Muscle Activation Patterns and Neck-Shoulder Pain in Computer Work

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ABSTRACT

Prolonged computer work is associated with high rates of neck and shoulder pain symptoms, and as computers have become increasingly more common, it is becoming critical that we develop sustainable interventions targeting this issue. Static muscle contractions for prolonged periods often occur in the neck/shoulder during computer work and may underlie muscle pain development in spite of rather low relative muscle load levels. Causal mechanisms may include a stereotypical recruitment of low threshold motor units (activating type I muscle fibers), characterized by a lack of temporal as well as spatial variation in motor unit recruitment. Based on this theory, although studies have postulated that individuals with chronic neck-shoulder pain will show less variation in muscle activity compared to healthy individuals when engaged in repetitive/monotonous work, this has seldom been verified in empirical studies of actual computer work.

Studies have rarely addressed temporal patterns in muscle activation, even though there is a consensus that temporal activation patterns are important for understanding fatigue and maybe even risks of subsequent musculoskeletal disorders. This study applied exposure variation analysis (EVA) to study differences in temporal patterns of trapezius muscle activity as individuals with and without pain performed computer work. The aims of this study were to: Assess the reliability of EVA to measure variation in trapezius muscle activity in healthy individuals during the performance of computer work; Determine the extent to which healthy subjects differ from those with chronic pain in trapezius muscle activity patterns during computer work, measured using EVA.

Thirteen touch-typing, right-handed participants were recruited in this study (8 healthy; 5 chronic pain). The participants were asked to complete three 10-minute computer tasks (TYPE, CLICK and FORM) in two pacing conditions (self-paced, control-paced), with the healthy group completing two sessions and the pain group completing one. Activation of the upper trapezius muscle was measured using surface electromyography (EMG). EMG data were organized into 5x5 EVA matrices with five amplitude classes (0-6.67, 6.67-20, 20-46.67, 46.67-100, >100% Reference Voluntary Exertion) and five duration classes (0-1, 1-3, 3-7, 7-15, >15 seconds). EVA marginal distributions (along both amplitude and duration classes) for each EVA class, as well as summary measures (mean and SD) of the marginal sums along each axis were computed. Finally, “resultant” mean and SD across all EVA cells were computed. The reliability in EVA indices was estimated using intra-class correlation coefficients (ICC), coefficient of variation (CV)

and standard error of measurement (SEM), computed from repeated measurements of healthy individuals (aim 1), and EVA indices were compared between groups (aim 2).

Reliability of EVA amplitude marginal sums ranged from moderate to high in the self-paced condition and low to moderate in the control-paced condition. The duration marginal sums were moderate in the self-paced condition and moderate to high in the control-paced condition. The summary measures (means and SDs) were moderate to high in both the self-paced and control-paced condition. Group comparisons revealed that individuals with chronic pain spent longer durations of work time in higher EVA duration categories, exhibited larger means along the amplitude, duration and in the resultant, and higher EVA SD in the amplitude and duration axes as compared to the healthy group.

To our knowledge, this is the first study to report on the reliability of EVA applied specifically to computer work. Furthermore, EVA was used to assess differences in muscle activation patterns as individuals with and without chronic pain engaged in computer work. Individuals in the pain group seemed to exhibit prolonged sustained activation of the trapezius muscle to a significantly greater extent than controls, even though they did not experience pain during the performance of the computer tasks (as obtained through self-reports). Thus, these altered muscle recruitment patterns observed in the pain subjects, even in the absence of task-based pain/discomfort, are suggestive of chronic motor control changes occurring in adaptation to pain, and may have implications for the etiology of neck and upper-limb musculoskeletal disorders.

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GENERAL AUDIENCE ABSTRACT

This study aims to assess the reliability of exposure variation analysis (EVA) to measure variation in trapezius muscle activity in healthy individuals during the performance of computer work, and determine the extent to which healthy subjects differ from those with chronic pain in trapezius muscle activity patterns during computer work, measured using EVA. Muscle activation was recorded for eight healthy individual and five suffering from chronic neck-shoulder pain. The data were then categorized into amplitude and continuous time categories, and summary measures of resulting distributions were calculated. These measures were used to assess reliability of participant responses to computer work of healthy individuals, as well as quantify differences between those with and without chronic pain. We found that individuals with pain activated their neck-shoulder muscles for longer continuous durations than healthy individuals, thus showing an inability to relax their muscles when performing work.

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To my mother, you are my rock and my best friend. Thank you for guiding me, sacrificing for me, and taking all of those road trips with me across the country. You are my biggest supporter, and I love you so much. To my father – the love of my life – although you are no longer with us, you made me strong and losing you made me even stronger. To my grandmother, thank you for being my greatest motivation, and to my big brothers, thank you for being my protectors. I also want to thank the rest of my family and friends for laughing and crying with me, and my spiritual coverings for reminding me who I am through this process.

