to muscle injury. Blood flow plays an important role in supplying and regenerating muscles, although its exact role in MSDs is unclear. Some studies of prolonged computer work have found lower blood flow in painful muscles of symptomatic subjects (Larsson et al. 1999) and observed an earlier peak of blood flow in symptomatic people (Strom et al. 2009b) suggesting insufficient recovery mechanisms. Extended periods of computer work may compromise circulation, as flexed-neck or round shoulder postures could limit the thoracic circulatory area and blood flow to more distal structures (Keller et al. 1998). Physical activity has been proposed as a positive strategy in promoting blood flow, as cycling with relaxed shoulders has shown to increase blood flow to the shoulder and forearm (Andersen et al. 2010; Green et al. 2002; Tanaka et al. 2006) and furthermore Cagnie et al. (2007) found that being physically active decreased the likelihood of developing neck pain (odds ratio = 1.85). However, no studies have measured the effectiveness of methods to augment blood flow (e.g. through exercise) on the upper limb patterns during computer work.

Posture also appears to be a large risk factor associated with MSD (Forde et al. 2002). Seated working postures may pose a risk as previous research has observed that neck pain was associated to prolonged sitting (odds ratio = 2.06) (Cagnie et al. 2007), was higher in seated jobs (Ariens et al. 2001), and was higher when sitting >5 hours a day (Kamwendo et al. 1991). Considering that computer work is traditionally performed while sitting, these aforementioned issues propel us to search for alternate work postures which may promote a better neck posture and may augment blood flow to the working muscles. A new trend in the workplace is walk-and-work workstations (i.e. computer workstations attached to a treadmill over which people can walk and simultaneously work) with some documented benefits on physical activity as well as cardiovascular health (Thompson et al. 2008; Levine and Miller, 2007). Nevertheless, one concern of this type of dual-tasking is impairments in work performance which was seen by John et al. (2009) and Straker et al. (2009), although Funk et al. (2012) tested three walking speeds and found an optimal speed of 2.25km/h where no effects were seen on typing performance. Another concern is the consequence of cognitive distraction and altered mechanical demands that the walk-and-work workstations could pose. Schabrun et al. (2014) observed a flexed neck position and greater global head range of motion while walking and reading or writing text on a cell phone. However, the impact of dual-tasking is known to vary between people, and some individuals may perform better than others (Watson and Strayer, 2010). Conversely, in one of the few studies on walk-and-work that accounted for acclimation to this novel task, a year-long study with treadmill workstations found all aspects of performance (quantity, quality, interaction quality) to exceed the initial performance measures (Ben-Ner et al. 2014). This may point to physical and psychological benefits of using a treadmill workstation, although the impacts on blood flow and musculoskeletal health, and the mechanisms underlying these potential benefits, remain unclear.

The objective of this study was to quantitatively compare the effects of a 90 minute computer typing task in the postures of sitting and walking on a treadmill on muscular, vascular, performance and discomfort indicators. We hypothesized that walking while working on the computer would display beneficial muscular strategies, would increase upper limb blood flow, would show lower levels of discomfort and would not impact typing performance.

2. Methods

2.1 Participants

A convenience sample of 20 healthy young adults (10 males, 10 females; mean age = 27.65 ± 6.18 years; mean height = 169.72 ± 9.07 cm; mean mass = 69.31 ± 12.41 kg) was recruited by the researchers from the institutional social network. The inclusion criteria were the use of a computer for more than 40 hours per 7 days, between the ages of 20-50, available for 3 experimental sessions, and free of neurological and musculoskeletal injuries, cardiovascular diagnoses and any other general health concern, as assessed by the Par-Q Health Questionnaire. A measure of perceived stress within the past month was assessed by a 14-question Perceived Stress Scale (PSS-14) (Cohen and Williamson, 1988), which each participant completed prior to beginning the first experimental session. The study was performed at the Occupational Biomechanics and Ergonomics Lab (OBEL) of the Jewish Rehabilitation Hospital in Laval, Quebec. Informed, written consent was given by the participants prior to partaking, by signing forms approved by the Research Ethics Board of the Center for Interdisciplinary Research in Rehabilitation (CRIR) of Greater Montreal.

2.2 Session Randomization

The 3 experimental sessions focused on recording data during the performance of a computer work task performed in the postures of sitting, standing or walking on a treadmill. In order to provide an opportunity for acclimation to the WaW (walk-and-work task) that session could not be scheduled first. First a randomization process took place between the seated and standing sessions, then between the remaining session and the walking session. The WaW practice trial was performed at the end of the session preceding the WaW session. The sessions were separated by at least 48 hours to avoid day-to-day fatigue or soreness effects. In this paper we only report the analysis and results pertaining to the seated and WaW data, as the standing data will be presented elsewhere.

2.3 Instrumentation

The participant was fitted with electromyographical (EMG) recording equipment (TeleMyo, Noraxon, USA, 10-350 Hz operating bandwidth). Eight muscle areas of the right arm, shoulder and trunk were prepared by being marked and shaved and then cleaned with rubbing alcohol to allow for better signal transmission. The Ag/AgCl surface electrodes (Ambu, Del) were then placed side by side in bipolar configuration, parallel to the muscle fibers. The 8 muscles were outfitted with electrodes in the same configuration each session. The placement over the cervical erector spinae (CES) was approximately 10 mm to the right of the C5 vertebra. For the upper trapezius (UT), the position was midpoint between C7 spinous process and acromion. Electrodes were placed on the following sites: anterior deltoid (AD): between the lateral 1/3 of the clavicle and the deltoid tuberosity of the humerus; wrist extensor (Wext): over the muscle belly, approximately 2 finger widths distal to the elbow; middle trapezius (MT): midpoint between the thoracic spine and the medial border of the scapula; lower trapezius (LT): midpoint between the T8 spinous process and the inferior angle of the scapula; lumbar erector spinae (LES): midpoint between T12 and S1, along the lumbar spine over the transversus process; external oblique (EO): two finger widths below the last rib and three inches forward to the body's midline (Basmajian & Blumenstein, 1980). A reference electrode was placed over the right external epicondyle. Following this, the participant was outfitted with the cardiovascular equipment. Two Laser Doppler Flowmetry (FloLAB Monitor, Moor Instruments, Devon, England) electrodes were used: one positioned over the right UT, medial to the UT electrodes (SLDF – shoulder LDF), and the second over the right Wext muscles, between the Wext electrodes and the external epicondyle (FLDF – forearm LDF), to measure skin surface blood flow in these two areas.

Figure 1 Rear view of subject outfitted with EMG electrodes and LDF electrodes. Subject is performing the walking procedure on the treadmill workstation.

2.4 Initial Measures

After the electrodes and attached cables were placed and fixed with medical tape, the participant was instructed in completing maximum isometric voluntary contractions (MIVC). The UT was tested with the arm at the side; participants elevated their shoulder against resistance applied on the shoulder. For the AD, the shoulder performed flexion with the arm flexed 45°, against resistance applied on the upper arm. The MT MIVC action consisted of scapula adduction with the shoulder at 90° flexion. The LT action was performed with the shoulder in an angle of 90° flexion and the scapula depressed against resistance applied under the upper arm. The Wext was tested by performing wrist extension from a neutral wrist angle, forearm pronated, with the arm resting on a table at 90° flexion in the elbow, against resistance applied on the dorsal part of the hand. To test the CES, subjects were lying prone, resistance was applied against the posterior aspect of the head, and the subject performed neck extension. The test for the LES involved the subject lying prone and performing lumbar extension with their arms at the side against resistance applied on their hamstrings. To test the EO, subjects laid supine and knees flexed 90°, the subject performed upper trunk flexion-rotation against resistance applied on the right pectoral. A rigid frame structure was custom adapted to subject sizes to allow external resistance to be applied in the procedures for the first 4 muscles listed above, while resistance was applied manually for the last 4 muscles listed above. For each, two ramp-up, ramp-down, five-second MIVC trials were completed for each muscle with encouragement to push as hard as possible in the designated force direction. One minute of rest was given between each of the trials to ensure maximum effort was given in the next trial.