Most importantly, I want to thank God. Without Him, this would not be possible. For I know it is not my ability, but my availability that allowed for this research work and thesis to happen:

> *"But by the grace of God I am what I am: and His grace which was bestowed upon me was not in vain; but I labored more abundantly than they all: yet not I, but the grace of God which was with me.*
>
> *– I Corinthians 15:10*

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1 Introduction

1.1 Computer Work and Risk Factors for Neck-Shoulder Pain Symptoms

In recent years, computers have become increasingly more common, with 78.5 percent of American households reporting ownership of a desktop or laptop computer in 2013 (File & Ryan, 2014). The annual prevalence of neck pain interfering with performance of daily activities was reported to be 11% in the United Kingdom (Palmer et al., 2001), and 14.1% in Canada (Leroux, Dionne, Bourbonnais, & Brisson, 2005). In the United States, the incidence rate of neck and shoulder musculoskeletal disorders (MSDs) was reported to be 35 cases out of every 100 computer workers, with the incidence rate of pain symptoms going up to 58% (Gerr et al., 2002). According to results of the Bone and Joint Decade 2000–2010 Task Force on Neck Pain (P. Côté et al., 2009), in office workers, the 1-year prevalence of neck pain varied from 17.7% in Norwegian administrative workers to 43.2% in Brazilian call center operators and 63.0% in Swedish secretaries. Other more recent reports indicate that the incidence rate of pain symptoms associated with computer work were still as high as 55% over one year, as of 2014 (Sadeghian, Raei, & Amiri, 2014).

Several studies have shown that the risk of upper-extremity musculoskeletal disorders increase with duration of computer work (Blatter & Bongers, 2002; Gerr, Monteilh, & Marcus, 2006; Jensen, 2003; Marcus et al., 2002). Along with non-neutral postures, static postures of the upper arms and hands, static muscle loads in the upper trapezius, and high repetitiveness of upper extremity movements while performing keyboard and mouse work are believed to be the key physical factors associated with high rates of pain symptoms in this population (Gerr, Marcus, & Monteilh, 2004).

While there has been extensive research on investigating the risk factors associated with work-related MSDs among computer workers, the etiology and work-relatedness of their disorders has been particularly complex to trace, with some researchers even being hesitant to relate any aspects of computer work as causal factors for clinically diagnosed MSDs (e.g. Wærsted, Hanvold, & Veiersted, 2010). Other researchers have attempted to uncover the etiology of neck-shoulder pain symptoms (instead of MSDs) associated with computer work (e.g. P. Côté et al., 2009). In this context, epidemiological evidence has identified three types of risk factors that put individuals at risk: *physical risk factors* such as force and repetition (e.g. Armstrong & Silverstein, 1987; Rempel, Harrison, & Barnhart, 1992; Silverstein, Fine, & Armstrong, 1987); *individual factors* such as age, gender, work technique and even personality type such as Type-A behavior (e.g. J. N. Côté, 2012; Hooftman et al., 2016; Malchaire, Cock, & Vergracht, 2001); and *psychosocial factors* including work environment stressors such as job demands, decision latitude and other social contextual descriptors (e.g. Andersen et al., 2003; Cassou, Derriennic, Monfort, Norton, & Touranchet, 2002; Feveile, Jensen, & Burr, 2002; Harkness, Macfarlane, Nahit, Silman, & McBeth, 2003;

Leclerc, Chastang, Niedhammer, Landre, & Roquelaure, 2004; Leclerc, Landre, Chastang, Niedhammer, & Roquelaure, 2001; Macfarlane, Hunt, & Silman, 2000; Torp, Riise, & Moen, 2001).

Using a best-evidence synthesis approach, P. Côté et al. (2009) has proposed a map of the causal pathways in transition from an asymptomatic state to a pain state, to guide future etiological research. A modified version of this etiological diagram is shown in Figure 1.

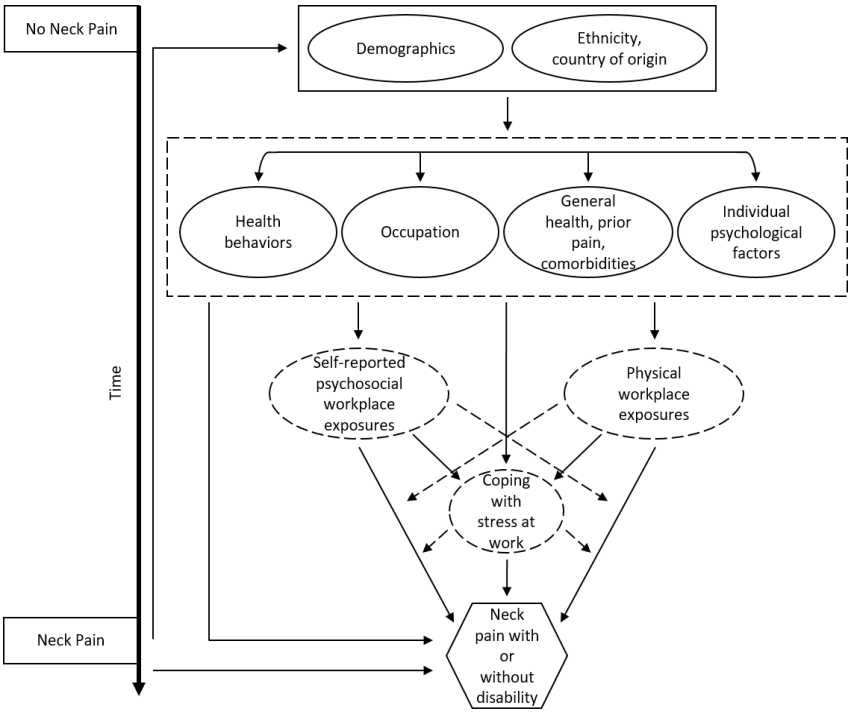

Figure 1 Etiological diagram based on P. Côté (2009) mapping risk factors with pain