Next, subjects were positioned in the desired work posture (sitting or walking), which included adjusting the chair and computer desk. In the seated posture, an angle of 90° was created at the knee. In the walking session, the treadmill speed was programmed to 2.25km/h as used in Funk et al. (2012). In all sessions, the work surface was adjusted to 5cm below elbow height (Kroemer and Grandjean, 1997) to maintain an approximate 90° elbow angle. After positioning the subject in the sessions' computer work posture, the baseline cardiovascular measures were taken when the subject adopted a relaxed, static state. In order to see if stress affected the computer task, at this time the subject was asked to rate their pre-test level of stress on a scale of 0-10. The question posed was: "On a scale of 0-10 how stressed do you feel about participating in this session?" and the response was recorded.

2.5 Computer Task

The typing task consisted of reproducing article text displayed on the computer using the Mavis Beacon Teaches Typing software, as used in (Funk et al. 2012; Straker et al. 2009). The subjects performed 10 blocks of 9 minutes each with EMG data collection taking place the last 30 seconds of each block. Immediately after each of these recordings, the participants were prompted to rest their arms at the sides of the computer. LDF was then collected for 30 seconds and during this time, participants were asked to refrain from shifting their body weight, in order to minimize movement artifacts in the LDF data. Following this, typing performance was recorded as average typing speed and errors during the previously finished block and discomfort was rated using a body map and discomfort scale (Messing et al. 2008; Antle et al. 2013). At the end of the 90 minute task, subjects again rated their stress level (on a scale of 0-10), and their response was recorded as post-test level of stress.

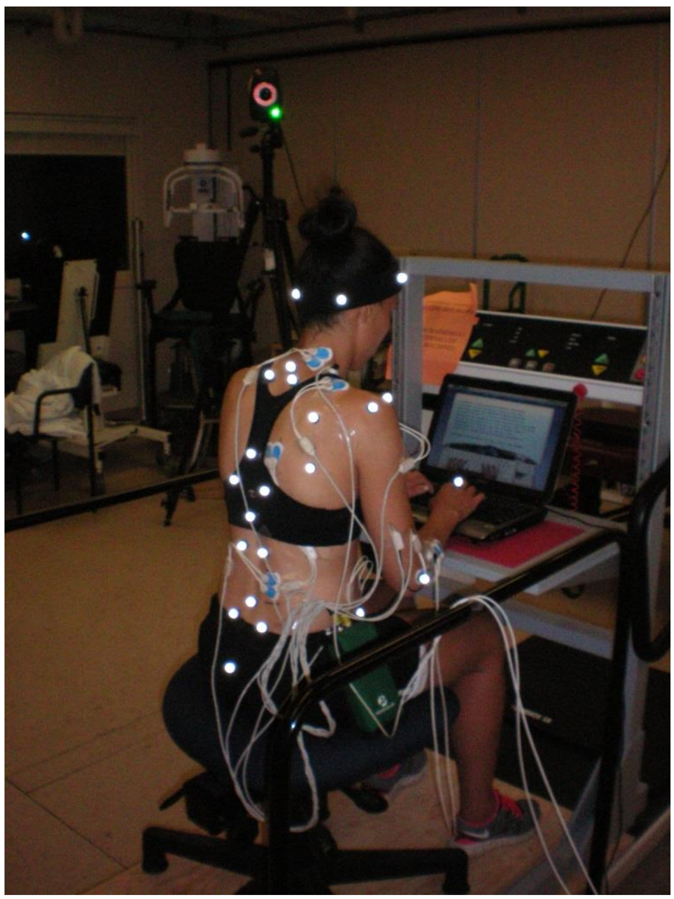


Figure 2 Rear view of subject outfitted with EMG electrodes and LDF electrodes during the seated task. Subject is also outfitted with Kinematic markers, although those results were not included in this thesis.

2.6 Data Analysis

EMG data was filtered using a dual-pass 4th-order Butterworth band-pass of 20-500 Hz. The heartbeats were removed from the signals by first identifying a reference heartbeat in one trial and then cross-correlating it with the other signals to eliminate heartbeats from all 8 muscle signals. Following this, signals were full-wave rectified and then normalized to the EMG data collected during the MIVC, giving a percentage of the MIVC values for each muscle. Root-mean-square (RMS) values were calculated over 30 1-s non-overlapping windows for each collection period and the 30 RMS values were averaged to obtain one representative mean amplitude value for each muscle from each collection block. Variability was calculated by computing coefficients of variation (CV) for each muscle in each block by dividing the standard deviation of the 30 RMS values by the average RMS value.

Normalized Mutual Information (NMI), which is a measure of functional connectivity between two muscles, was calculated using EMG time series from each block. Calculations are detailed in Johansen et al. (2012). Briefly, NMI is based on the Entropy calculation, (average amount of information: H) of EMG time series where NMI is valued between 0, indicating no connectivity and 1, indicating complete functional connectivity of the muscle pair. NMI was calculated for all the possible pairs in this study within two muscle area groups: neck/shoulder group – CES, UT, AD, MT, LT and trunk group: LES, EO. NMI of each muscle pair was calculated over 500-ms windows for each trial, and the median value was taken to represent the trial.

The data collected from LDF was integrated over non-overlapping 1 s windows for the 30 s time series. The 30, 1-s windows were averaged to obtain one representative value of blood flow following each work block. The initial LDF collection taken during the static state was considered the baseline blood flow measure, and the 10 following measures taken during the task were calculated as a percent change from this baseline. All analyses were done using Matlab software (Mathworks, Massachusetts, USA).

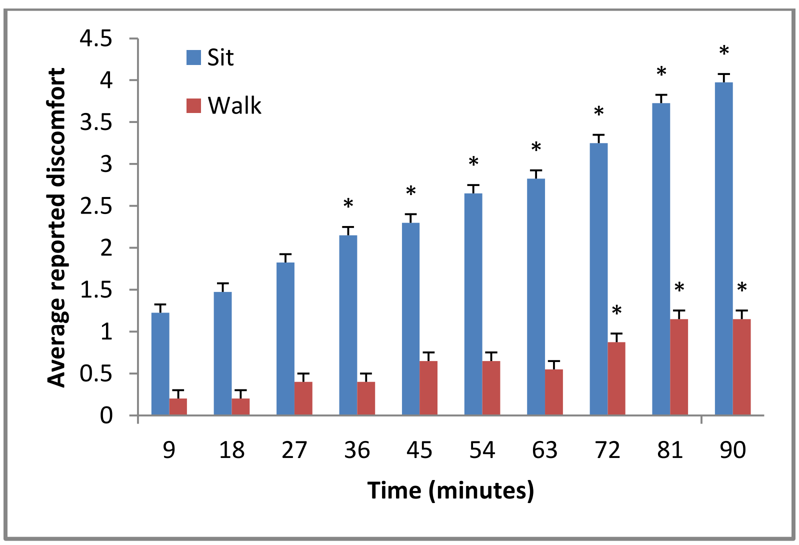
2.7 Statistical Analysis

Time (blocks 1-10) x Work posture (sit, walk) repeated measures ANOVA was run on the RMS, CV, NMI and LDF variables. A Friedman ANOVA of Work posture x Time was run on discomfort measures reported for the neck/shoulder. A post-hoc Wilcoxon paired analysis was run to establish where significant differences existed. Pearson Correlation Coefficients were computed using each subject's difference of Time 10 from Time 1 for the following variables: PSS scores; CES, UT, MT and LT average EMG RMS; Shoulder and Forearm LDF; and the computer performance measures [errors and adjusted words per minute (AWPM)]. Significance was set as $p < 0.05$. All analyses were run using SPSS software.

3. RESULTS

3.1 Discomfort and Performance

Upper limb (UL) reported discomfort was found to have a significant Posture effect (Friedman ANOVA (19,19), 153.95, $p < .0001$), with Wilcoxon post-hoc tests revealing significantly higher discomfort in the seated work posture, from time 1 through time 10 (see **Figure 3**). Significant Time effects were also seen for each of the postures *sit*: Friedman ANOVA (19,9), 89.258, $p < .0001$ and *walk*: Friedman ANOVA (20,9), 53.831, $p < .0001$. Wilcoxon Post-hoc tests revealed significant time-based differences (increases) from time period 1 in each of the postures, starting at 36 min during seated computer work, and at 72 min during walking. Average performance measures after sitting for 9 minutes yielded *errors*: 105.2 ± 42.68; *AWPM*: 40.32 ± 11.85 and after 90 minutes, yielded *errors*: 113.6 ± 48.84; *AWPM*: 41.22 ± 11.12. The average performance measures after walking for 9 minutes were: *errors*: 96.85 ± 47.63; *AWPM*: 41.50 ± 9.54 and after 90 minutes *errors*: 109.25 ± 50.68; *AWPM*: 42.25 ± 9.16. There were no significant effects found on any of the typing performance variables.



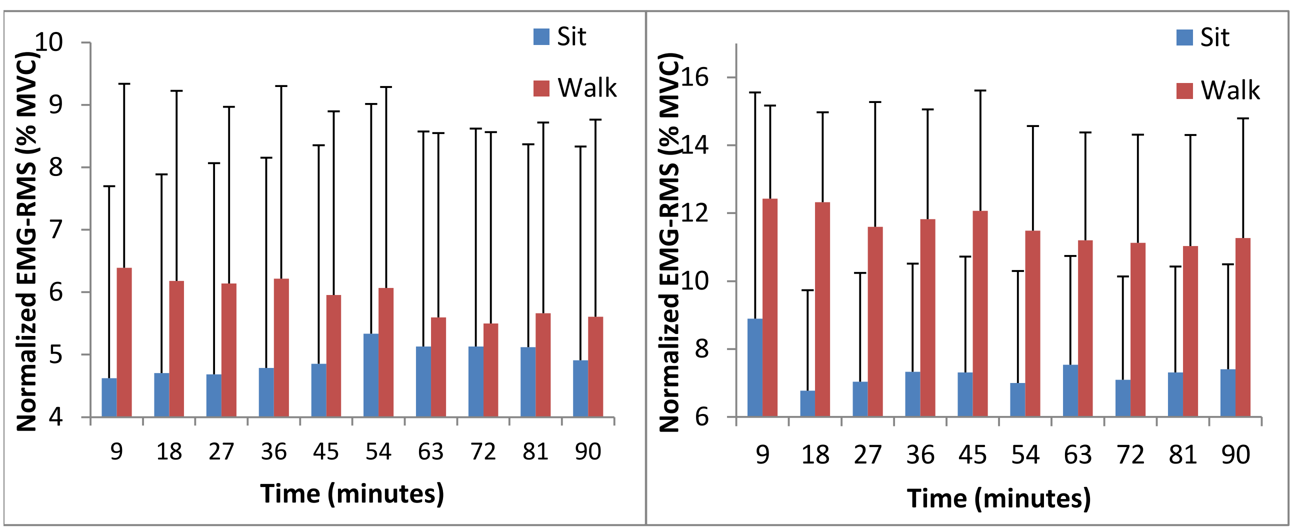
*$p < 0.05$

Figure 3 Discomfort ratings over time in the upper limb. Significant posture effects exist at each time period. A * denotes a significant time-based difference from the time period 1 within each posture.

3.2 Posture and Time Effects

Significant Time x Posture interaction effects were found in EMG RMS average values of two muscles, the LES [$F(9,144) = 2.845$, $p = .004$] (see **Figure 4a**) and Wext [$F(9,126) = 2.651$, $p = .008$] (see **Figure 4b**). Both muscles displayed decreases over time in the walking session but conversely increases with time were seen during sitting. Two muscles displayed significant Posture main effects, the AD [$F(1,15) = 9.447$, $p = .008$] and EO [$F(1,15) = 19.001$, $p = .001$].
The AD EMG was found to be 64% lower (as a % of MVC) during walking compared to sitting, whereas the EO EMG was found to be 43% higher during walking compared to sitting. A main effect of Time was also found in the LT [$F(9,144) = 2.068$, $p = .036$], where average muscle activity displayed a significant 7% increase from 9 mins to 90 mins. No other significant effects were found for average EMG-RMS variables.

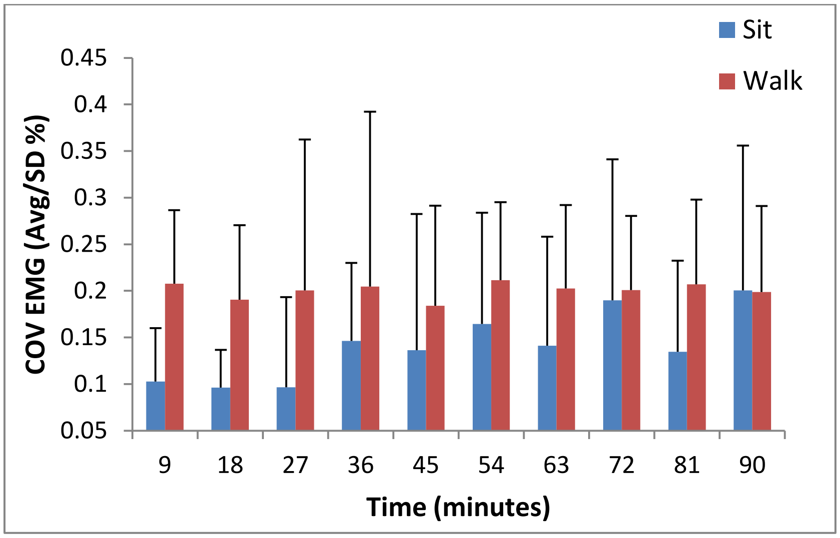
(a) **(b)**



$p < 0.01$

Figure 4 Average normalized EMG-RMS of the **(a)** LES muscle and **(b)** Wext muscle during sitting and walking. There are significant Time x Posture interaction effects for both.

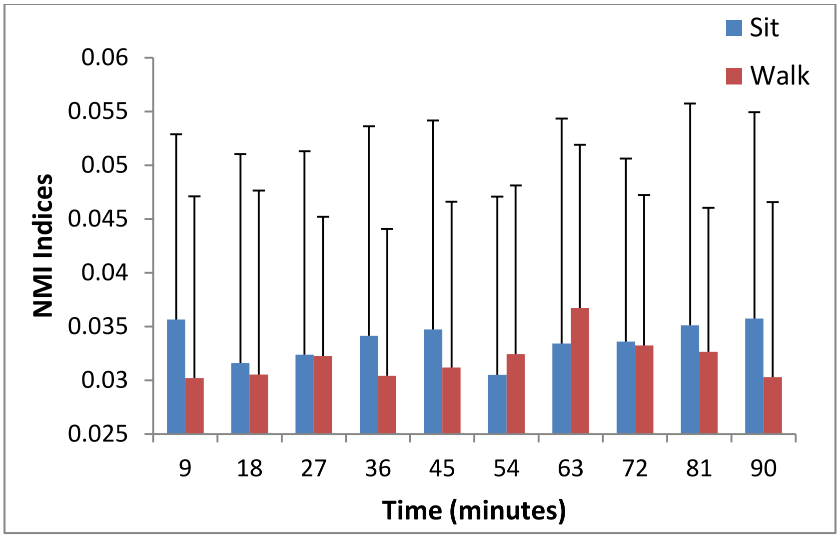
Results of CoV showed a Time x Posture interaction effect for the LES [$F(9,144) = 2.306$, $p = .019$] (see **Figure 5**). The variability of this muscle was shown to somewhat decrease over time with walking, but to increase while sitting. In addition, a significant Posture main effect was observed in the LT [$F(1,16) = 23.548$, $p = .000$], where 65% higher variability was displayed in the walking condition compared to sitting. No other effects were found significant for any of the other variability parameters.