This diagram classifies risk factors into 2 types: those that are inherent to the worker and those that are related to the workplace. The risk factors inherent to the worker are represented on the top panels of Figure 1. They include physical, psychological and individual factors and are grouped into 6 categories: 1) demographic; 2) ethnicity; 3) health behaviors; 4) occupation; 5) general health, prior pain and comorbidities; and 6) individual psychological factors. The risk factors related to the workplace are represented below and have been grouped into 3 categories: 1) psychosocial workplace exposures; 2) physical workplace exposures; and 3) how the worker copes with stress at work. The map in Figure 1 suggests that risk factors inherent to the worker can have a direct effect on the development of pain with or without functional limitations (represented by the uninterrupted arrow starting at the far left and pointing to pain). Risk factors inherent to the worker can also have indirect mediating effects on neck pain, with workplace factors also having a mediating effect (represented by arrows between risk factors inherent to the worker and those related to the workplace). Furthermore, co-existing risk factors inherent to the worker may be correlated (represented by curved arrows between risk factors). While this and other epidemiological evidence and pain models suggest the complex, multi-faceted nature of these disorders, they do not elucidate the underlying pathophysiological changes accompanying the development of pain symptoms, and how behaviors are progressively modified during chronic pain.

1.2 The Trapezius Muscle

Muscular pain resulting from static work, or "occupation myalgia" (Lundervold, 1951) is common in computer work where postural muscles, such as the trapezius, have low and sustained muscle activity. The trapezius muscle is a complex, superficial muscle in the upper back and neck regions that consists of distinct anatomical and functional subdivisions, or "neuromuscular compartments" (Holtermann et al., 2009). With distinct origin and insertion points, these compartments have different muscle fiber directions and therefore, different mechanical actions (Johnson, Bogduk, Nowitzke, & House, 1994; Johnson & Pandyan, 2005). The muscle fibers of the upper trapezius, descending from the superior ligamentum nuchae, contract to oppose the moment about the sternoclavicular joint, elevating the shoulder. The muscle fibers of the middle trapezius, which are mostly transverse in orientation, work to pull the clavicle backwards and medial. Finally, the lower muscle fibers of the trapezius ascend from below the 1st thoracic vertebrae to the medial border of the deltoid tubercle on the scapula, stabilizing the scapula while also aiding the middle trapezius (Johnson et al., 1994; Lindman, Eriksson, & Thornell, 1990).

There are distinctions in the muscle fiber composition within the descending trapezius muscle. Within the lower regions of the descending trapezius, there is a predominance of type I motor units, which is distinctive of postural muscles. This is also true for the transverse and ascending trapezius. On the other hand, the superior region of the descending trapezius muscle has a higher frequency of type II motor units that when stimulated, causes rotational movement in the head (Lindman et al., 1990). In a study by Lindman et al. (1991) comparing the muscle biopsies of healthy female participants and those suffering from trapezius myalgia, changes to the fiber composition were found for those with chronic trapezius myalgia. Those pathological subjects exhibited larger type I motor units and lower ratio of capillary to fiber area for both type I and type IIA motor units compared to healthy controls, which may be representative of an adaptive strategy to frequent use of those motor units (Edwards, 1988; Salmons & Henriksson, 1981). The study went on to suggest that increase in fiber area, despite long absences from work, may be caused by changes in central motor control mechanisms (Edwards, 1988; Lindman et al., 1991). Additionally, a lower capillary to fiber area ratio results in a larger diffusion distance, meaning that a small volume of blood is available. These morphological changes may be related to the development of muscle fatigue and pain (Lindman et al., 1991), and therefore, the balance of muscle activity between these subdivisions of the trapezius may play a role in the development and rehabilitations of neck and shoulder musculoskeletal disorders (Cools, Declercq, Cambier, Mahieu, & Witvrouw, 2007; Ludewig & Cook, 2000).

Thus, given the important functional postural and stabilization roles of the trapezius muscle during computer work and strong prior evidence in the literature on trapezius muscle activation playing a major

role in the development of chronic neck/shoulder pain, we chose to investigate trapezius muscle activation in our work.

1.3 Muscle Activity and Pain in Computer Work

Static sustained and monotonous repetitive muscle contractions for prolonged periods often occur in the neck/shoulder during computer work and may underlie muscle pain development in spite of rather low relative muscle load levels. Causal mechanisms may include a stereotypical recruitment of low threshold motor units (activating type I muscle fibers), characterized by a lack of temporal as well as spatial variation in motor unit recruitment (Sjøgaard, Lundberg, & Kadefors, 2000). Since not all motor units have to be recruited to produce the necessary submaximal force in low load tasks, there is unequal distribution of loads among motor units, and only some motor units in a muscle are activated. According to Henneman's size principle (Henneman, Clamann, Gillies, & Skinner, 1974), smaller type I motor units are activated during such low-intensity work, causing stereotypical motor recruitment patterns (Madeleine, 2010; Madeleine & Madsen, 2009; Madeleine, Mathiassen, & Arendt-Nielsen, 2008). Accordingly, the Cinderella hypothesis postulates that such stereotypical recruitment patterns of type I motor units can cause fiber damage, as the Cinderella fibers may be intensely active even though the overall force developed by the whole muscle is not excessive (Hägg, 1991). Empirical evidence in support of this hypothesis has been documented by some studies: e.g. Motor unit firing frequencies recorded using needle electrodes in shoulder muscles confirmed a very high activation of specific motor units for specific tasks (Søgaard, Laursen, Jensen, & Sjøgaard, 2001).