$p < 0.05$

Figure 5 Variability (CoV) of the LES during sitting and walking. There is a significant Time x Posture interaction effect.

A significant interaction effect was found for NMI of the CES-AD muscle pair [$F(9,135) = 1.951$, $p = .050$]. There was somewhat of an increase in connectivity over time during sitting especially in the later blocks of the typing task, but an opposite pattern of decrease towards the end occurred during walking (see **Figure 6**). One muscle pair displayed a significant main effect of Time, the CES-LT [$F(9,144) = 2.479$, $p = .012$]. Connectivity was found to increase over time, for the two postures. A Posture effect was also shown between the muscle pair of LES-EO [$F(1,16) = 5.573$, $p = .031$]. The walking condition displayed significantly greater connectivity compared to sitting. No other effects were found for any of the other muscle pairs.



p < 0.05

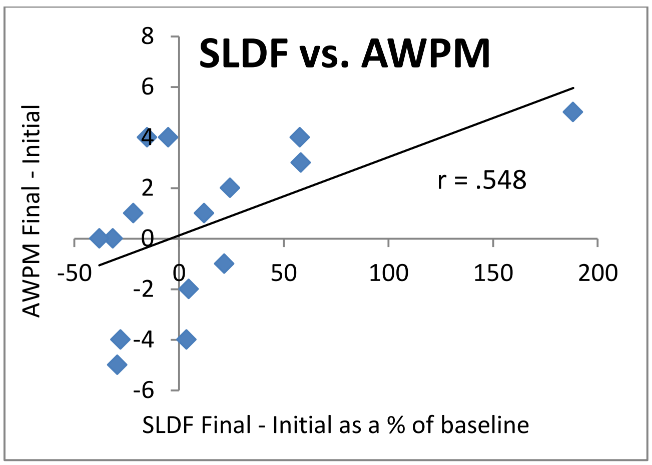
Figure 6 Normalized Mutual Information for the muscle pair CES-AD. There was a significant Time x Posture interaction effect.

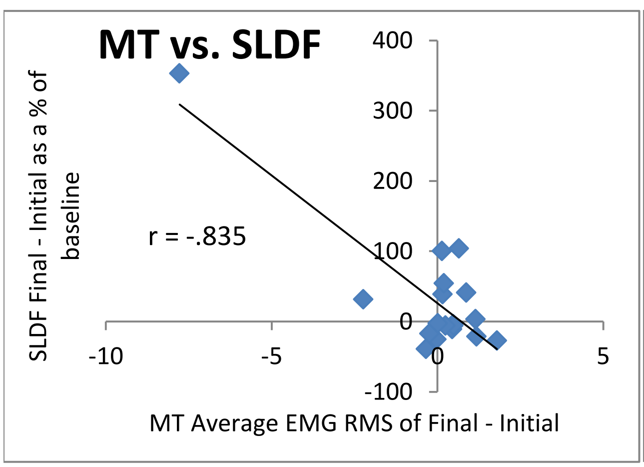
LDF analyses looking at percent change from baseline found increased blood flow with time at the Shoulder [$F(9,126) = 1.928$, $p = .054$] and Forearm [$F(9,117) = 1.736$, $p = .088$]. However, these results were found to not be statistically significant. There were no significant effects of Posture either (Shoulder: [$F(1,14) = 1.321$, $p = .270$], Forearm: [$F(1,13) = .934$, $p = .351$]).

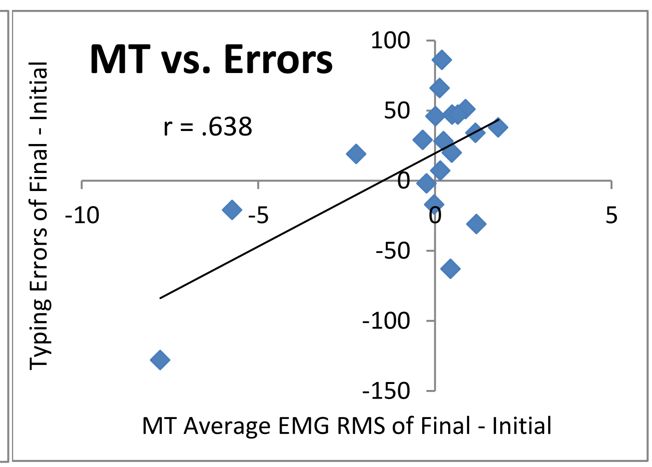
3.3 Correlations

The correlated time 10 – time 1 difference in variables revealed a significant positive correlation between SLDF and AWPM ($r = .548$, $p = .035$) (see **Figure 7a**) and a negative correlation between Errors and AWPM ($r = -.503$, $p = .033$) in the sitting posture. This indicates that subjects who had a greater increase in shoulder LDF also had the highest increase in words per minute (and vice versa). As well those subjects, who had the highest increase in typed words per minute, had the greatest decrease in number of errors. In the walking posture, significant positive correlations were found between CES and UT ($r = .498$, $p = .030$) as well as MT and Errors ($r = .638$, $p = .003$) (see **Figure 7c**). This indicates that subjects who displayed higher increases in muscle activity in the CES also displayed higher increases the activity of the UT. Also those subjects with higher increases in MT muscle activity also had a greater increase in typing errors. Finally, a significant negative correlation was also found between the MT and SLDF (r = -.835, p = .000) (see **Figure 7b**), indicating that subjects who had a low increase in the amount of muscle activity in their MT showed the highest increase in shoulder LDF. No other correlations were found significant.

(a)







(b) (c)

$p < 0.05$

Figure 7 Correlations between the Difference of time 10 – time 1 for (a) shoulder LDF and adjusted words per minute (sitting); (b) middle trapezius and shoulder LDF (walking); (c) middle trapezius and Errors (walking).

The stress scale (0 – indicating no stress up to 10 – highly stressed) which was measured before and after sessions yielded a lack of change in response from pre- to post-test; therefore these measures were chosen to be excluded from analyses. During the sitting session, average values showed pre-test: M = 0.211, SD = 0.419; and post-test: M = 1.18, SD = 1.81 displaying little change in stress levels. Similarly during walking, average values pre-test: M = 0.150, SD = 0.489; and post-test: M = 0.500, SD = 1.05 displayed a very small change from pre- to post-test.

4. Discussion

The purpose of this study was to quantify the effects of modifying traditional computer work posture on neck/shoulder muscular, vascular, discomfort and computer performance patterns during a prolonged computer work task. We hypothesized that the walking posture would produce less discomfort and require a lower amount of neck/shoulder muscle activity, compared to in the traditional seated work posture. We also hypothesized that while walking and working, muscle activity would be more variable and upper limb blood flow would be higher. Lastly, we hypothesized that there would be associations between blood flow, discomfort, variability and computer task performance.

4.1 Discomfort and Performance

The UL discomfort was found to be significantly lower during walking compared to sitting. In addition, there was a later onset of discomfort while walking and performing computer work: discomfort began to manifest after 72 minutes of walking, twice as late as compared to sitting. This may point to some mechanisms of walking which are beneficial in prolonging computer work in the absence of discomfort. These results are important in themselves since discomfort may lead to pain as part of the injury and chronicity pathway. However, additional analyses were conducted as part of this thesis so that biomechanical pathways for this discomfort could be further analyzed and understood. These additional results are interpreted below.