Pain may also be symptomatic of an underlying challenge in the neuromuscular system. It originates in nociceptive free nerve endings, which are located within the muscle interstitium. These nociceptors are sensitive to chemical and mechanical stimuli that may cause tissue damage, and react by sending pain signals to the central nervous system. However, the release of certain chemicals during continuous contractions may lower the threshold of activation in nociceptors. Furthermore, although it is traditionally believed that reducing the development of perceived fatigue is effective in also effective in reducing the development of musculoskeletal disorders, however, during low-intensity work, fewer motor units are activated and a relatively high blood flow is maintained through the muscle. This results in homeostasis in the interstitium with nociceptors releasing less pain signals. Thus, even though less pain may be sensed and less fatigue may be perceived during low level contractions, there are still morphological changes occurring within the muscle with low-threshold motor units being continuously activated (Sjøgaard et al., 2000).

Accordingly, a review of pathophysiological mechanisms associated with upper extremity muscle disorders (Visser & Van Dieën, 2006) concluded that among various potential mechanisms reviewed, evidence from both epidemiological and mechanistic studies mostly supported the hypothesis of sustained low-intensity muscle activity causing selective and sustained activation of type I motor units as proposed in the Cinderella hypothesis. This may lead to Ca^{2+} accumulation in the active motor units and other homeostatic disturbances due to limitations in local blood supply and metabolite removal in muscle compartments with larger numbers of active motor units. The key-factor in this scenario, according to the authors, is likely the duration of continuous muscle activity, although an interaction effect with activity level is likely to occur.

Direct motor unit recordings through methods like fine wire EMG can help in further elucidating causal role of these affected type I motor units in development of chronic pain, shed light on how people with chronic pain cope with their pain to perform their daily computer work, and on intervention effectiveness when targeting those at risk of chronic pain development. However, such methods are experimentally complex, sensitive, and invasive; and thus do not lend for implementation in large-scale studies or field investigations. Hence, researchers have sought reliable and valid alternatives for studying these phenomena using more accessible methods such as surface electromyography recordings and muscle blood flow patterns using optical techniques such as NIRS.

In studies of real industrial work, sustained activation of type I motor units was expected to correspond with lower occurrence of EMG "gaps", which are interruptions in muscle activation (detected as time when amplitude of EMG drops below 1% of maximal voluntary capacity for at least 0.3 seconds continuously (Kumar & Mital, 1996)). One study has shown that work associated with fewer EMG gaps have higher risk of musculoskeletal disorders such as trapezius myalgia in chocolate packing (Veiersted, Westgaard, & Andersen, 1990, 1993). However, in studies of seated office work involving visual-display units (VDU), some studies have found similar results (Hägg & Åström, 1997; Veiersted et al., 1993) while others have found that EMG gaps did not differ between those with trapezius myalgia and healthy controls (Vasseljen & Westgaard, 1995; Westgaard, Vasseljen, & Holte, 2001). The Vasseljen & Westgaard (1995) study also found that people with chronic trapezius myalgia did not differ from healthy individuals in the amplitude of muscle activations recorded from the trapezius muscle. Gap analysis has been suggested to have limited application in understanding symptomatic differences in muscle activation patterns during computer work due to the inherently low levels of muscle activity associated with computer work, thus making it difficult to distinguish between different computer, non-computer tasks and rest (Blangsted, Søgaard, Christensen, & Sjøgaard, 2004). Thus, while gap analysis can provide some relevant information on resting muscle

activity, it has been unsuccessful in discriminating between people with and without chronic neck-shoulder pain performing computer work.

1.4 Variation in Muscle Activity

Quantifying the patterns of variation in surface EMG signals recorded from neck-shoulder muscles during computer work may be a promising approach to discriminate between people with and without chronic pain, as suggested by several previous studies (Srinivasan & Mathiassen, 2012). While stereotypical motor unit recruitment has been causally implicated in the development of chronic pain during computer work, there are still substantial inter-individual differences in susceptibility to pain development despite performing the same computer work. It is believed that increased variation in postures and movements even when performing the same external work may be protective, and thus cause inter-individual differences in risk due to repetitive and monotonous work (Madeleine, 2010; Mathiassen, 2006). This is based on the motor-unit rotation principle, which states that substitution occurs when there is a decrease and then increase in the excitation of a particular pool of motor neurons (Westgaard & de Luca, 1999).

Lab-based neurophysiological studies have confirmed the plausibility of this hypothesis by showing that occasional increases or spikes in force levels could actually prolong endurance time (Falla & Farina, 2007) and also stimulate motor unit de-recruitment (Holtermann, Roeleveld, & Karlsson, 2005). Studies show that neck and shoulder muscle fatigue may be brought on by repetitive and monotonous work, and that fatigue may be representative of exposures leading to MSDs (Dennerlein, Ciriello, Kerin, & Johnson, 2003; Iridiastadi & Nussbaum, 2006; Nussbaum, 2001; Winkel & Mathiassen, 1994). Muscle fatigue is defined as a decline in muscle force generation and an increased sense of effort (Enoka & Stuart, 1992). A study examining low levels of muscle activity in the trunk muscles, found that higher variation in EMG was associated with prolonged endurance (van Dieën, Westebring-van der Putten, Kingma, & de Looze, 2009). Variation in muscle activity has been shown to be affected by the kind of pain (intensity and duration): One study compared healthy workers with those in whom experimental acute pain was induced and those who were suffering from chronic pain in the neck and shoulder region (Madeleine, Mathiassen, et al., 2008). They found that while variation in neck and shoulder muscle activity increased with acute, experimentally induced pain, variation decreased in workers with chronic pain in both the active and non-active parts of their butchering task. Madeleine et al. (2008) suggested that the increased posture variation associated with an acute onset of pain is related to the search for new motor solutions to mitigate pain. However during chronic pain, a successful pain-avoidance strategy has evolved and motor variability is reduced, so as to not induce increased pain (Madeleine, Mathiassen, et al., 2008; Madeleine, Voigt, & Mathiassen, 2008). Another study, in which subjects were asked to perform a reaching task until fatigue, found that the healthy

controls were able to perform the task 55% longer than the pain group. The chronic pain group used adaptive movements, such as shifting the body rather than using the shoulder as much in order to complete the task (Lomond & Côté, 2010, 2011).

Taken together, these studies suggest that pain is associated with reduced variation in muscle activations (spatial and temporal). However, most of these studies have so far only been using simple short-cycle repetitive tasks and isometric exercise. There is currently *no* empirical evidence for variation in muscle activity having any association with physiological outcomes in studies of prolonged static work as typical of computer work. More concretely, and as a first step, there is also no evidence of *variation in muscle activation patterns* being the key characteristic that is different between individuals with and without pain, performing computer work (Srinivasan & Mathiassen, 2012).

Studies quantifying and interpreting patterns of variation in monotonous and non-repetitive work are limited, as this requires more sophisticated tools to describe patterns of variation. In this context, exposure variation analysis is a tool that reduces continuous exposure-vs-time data into exposure amplitude and accumulated time data, thus giving way to an understanding of the differences in the continuity of muscle activation patterns at different amplitude levels. Approaches such as gap analysis and Amplitude Probability Distribution Functions have been attempted to quantify muscle activation patterns in the past, with varying levels of success (Ciccarelli, Straker, Mathiassen, & Pollock, 2013; Jensen, Finsen, Hansen, & Christensen, 1999; Szeto, Straker, & O'Sullivan, 2005; Westgaard et al., 2001). While gap analysis considers only the low levels of muscle activations, and APDF considers muscle activation amplitudes, EVA is able to categorize exposures into categories involving amplitude levels and the corresponding time periods of continuous activation. Hence, EVA may be a potential approach for quantifying variation in continuously activated muscles such as the trapezius during computer usage.

1.5 Exposure Variation Analysis (EVA)

Exposure Variation Analysis (EVA) reduces exposure-vs-time data to exposure amplitude, as well as, accumulate time spent in each level of exposure (Mathiassen & Winkel, 1991). EVA has been shown to be sensitive to variation in task (Ciccarelli, Straker, Mathiassen, & Pollock, 2011; Ciccarelli et al., 2013; Jensen et al., 1999; Mathiassen, Burdorf, van der Beek, & Hansson, 2003; Wærsted & Westgaard, 1997), occupation group (Svendsen, Bonde, Mathiassen, Stengaard-Pedersen, & Frich, 2004), demographic groups (pain, age and pregnant vs. non-pregnant) (Dumas et al., 2008; Hägg & Åström, 1997; Maslen & Straker, 2009), and configuration of work environment (Dumas et al., 2008, 2009, Samani, Holtermann, Søgaard, & Madeleine, 2009a, 2009b). Modifications to EVA have included clustering of exposure and temporal

data in order to compare separate groups of workers, and using equidistant categories as opposed to logarithmic. With respect to computer work, EVA has been used in various studies to compare variation involved with types of VDU tasks and paper-based tasks (Ciccarelli et al., 2011, 2013; Ciccarelli, Straker, Mathiassen, & Pollock, 2014; Straker et al., 2008; Straker, Maslen, Burgess-Limerick, & Pollock, 2009; Wærsted & Westgaard, 1997), industrial task and simulated computer work (Jensen et al., 1999), children and adults during computer work (Maslen & Straker, 2009), and pregnant and non-pregnant women (Dumas et al., 2009). Studies have also focused on how motor variation is affected when interventions are introduced, such as, active pauses (Samani et al., 2009a, 2009b) and workstation forearm support (Dumas et al., 2008, 2009). In a study by Hägg and Åström (1997), muscle activity in the upper trapezius and posture was examined in medical secretaries with and without chronic pain. This study found that secretaries in pain had less frequent episodes of relaxed muscle (Hägg & Åström, 1997). However, this study focused on the frequency of EMG gaps. There is need to have a broader look at variation with respect to chronic pain in computer work. Additionally, there is a need to assess the reliability of EVA as a tool to quantify variation in muscle activity in computer work.