Interestingly there were no effects of time or posture on any of the typing parameters. John et al. (2009) and Straker et al. (2009) both observed impairments in computer performance while walking. However, those studies had not provided acclimation periods, and they used speeds of 1.6 km/h and 3.2 km/h. In comparison, a 2.25km/h walking speed (deemed to be an average, self-selected, comfortable speed in that study) was found to produce no decline in performance as observed by

Funk et al. (2012), therefore we believed that using this speed would produce similarly stable performance measures. Indeed, in our study, the practice session with the WaW prior to completing the WaW experimental session seems to have been beneficial in habituating participants to the workstation, at least in terms of computer performance. Thus, in order to obtain benefits from WaW without affecting performance, our results lead us to recommend an acclimation period, and regulation of the speed of walking while working.

4.2 Posture and Time Effects

Previous studies have found that increases in muscle activation over time may be associated with low-force, slow-developing fatigue and increased risk to develop musculoskeletal disorders (MSD) (Cooper and Straker, 1998; Aaras et al. 1997; Kleine et al. 1999). Our results showing increases in EMG RMS values of the LES, Wext, AD, EO, and LT denote that these muscles were significantly affected by the computer task. These activity amplitude increases may be small especially when normalized to each muscle's maximum voluntary activity levels, but it should be emphasized that these increases were observed over only 90min, suggesting that further increases could occur over a work day, which over time could represent a non-negligible muscular load during computer work. Moreover, the significant interaction effect of the LES muscle showed initially higher activity in the LES during walking. This seems plausible as this muscle, along with the EO which was also more activated while walking, may be working to stabilize the upper trunk and upper limbs against moving lower limbs, so that computer typing movements can be adequately performed. Although higher activity may place these muscles at greater risk of developing injuries, the initially high activity of the LES during walking displays a significant decrease over time and by the end of the 90-minute task, is nearly the same as the activity levels seen during sitting. One explanation of this finding is that motor learning takes place during the first few minutes of the walk and work task, with the body searching and finding upper trunk stabilizing strategies that at first depend on low back muscles, but that may eventually span more muscles. Alternatively, this low back muscle activity decrease may indicate that some other muscle recovery mechanisms take place during walking, but does not occur during sitting. Furthermore, the increases seen while sitting may indicate a negative effect as this may place the LES more at risk of developing risks of injury in a sitting position. Although the suggestion that seated work may place a higher strain on the low back may seem surprising at first, previous studies have suggested that seated work may indeed place a higher strain on low back structures than for instance the standing posture (Nachemson, 1966; Wilke et al. 2001). However, although higher disc compression and higher passive tissue strain in the seated position have been mentioned, little is known about the specific mechanisms that could underlie this somewhat high low back load in the seated position (Mork and Westgaard, 2009).

The Wext EMG RMS activity level was similar to levels reported previously during a seated computer study (Strom et al. 2009a). In our study, the significant interaction effect of the Wext muscle showed higher muscle activity during walking, although it increased over time only in sitting. Some previous research has found increases in forearm muscle activity to be due to increases in work speed (Bloemsaat et al. 2005) and workplace stressors (Eijckelhof et al. 2013). Considering that we did not observe any changes in typing speed or individual stress levels, this indicates that some other mechanism might be causing an increase in activity while sitting. Conversely, although initially higher while walking, the activity in the Wext is seen to decrease over time. A possible explanation for the initially higher level of Wext activity during walking may be an attempt to stabilize the forearms when walking and typing, as walking creates more lateral body sway. Furthermore, the decreased Wext activity with time during walking can be interpreted in a way similar as for the decreased trunk muscle activity: it could in part be due to habituation to the WaW task, so over time the subjects may become better apt to type while walking, or alternatively, could indicate that walking may help to induce an injury preventative response strategy of lowering Wext muscle activity.

The LES muscle displayed higher variability during walking compared to sitting, which is in line with our hypothesis, and with previous research that has found that high variability was associated with high endurance (Vandieen et al. 1993, Fedorowich et al. 2013). Furthermore, high motor variability has been hypothesized to prevent the development of symptoms and less variable movement patterns may be associated with a greater risk of injury (Mathiassen et al. 2003; Madeleine et al. 2008a). In the current study, the higher LES variability seen throughout the task during walking likely indicates a search to adapt to the novel task of typing while walking, with the added desirable effects of it being a good strategy for decreasing the risk of developing low back symptoms, as opposed to during sitting. However, the fact that variability was shown to somewhat increase with time in sitting suggests that it is possible for people to increase the variability of their low back musculature during prolonged sitting which could help alleviate discomfort and prevent the development of symptoms. Nevertheless, the fact that LES variability remains higher during walking compared to sitting, over the duration of the 90min task, supports that walking may be better than sitting with regards to low back strain. Another postural muscle but this time for the shoulder girdle, the LT - which displayed higher variability while walking compared to sitting, may play a role in steadying the arms for typing. Therefore greater variability in the LT may indicate a healthy adaptive mechanism to performing a prolonged typing task.

When looking at the analysis of between-muscle connectivity, 3 pairs of muscles exhibited significant effects. The muscle pair of CES-AD showed a significant interaction effect, with differing trends through time in the two postures, notably an increase over the last few work blocks while sitting and an opposite pattern of decrease towards the end while walking. The CES-LT connectivity was shown to increase over time in both of the postures, whereas the LES-EO displayed greater functional connectivity during walking compared to sitting. The statistical method of mutual information has only recently been developed and so not many studies have used this technique in analyzing muscle sharing activation patterns (Madeleine et al. 2011; Johansen et al. 2013; Fedorowich et al. 2013). Regardless, the increases over time seen in the CES-LT pair or the increase towards the end during sitting for the CES-AD pair seem in line with the findings from Madeleine et al. (2011) who found functional connectivity within the trapezius of males to increase with muscle fatigue. Although the computer task here was not fashioned to induce muscle fatigue, the significances seen in EMG RMS muscle activation may support that some muscles experienced fatiguing effects. Therefore the increased connectivity seen in these muscle pairs may suggest that over a prolonged time and during sitting, the CES may search for a muscle to partner with in order to share the load to continue the task, in line with the interpretation provided in Fedorowich et al. 2013. Conversely, during walking, the CES-AD pair showed a decrease in connectivity during the last few minutes of the task, which is in line with the decreases seen in NMI of the neck/shoulder area in the Fedorowich et al. (2013) study, although in that study, the task was performed to exhaustion. In that study, authors had alluded to strategies of lowering NMI as efficient strategies of isolating muscle fatigue effects in order to prevent the spread of symptoms across more muscles. Furthermore, Svendsen et al. (2011) found lower NMI between muscle pairs in the forearm during a dynamic task compared to a static task which could indicate a beneficial muscular strategy during active work. Thus, our results of decreased CES-AD connectivity with time during walking could also seem to be a beneficial strategy. However, the literature on functional connectivity remains very equivocal to this day, with arguments both in favour and against a possible protective role of between-muscle shared information on injury risk. In addition, it is possible that the role of functional connectivity on impacting motor behaviour could be muscle- and task-specific, in line with the interpretation of findings of changes in motor behaviour with fatigue in Fuller et al. (2009). Indeed, the studies referred to in this section investigated functional connectivity between a variety of pairs of muscles with different mechanical roles, and studied the tasks of eccentric shoulder efforts (Madeleine et al. 2011), sub-maximal box-folding (Johansen et al. 2013), repetitive pointing to exhaustion (Fedorowich et al. 2013) and computer work performed seated and standing. All of these tasks are quite different, and the associated task objectives likely also vary, from precision to force to coordinating a complex task, such that it is possible that in these various tasks, functional connectivity could at times be desirable, and at other times less so. Finally, it should be pointed out that surface EMG has shown muscle activity in the neck/shoulder area to exhibit low values during computer work, less than 10% of maximum contractions (Johansson et al. 1999; Roe and Knardahl, 2002; Blangsted et al. 2004). This overall low-level of muscle activity needed for the computer typing task may be the reason for fewer significant results compared to previous studies or to different types of fatigue experienced in other studies which may impact the mechanisms of the fatigue response (Hunter et al. 2006). Despite this, one last significant effect related to functional connectivity, the significantly higher mutual information between the trunk pair during walking, is easily explained by a need to coordinate the low trunk region during the highly stereotypical task of walking.