1.6 Aims, Hypotheses and Anticipated Contributions

This thesis will utilize exposure variation analysis specifically to study patterns of muscle activation in the neck/shoulder region during computer work: As Aim 1, we will test the day-to-day reliability of EVA when applied on healthy individuals. As Aim 2, we will use EVA to quantify the extent to which individuals with chronic neck-shoulder pain and healthy non-symptomatic individuals differ in muscle activation patterns when performing computer work. Aim 1 is a descriptive study and involves no hypothesis testing. For Aim 2, while we expect the individuals in the pain group to exhibit more prolonged continuous muscle activations in the trapezius muscle as compared to the healthy group, our study is largely an exploratory effort. As a secondary aim, this thesis will also contribute to understanding which EVA measures (amplitude/duration marginal sums, EVA summary measures such as means and standard deviations along each axis) are most reliable, and can identify differences between those with and without pain. This study will contribute to the literature on understanding the extent to which individuals with chronic pain exhibit altered patterns of trapezius muscle activations when performing computer work. While several interventions to “increase” variation during computer work have been advocated, the issue of “how much” variation is useful or necessary has been particularly hard to tackle. Our work is expected to contribute towards this by both quantifying the day-to-day variation in muscle activity patterns exhibited by healthy individuals and by characterizing the differences between healthy and chronic pain groups.

2 Methodology

2.1 Subjects

Thirteen participants, between the ages of 18-40, completed the study from the Virginia Tech student population and the local area. Two participant groups were formed: chronic pain (P) and healthy control (H). The anthropometric information, as well as, responses for pain criteria for the participants are shown in Table 1.

Table 1 Anthropometric data and questionnaire responses for each subject group; SD in parentheses

Group	Gender	Age	BMI (kg/m^2)	Pain Intensity		Pain Frequency	
				Neck	Shoulder	Neck	Shoulder
Healthy	4M:4F	22.4 (4.9)	25.8 (9.2)	0.4 (1.9)	0.2 (1.9)	1.5 (1.5)	1.1 (1.9)
Pain	2M:3F	23.0 (4.0)	27.3 (4.9)	3.3 (0.4)	2.3 (0.3)	3.6 (0.5)	2.8 (0.4)

All participants self-reported as being right-handed, using a computer more than 15 hours per week on average, were touch typists, and could type at least 40 words per minute. Participants were excluded if they had been diagnosed with any cardiovascular, neurological or musculoskeletal condition, or had any previous surgery in their neck or shoulder. Participants were included in the chronic pain group using criteria for pain/discomfort intensity, duration and frequency, using a questionnaire presented in Appendix A. Using a Borg CR-10 scale (Borg, 1990), participants must rate a “moderate”, or three out of ten, in their neck or shoulder. They also had to have pain at least 2-3 times a week and 30 days or more in the year preceding the experiment. They needed to be able to perform 1-2 hours of continuous computer work without substantial discomfort. Participants in the chronic pain group were also asked to complete a questionnaire on pain treatment and pain management solutions. Participants were excluded if they rated at least a “moderate” on the Borg CR-10 scale in at least three other regions, as this would indicate widespread or general pain.

Participants in the control group must not have experienced 30 days or more of pain in their neck or shoulder in the year preceding the experiment. The questionnaires used are presented in the Appendix A. All participants signed an informed consent, and the experiment was approved by the Virginia Tech Institutional Review Board (IRB). Participants were compensated for their time.

2.2 Workstation Set-Up

At the beginning of the session, participants were seated at an adjusted computer workstation. A computer chair were adjusted in height so that the participant’s feet could rest flatly on the floor, and their upper leg was parallel with the ground. The computer desk was height-adjusted so that the participant’s lower arms would be horizontal when they sat upright with their arms rested on the desk. There were two computer

monitors – one to view the task instructions and another to input information. The input monitor was centered in front of the participants with the top of the monitor level to their eyes and set one arm's length away. Measurements were documented for consistency across sessions, but other than these basic adjustments, a participant was free to perform computer work in their preferred seated postures, to maximize the ecological validity of our findings.

2.3 Computer Tasks

For the session, there were three tasks – typing (TYPE), completing a point-and-click task (CLICK), and completing a digital form (FORM). These three tasks were performed in two pacing conditions over the course of one hour. For the TYPE tasks, participants typed a passage of text into a word processing program. For the CLICK tasks, participants would select boxes in an image that correspond with a pre-determined symbol. The TYPE task was primarily a keyboarding task, and the CLICK task was primarily a mouse work task. For the FORM tasks, participants would read a series of instructions on a text or mouse field, and the select the correct field (typing if instructed). The two pacing conditions were a controlled pace (CP), and a self-selected pace (SP). For the CP condition, participants were paced using visual and audio feedback at each minute, with a pre-selected amount of work to be done by each minute. For the TYPE task, participants were asked to complete 65 words per minute, which was based on pilot research and the need for participants to work at a reasonable pace but not run out of words to type during the measurement period. For the SP condition, participants worked for the entire task with no feedback and were told to work at a "natural, comfortable pace" for 10 minutes of continuous data collection. Each task lasted 10 minutes for a total of 60 minutes of computer work. Tasks were randomized within each condition, and the two conditions were randomized.

2.4 Experimental Protocol

Participants in the pain group completed one session while the healthy participants completed two sessions, with the second session at least 48 hours after the first, but not more than a week later. All participants in the pain group were pain-free at the start of the session, so that the measured differences between the pain and healthy groups could be attributed to chronic motor control adaptations rather than the effects of short-term pain. Additionally, this criterion was also used to minimize the potential variation in responses (and pain levels) across participants in the pain group. All participants completed a sub-maximal reference voluntary exertion activity (RVE), in which participants were asked to complete three bilateral arm abductions at 90 degrees in the frontal plane for 10 seconds while holding a 0.5-kg weight in each hand, with 1 minute of rest in between. This was based on previous literature (Mathiassen, Winkel, & Hägg, 1995), with the addition of weights to ensure that the RVE was about 15% of the maximum voluntary

exertion (MVE) exercise. This reference activity was set at a sub-maximal level since it was expected that participants in the pain group may not be able to truly achieve maximal voluntary exertions, and even if they did, the data may not be reliable. The middle 3 seconds of the three RVE trials were averaged for normalization of the muscle activity data. Healthy participants were also asked to complete an MVE exercise: while sitting upright looking straight ahead, participants were asked to complete three bilateral maximum shoulder elevations for 5 seconds, with 1 minute of rest in between. Maximum voluntary exertions were obtained for the healthy subjects to ensure that the reference contraction was on average, indeed ~15% MVE.

Pain group participants completed their session (and for healthy participants, their first session) in the morning in order to ensure differences in muscle activation patterns were due to tasks and not previous work done throughout the day. Prior to the session, participants were asked to complete a training – lasting a total of about 20 minutes – on each task, and following this, a resting electromyographic (EMG) signal was collected. The training for each task consisted of a 2-3 minute exercise that replicated the experiment in order for participants to ask questions and be given feedback prior to the start of data collection. The instructions for each task are shown in Appendix B.

2.5 Data Collection

During each session, muscle activity on the dominant side was collected using surface EMG on the trapezius in four positions (clavicular, descending, transverse and ascending). As outlined in Section 1.2, given that the upper, middle and lower parts of the trapezius muscle have different functions, and that within the upper trapezius, while stimulation of the superior fibers (i.e. those medial to the midpoint between C7 and the acromion) produces rotation of the neck whereas the inferior fibers (i.e. lateral to the midpoint between C7 and acromion) works primarily to elevate the shoulder, we chose to study the muscle activation patterns in each of these functionally distinct trapezius compartments. Furthermore, the inferior fibers in the upper trapezius (corresponding to CT in our study) have also been reported to exhibit a predominance of type I motor units, making the CT location a central focus of this study, given our aims and hypotheses. Table 2 shows the placement of each electrode (Samani & Madeleine, 2014). The electrode placement for the four positions along the trapezius muscle is also shown in Figure 2. Following skin preparation (abrasion of skin using sandpaper and cleaning using alcohol), pairs of bipolar Ag/AgCl surface electrodes (AccuSensor, Lynn Medical, MI, USA) with a 2.5-cm inter-electrode distance were placed on each location on the skin.

Table 2 Descriptions and placements of electrodes (Samani & Madeleine, 2014)

Trapezius Location	Electrode Placement
Clavicular Trapezius, CT	20% of the lateral to the mid-point between the acromion and C7 spinal bone
Descending Trapezius, DT	20% of the medial to the mid-point between the acromion and C7 spinal bone
Transverse Trapezius, TT	50% between the medial border of the scapula and the spine, at the level of T3
Ascending Trapezius, AT	33% medial on the line from the medial scapular to the T8 vertebra

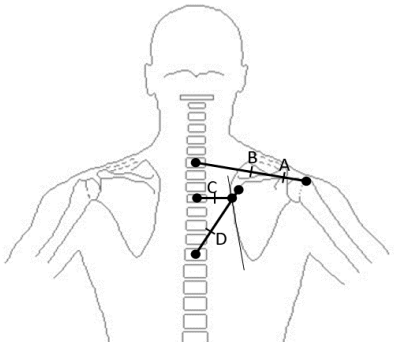

Figure 2 Electrode placement of four positions on trapezius muscle: A) clavicular, B) descending, C) transverse, and D) ascending

EMG data was recorded using a telemetered system (TeleMyo Desktop DTS, Noraxon, Scottsdale, AZ, USA) at a sampling frequency of 1500 Hz. All EMG signals were band-pass filtered using a sixth-order Butterworth filter of zero lag in the 20–450 Hz band and corrected for DC offset, passed through an 800th order median filter in order to remove spikes in data from motion artifacts of signal cables, and then RMS converted using consecutive 100 ms moving windows. The RMS signal was then corrected for noise using EMG values collected during instructed rest (Jackson, Mathiassen, & Dempsey, 2009)jackson, according to the following equation:

$$RMS_{adjusted} = \sqrt{{RMS_{unadjusted}}^2 - {RMS_{rest}}^2} \quad \text{Eq. 1}$$

The $RMS_{adjusted}$ EMG was normalized to the middle three seconds of the corresponding RVE to give results expressed in percentage of reference EMG (%RVE, Mathiassen, Winkel, & Hägg, 1995).

Using a printed Borg CR-10 scale, participants were asked to rate perceived discomfort in each region of their body after each 10-minute task, which is shown in the Appendix C.

2.6 Data Analysis

EVA was used to organize and analyze muscle activity data. For low-level repetitive work, logarithmic scales for time periods and intensity are recommended when analyzing muscle activity (Mathiassen & Winkel, 1991). The RVE activity was used for normalization. For each of the six 10-minute tasks, an EVA analysis was performed using five amplitude classes (0-6.67, 6.67-20, 20-46.67, 46.67-100, >100% RVE) and five duration classes (0-1, 1-3, 3-7, 7-15, >15 s). The time in which muscle activity was categorized to be in each cell was then divided by the total working time as shown in the equation below:

$$d_{ij} = \frac{time\ in\ ij\ class}{total\ time}\% \quad \text{Eq. 2}$$

where d_{ij} is the cell corresponding to the i^{th} amplitude class ($i = 1 - n_i$), and j^{th} duration class ($j = 1 - n_j$). The means and standard deviations (SDs) along each axis and for all of the 25 cells were found as summary measures. The means of each amplitude and duration class were found using the following equations, which is a weighted mean along each axis:

$$Amplitude\ Mean = \frac{\sum_{i=1}^{n_i}(\sum_j d_{ij} \times i)}{100} \quad \text{Eq. 3}$$

$$Duration\ Mean = \frac{\sum_{j=1}^{n_j}(\sum_i d_{ij} \times j)}{100} \quad \text{Eq. 4}$$

The Total Mean was the resultant of these two means:

$$Total\ Mean = \sqrt{(Amplitude\ Mean)^2 + (Duration\ Mean)^2} \quad \text{Eq. 5}$$

These measures were depicted on the EVA matrix as shown in Figure 3.