The pattern of blood flow to the forearm and upper limb during computer work is still not well understood at this time. Strom et al. (2009a) found blood flow to peak at 30 minutes during their 90-minute seated computer task and then decline afterwards. However, in that study, there were time and precision demands which may have played a role. We initially hypothesized that walking would increase blood flow in the neck/shoulder, as exercise has previously been shown to augment blood flow in non-working limbs (Green et al. 2002; Tanaka et al. 2006) and more specifically, the neck/shoulder area (Anderson et al. 2010). However, this effect turned out to be non-significant in our study. The difference between our results and those mentioned above could be explained by the fact that in all three previous studies, participants were not performing an upper limb task, and were instructed to relax their upper limbs, whereas in our study, the muscle activity required to stabilize the shoulders and forearms during computer work may have been sufficient to prevent a significant increase in blood flow to occur during walking. Another computer study also found significant blood flow increases in the upper trapezius during and after a mouse and keyboarding task (Roe and Knardahl, 2002). However, in that study, a catheter was used to sample blood flow and obtain more precise measurements. Moreover, this way, blood samples were measured while the subjects were performing computer work (as compared to our study, where blood flux was measured at rest immediately after computer work bouts), and the majority of the participants suffered from chronic shoulder pain. Thus, we interpret the absence of a significant effect of walking on blood flow in our study to be due to the stabilizing action required of the upper limb muscles, and also possibly to the surface measurement method. Lastly, our data may also be underpowered although these studies referred to had on average 8 (Green, Tanaka, Anderson) and 28 (Strom) healthy participants, which is comparable to our sample size.

4.3 Correlations

Despite the non-significant effects on blood flow, the significant correlation seen during sitting showed that those people with higher shoulder blood flow also typed more words per minute. One interpretation of this could be that techniques that are effective in augmenting upper limb blood flow should also be effective in augmenting productivity, which intuitively could be explained by a mechanism whereby more effective tissue regeneration mechanisms illustrated by increased blood flow would indeed be beneficial not only in terms of injury avoidance but in terms of productivity. However, during walking, the MT showed a significant negative correlation with shoulder LDF, with high increases in blood flow correlated with low increases in MT EMG. Here it should be noted that as seen in **Figure 5b**, one participant was identified as an outlier in this correlation; however, this participant displayed a high percent change from baseline in LDF and furthermore the MT was found to be working at a low percent of the MIVC. Therefore this subject showed a combined LDF and MT relationship that was consistent with the group, and was thus kept in the data set, as removing him did not affect these statistical trends anyway. Furthermore, the MT was also found to correlate significantly with typing errors, with higher increases in muscular load correlating with more errors. This could be an attempt at stabilizing the arms while walking. Taken together, these data point to the role of the MT muscle in impeding upper limb blood flow and computer performance, possibly through an action of stiffening the shoulder during computer work. Since no time or posture effects have been observed on MT EMG or NMI, other experimental conditions, for instance the absence of a backrest, could explain how some subjects could display elevated MT EMG with a consequence of preventing blood flow to the upper limbs. Yoo et al. (2012) indeed recommend using a backrest in order to decrease the requirement to activate the MT muscle to maintain shoulder posture during computer work. However, more detailed studies on the role of the MT muscle during computer work are required to precisely understand its role.

4.4 Limitations

A few limitations exist in relation to this study. The LDF electrode method we used is only able to detect superficial blood flow, and is sensitive to movement, so the subjects had to stop the typing task every 9 minutes for collection, which could be allowing some recovery time. Also 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, treadmill workstations may not be feasible in all work situations as they are costly and can be noisy, limiting the real-life usefulness of this study, although it remains that WaW are more and more popular in the work culture of advanced industrial societies.

5. Conclusion

The present study investigated effects of modifying computer work posture on neck/shoulder patterns during a prolonged computer task. Walking displayed lower muscle activity and higher variability patterns whereas sitting was characterized by higher inter-muscle patterns and greater discomfort. Correlations suggest that the middle trapezius may play a role in impeding upper limb blood flow and computer performance. This study contributes to the growing literature around walk-and-work computer workstations and may further help to identify mechanism-based interventions to reduce or even prevent neck/shoulder MSD.

Acknowledgements

In addition to the participants in the study, the authors wish to thank Kim Emery, David Antle, Amanda Farias and Zach Weber for their assistance in data collection and analyses.

CONCLUSION

This study contributes to the growing literature around WaW computer workstations and may further help to identify mechanism-based interventions to reduce or even prevent computer work-related neck/shoulder MSD. The interaction effects of decreasing LES and Wext muscle activity over time during walking may point to positive strategies developed while walking compared to sitting. Along with muscle activity, other muscular patterns have been observed to help identify if the walking posture while working could be beneficial. Higher variability and lower NMI have previously been hypothesized as possible ways to prevent the development of symptoms, therefore the muscular mechanisms observed during walking of higher variability displayed by the LES, and the decrease with time in mutual information for the CES-AD pair could indicate strategies that could be effective in prolonging symptom-free computer work while walking. Previous research has already identified that the use of a WaW computer workstation is beneficial to cardiovascular health risk factors (Thompson et al. 2008; Levine and Miller, 2007) and physical and psychological well-being (Erickson et al. 2011 ; Ben-Ner et al., 2014). Indeed our results, including the decreased upper limb discomfort while walking, may add to these previously documented benefits. Research has shown blood flow to be altered with computer work and although we did not observe changes over time, those individuals who typed at quicker speeds also displayed higher shoulder blood flow which may indicate that promoting blood flow to the upper limbs, for instance by walking, could have some beneficial effect on computer work productivity. Future research could help clarify this pathway between blood flow and computer work. Finally, the true effects of WaW on computer work-related health should be verified in studies of symptomatic groups to identify if WaW can actually relieve symptoms, and in prospective studies to verify if WaW is actually effective in preventing symptoms from developing. Nevertheless, this study provides some needed objective data to guide the use of WaW in a way that links to specific injury pathways, which provides novel information to this research area.

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APPENDICES

A. Consent Form (English version)

Better understanding for better prevention of work-related musculoskeletal disorders: a concerted, sex/gender sensitive approach (CIHR # 289726)

Consent form

1 - Title of project

Better understanding for better prevention of work-related musculoskeletal disorders: a concerted, sex/gender sensitive approach (CIHR # 289726)

2 - Researcher in charge of project

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

Larissa Fedorowich, B.Sc. Master Student in Kinesiology, McGill University, (450) 688-9550, ext 4827

Suzy Ngomo, Ph.D. Post Doctorate student in Kinesiology, McGill University, (450) 688-9550, ext 4827

Kim Emery, M.Sc. Research Assistant, Jewish Rehabilitation Hospital/McGill University, (450) 688-9550, ext 4827

3 - Introduction

Before agreeing to participate in this project, please take the time to read and carefully consider the following information.

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

This consent form may contain words that you do not understand. We invite you to ask any question that you deem useful to the researcher and the others members of the staff assigned to the research project and ask them to explain any word or information which is not clear to you.

4 - Project description and objectives

The objective of this research is to study the effects of the computer work posture on muscular, postural and cardiovascular outcomes. Fourteen healthy female and 14 generally healthy male adults will be recruited to complete a simulated computer work protocol for 90 minutes. Participants will perform 3 sessions of computer work in 3 different postures (sitting, standing and walking on a treadmill) in which they will be asked to work at a computer for 90 minutes (writing and editing text). Equipment will be placed on participants in order to record muscle activity, blood flow and tridimensional posture. The long-term objectives of this research are to better understand and quantify the impact of work posture on health outcomes.

5 - Nature and duration of participation

The research project in which you are invited to participate aims at understanding the impact that the computer work posture has on muscles, posture and blood flow. The experimental procedure will be performed at the research center of the Jewish rehabilitation hospital. You are asked to participate in 3 experimental sessions, which will last approximately three hours each, with at least 48 hours between consecutive sessions. During each session, we will ask you to wear sport shoes and a tight fitting tank top.

If you choose to participate in this study, there will be two phases in each session: a preparation phase, and an experimental phase. The preparation will last approximately 1 hour and will remain the same for the 3 sessions. Surface electrodes will be fixed on the skin over muscles of your trunk and arms in order to measure muscle activity and blood flow. Reflective markers will be placed over your trunk and arms. None of these procedures are invasive. Baseline (rest) measures will be recorded. Also, you will be asked to complete several efforts using your trunk and arm muscles.

After the preparation phase, you will be asked to perform a computer task in one of the chosen postures (sitting, standing and walking) for a total of 90 minutes (Figure 1). The computer task will consist of typing a text as quickly and error-free as possible. You will be asked to come back two other times in order to test all three postures. A practice trial will be provided at the end of the session before the walking session. At various points during the task the research equipment will collect data. Each 10min, you will be asked to stop working for about 1min so that other data will be collected. At various points during the experiment, the researcher will ask you to give your subjective opinion about the difficulty of the task your discomfort during the task. You are free to leave the experiment at any point if you do not wish to continue, or if you are not comfortable with the procedure.

Figure 1: experimental setup, walking condition

6 - Advantages associated with my participation

As a participant you will receive no direct benefit from your involvement in this study. However, you will contribute to the fundamental science of human physiology and biomechanics and to applied knowledge in ergonomics and occupational health.

7 - Risks associated with my participation

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

8 - Personal inconvenience

The duration of each session (approximately 3 hours) and the fact that you need to come back two times may represent an inconvenience for you. The possibility that a few small areas (8, 3x3 cm each) of the skin over your back, stomach and arms may have to be shaved before positioning the electrodes might also be an inconvenience to 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. You may experience some slight fatigue towards the end of the session, which may cause some neck, trunk, and lower limb muscle tenderness or stiffness. If this occurs, symptoms should dissipate within 48 hours following the completion of the protocol. A clinician will be present at all times during the protocol in case of allergic reaction, non-anticipated injury or accident.

9 - Access to my medical file

No access to your medical file is required for this study.

10 - Confidentiality

All the personal information collected for this study will be codified to insure its confidentiality. Only the people involved in the project will have access to this information. However, for means of control of the research project, your research records could be consulted by a person mandated by the REC of the CRIR establishments or by the ethics unit of the ministry of health and social services, which adheres to a strict confidentiality policy. Information will be kept under locking key at the research center of the Jewish Rehabilitation Hospital by the person responsible for the study for a period of five years following the end of the study, after which it will be destroyed. If the results of this research project are presented or published, nothing will allow your identification.

12 - Withdrawal of subject from study

Participation in the research project described above is completely voluntary. You have the right to withdraw from the study at any moment. If ever you withdraw from the study, all documents concerning yourself will be destroyed at your request.

13 - Responsibility

By accepting to participate in this study, you do not surrender your rights and do not free the researchers, sponsor or the institutions involved from their legal and professional obligations.

14 - Monetary compensation

No monetary compensation will be given to you for participation in this protocol. Transport costs encumbered by our participation in this research can be reimbursed upon request and upon receipt of appropriate documentation.

15 - 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 Larissa Fedorowich at larissa.fedorowich@mail.mcgill.ca or at (450) 688-9550,. For further questions related to this study, you may also contact M. Michael Greenberg, local commissioner for complaints at the JRH, at (450) 688-9550, extension 232.

Also, if you have any questions concerning your rights regarding your participation to this research project, you can contact Ms. Anik Nolet, Research ethics co-ordinator of CRIR at (514) 527-4527 ext. 2649 or by email at anolet.crir@ssss.gouv.qc.ca.

CONSENT

I declare to have read and understood the project, the nature and the extent of the project, as well as the risks and inconveniences I am exposed to as described in the present document. I had the opportunity to ask all my questions concerning the different aspects of the study and to receive explanations to my satisfaction.

I, undersigned, voluntarily accept to participate in this study. I can withdraw at any time without any prejudice. I certify that I have received enough time to take my decision.

A signed copy of this information and consent form will be given to me.

NAME OF PARTICIPANT (print): ________________________________

SIGNATURE OF PARTICIPANT: ________________________________

SIGNED IN ...., on ...., 20 ......

COMMITMENT OF RESEARCHER

I, undersigned, ________________________________, certify

(a) having explained to the signatory the terms of the present form ;

(b) having answered all questions he/she asked concerning the study ;

(c) having clearly told him/her that he/she is at any moment free to withdraw from the research project described above; and

(d) that I will give him/her a signed and dated copy of the present document.

____
Signature of person in charge of the project or representative

SIGNED IN ...., on .... 20 ...

B. Consent Form (French version)

Formulaire de consentement

1 - Titre du projet

Meilleure compréhension pour une meilleure prévention des troubles musculosquelettiques : une approche concertée et sensible au sexe/genre (CIHR # 289726)

2 - Responsable(s) du projet

Julie Côté, Ph.D. professeure agrégée, département de kinésiologie et d'éducation physique, université McGill, (514) 398-4184 poste 0539, (450) 688-9550, poste 4813.

Larissa Fedorowich, B.Sc. étudiant à la maîtrise en Kinésiologie, université McGill, (450) 688-9550, poste 4827.

Suzy Ngomo, Ph.D. étudiante postdoctorale en Kinésiologie, université McGill, (450) 688-9550, poste 48247

Kim Emery, M.Sc. Assistante de recherche, Hôpital Juif de Réadaptation/Université McGill, (450) 688-9550, poste 4827

3 - Préambule

Avant d'accepter de participer à ce projet de recherche, veuillez prendre le temps de comprendre et de considérer attentivement les renseignements qui suivent.

Ce formulaire de consentement vous explique le but de cette étude, les procédures, les avantages, les risques et inconvénients, de même que les personnes avec qui communiquer au besoin.

Le présent formulaire de consentement peut contenir des mots que vous ne comprenez pas. Nous vous invitons à poser toutes les questions que vous jugerez utiles au chercheur et aux autres membres du personnel affecté au projet de recherche et à leur demander de vous expliquer tout mot ou renseignement qui n'est pas clair.

4 - Description du projet et de ses objectifs

L'objectif de cette recherche est d'étudier les effets de différentes postures de travail à l'ordinateur (assis, debout et en marchant) sur des indicateurs musculaires, posturaux et cardiovasculaires. Quatorze hommes et

14 femmes adultes, en bonne santé générale, seront recrutés pour compléter un protocole de travail simulé à l'ordinateur pour 90 minutes. Les participants devront effectuer trois séances de travail à l'ordinateur soit assis, debout, et en marchant sur un tapis roulant et on leurs demandera d'effectuer certaines tâches à l'ordinateur (correction et rédaction de texte). De l'équipement sera installé sur les participants pour enregistrer l'activité des muscles, le flux sanguin et la posture tridimensionnelle. Les objectifs à long terme de cette recherche sont de mieux comprendre et quantifier l'impact de la posture de travail sur les indicateurs de santé.

5 - Nature et durée de la participation

Le projet de recherche auquel vous êtes invité(e) à participer cherche à comprendre l'impact de la posture de travail à l'ordinateur sur les muscles, la posture et le flux sanguin. Le protocole de recherche sera effectué au centre de recherche de l'Hôpital juif de réadaptation. On vous demande de participer à trois séances expérimentales d'une durée approximative de 3 heures chacune, avec au moins 48 heures entre chaque séance. Durant chaque séance, on vous demandera de porter des souliers de sport et une camisole ajustée à la peau.

Si vous acceptez de participer à cette étude, il y aura deux phases par séance : une phase de préparation et une phase expérimentale. La phase de préparation durera environ une heure et sera la même pour les trois séances. Des électrodes de surface seront fixées sur la peau des muscles de votre tronc, et de vos bras afin de mesurer l'activité des muscles et le flux sanguin. Des marqueurs réfléchissants seront posés sur votre tronc et vos bras. Aucune de ces procédures n'est invasive. Des mesures de base (repos) seront effectuées. On vous demandera aussi d'effectuer quelques efforts maximaux avec les muscles de votre tronc et de vos bras.

Après la phase de préparation, vous effectuerez une tâche à l'ordinateur à partir de la posture expérimentale choisie (assis, debout ou en marchant) pour un total de 90 minutes (Figure 1). La tâche à l'ordinateur consistera à copier un texte aussi rapidement et sans erreurs que possible. On vous demandera de revenir au laboratoire pour deux autres séances afin de pouvoir tester toutes les postures. Une période de pratique sera mise à votre disposition à la fin de la séance précédant celle sur le tapis roulant. À certains moments durant la tâche, l'équipement de recherche enregistrera des données. À chaque 10min, on vous demandera d'interrompre la tâche pendant environ 1min afin d'enregistrer d'autres données. A certains moments durant le protocole, le chercheur vous demandera de donner votre opinion subjective à propos de la difficulté de la tâche et votre inconfort durant la tâche. Vous serez libre d'abandonner le protocole à tout moment si vous ne voulez pas continuer ou si vous êtes inconfortable à propos de la procédure.

Figure 1 : montage expérimentale, condition de marche

6 - Avantages pouvant découler de votre participation

En tant que participant, vous ne retirerez personnellement pas d'avantages à participer à cette étude. Toutefois, vous aurez contribué à l'avancement de la science fondamentale de la physiologie humaine et de la biomécanique et aux connaissances appliquées de l'ergonomie et la santé au travail.

7 - Risques pouvant découler de votre participation

Aucune des procédures décrites n'est invasive. Votre participation à cette recherche ne vous fait courir aucun risque médical.

8 - Inconvénients personnels

La durée de chaque séance expérimentale (environ trois heures chacune) et le fait de devoir revenir deux autres fois peut représenter un inconvénient pour certaines personnes. La possibilité que quelques régions (8, 3x3 cm chaque) de la peau de votre colonne et de vos bras doivent être rasées avant d'y apposer des électrodes peut également représenter un inconvénient pour vous. Bien qu'il soit hypo-allergène, le ruban adhésif utilisé pour maintenir les électrodes sur la peau peut occasionnellement provoquer de légères irritations de la peau. Le cas échéant, une lotion hypo-allergène sera appliquée pour soulager l'irritation cutanée. De plus, Il est possible que vous ressentiez une légère fatigue vers la fin de la séance expérimentale, ce qui pourrait causer de la sensibilité ou de la raideur des muscles du cou, de la colonne ou des jambes. S'ils se manifestent, les symptômes devraient disparaître dans les 48 heures suivant la fin du protocole expérimental. Un clinicien sera présent en tout temps durant le protocole en cas de réaction allergique, blessure ou accident non anticipés.

9 - Accès à mon dossier médical

L'accès à votre dossier médical n'est pas requis pour cette étude.

10 - Confidentialité

Tous les renseignements personnels recueillis à votre sujet au cours de l'étude seront codifiés afin d'assurer leur confidentialité. Seuls les membres de l'équipe de recherche y auront accès. Cependant, à des fins de contrôle du projet de recherche, votre dossier de recherche pourrait être consulté par une personne mandatée par le CÉR des établissements du CRIR ou de l'Unité de l'éthique du ministère de la Santé et des Services sociaux, qui adhère à une politique de stricte confidentialité. Ces données seront conservées sous clé au centre de recherche de l'Hôpital juif de réadaptation par le responsable de l'étude pour une période de 5 ans suivant la fin du projet, après quoi, elles seront détruites. En cas de présentation de résultats de cette recherche ou de publication, rien ne pourra permettre de vous identifier.

12 - Retrait de la participation du sujet

Votre participation au projet de recherche décrit ci-dessus est tout à fait libre et volontaire. Il est entendu que vous pourrez, à tout moment, mettre un terme à votre participation. En cas de retrait de votre part, les documents électroniques et écrits vous concernant seront détruits à ma demande.

13 - Clause de responsabilité

En acceptant de participer à cette étude, vous ne renoncez à aucun de vos droits ni ne libérez les chercheurs, le commanditaire ou les institutions impliquées de leurs obligations légales et professionnelles.

14 - Indemnité compensatoire

Aucune compensation financière ne vous sera offerte pour votre participation à cette étude. Des frais de déplacement encourus par la participation à cette recherche pourront vous être remboursés à votre demande et sur présentation de pièces justificatives.

15 - Personnes ressources

Si vous désirez poser des questions sur le projet ou signaler des effets secondaires, vous pouvez rejoindre en tout temps Larissa Fedorowich, étudiante à la maîtrise, à larissa.fedorowich@mail.mcgill.ca, ou au (450) 688-9550 poste 4827. Vous pouvez également contacter Monsieur Michael Greenberg, commissaire local au plaintes de l'HJR, au (450) 688-9550 poste 232.

De plus, si vous avez des questions sur vos droits et recours ou sur votre participation à ce projet de recherche, vous pouvez communiquer avec Me Anik Nolet, coordonnatrice à l'éthique de la recherche des établissements du CRIR au (514) 527-4527 poste 2649 ou par courriel à l'adresse suivante: anolet.crir@ssss.gouv.qc.ca

CONSENTEMENT

Je déclare avoir lu et compris le présent projet, la nature et l'ampleur de ma participation, ainsi que les risques auxquels je m'expose tels que présentés dans le présent formulaire. J'ai eu l'occasion de poser toutes les questions concernant les différents aspects de l'étude et de recevoir des réponses à ma satisfaction.

Je, soussigné(e), accepte volontairement de participer à cette étude. Je peux me retirer en tout temps sans préjudice d'aucune sorte. Je certifie qu'on m'a laissé le temps voulu pour prendre ma décision.

Une copie signée de ce formulaire d'information et de consentement doit m'être remise.

NOM DU SUJET ____

SIGNATURE ____

Signé à _________________________, **le** ___________, **20**_____.

ENGAGEMENT DU CHERCHEUR

Je, soussigné (e), ________________________________ certifie

(a) avoir expliqué au signataire les termes du présent formulaire;

(b) avoir répondu aux questions qu'il m'a posées à cet égard;

(c) lui avoir clairement indiqué qu'il reste, à tout moment, libre de mettre un terme à sa participation au projet de recherche décrit ci-dessus;

et (d) que je lui remettrai une copie signée et datée du présent formulaire.

____
Signature du responsable du projet
ou de son représentant

Signé à __________________, le ______________ 20__.