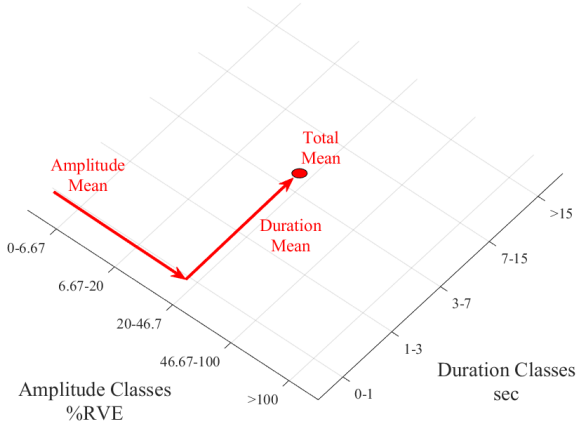

Figure 3 Depiction of positions of Amplitude, Duration and Total Mean on EVA matrix

The variability indices were the SD along each axis and for all the cells. They were found using the following equations:

$$Amplitude\ SD = SD(d_{\cdot 1}, \ldots, d_{\cdot 5}) \quad \text{Eq. 6}$$

$$Duration\ SD = SD(d_{1\cdot}, \ldots, d_{5\cdot}) \quad \text{Eq. 7}$$

$$Total\ SD = SD(d_{ij}) \quad \text{Eq. 8}$$

Table 3, modified from Delisle et al., (2006), describes the meaning of each index. EVA analyses were computed for muscle activity data for the four positions on the trapezius. The clavicular trapezius (CT)

muscle is shown in the results section because of its high functional relevance to computer work, while the results of the other three muscle positions are available in Appendix D.

Table 3 Description and meaning of the summary measures of the EVA based on Delisle et al. (2006)

Variable	Description	Meaning
Amplitude Mean	Average position of the EVA distribution along the amplitude axis maximum distance = 5 minimum distance = 1	A high value between 4 to 5 indicates that a large percentage of working time is spent in the high intensity class.
Duration Mean	Average position of the EVA distribution along the duration axis maximum distance = 5 minimum distance = 1	A high value between 4 to 5 indicates that a large percentage of working time is spent in the long duration class.
Total Mean	Average position of the EVA distribution; resultant of Amplitude and Duration Mean maximum distance = 7.07 minimum distance = 1.41	A high value of 7 indicates that a large percentage of working time is spent in both the high intensity and the long duration classes.
Amplitude SD	Standard deviation over the five sums of time spent in each amplitude class maximum = 44.72% when one cell = 100% minimum = 0 when the five cells = 20%	A high value indicates that the time spent in one intensity class is larger than the four others
Duration SD	Standard deviation over the five sums of time spent in each duration class maximum = 44.72% when one cell = 100% minimum = 0 when the five cells = 20%	A high value indicates that the time spent in one duration class is much larger than the four others.
Total SD	Standard deviation over the 25 cells maximum = 20% when one cell = 100% minimum = 0 when the 25 cells = 4%	A high value indicates that the time spent in one cell is large. Smaller standard deviations reflect a more equal distribution over all the cells.

2.7 Statistical Analysis

2.7.1 Specific Aim 1

Between-subjects and within-subjects (i.e. between-days) variance components were computed for each of the marginal distributions of EVA matrices among the amplitude and duration axes, as well as the EVA summary measures presented in Table 2, using the following random-effects model:

$$P_{sub,day} = \mu + \alpha_{sub} + \varepsilon_{day(sub)} \quad \text{Eq. 9}$$

where $P_{sub,day}$ is the recorded EVA measure for a particular subject on a certain day, μ is the grand mean, α_{sub} is the subject effect, and $\varepsilon_{day(sub)}$ is the residual effect of repeated recordings over days within subject which includes any other sources of error such as measurement error. The model was resolved using ANOVA in MATLAB to give estimates of the between-subjects, and between-days within-subject variance components (${\sigma_b}^2$ and ${\sigma_w}^2$, respectively), specifically the variances of α_{sub} and $\varepsilon_{day(sub)}$ in Equation 9, along with their 95% confidence intervals. These variance components show the consistency of the analyzed EVA measures across subjects, and, for any particular subject, across days.

These variance components were used to compute intra-class correlation coefficients (ICCs) (Denegar & Ball, 1993), using the following equation:

$$ICC = \frac{{\sigma_b}^2}{{\sigma_b}^2 + {\sigma_w}^2} \quad \text{Eq. 10}$$

where ${\sigma_b}^2$ is the between-subjects variance, and ${\sigma_w}^2$ is the within-subjects variance. These variance components have been used extensively in the past to examine the reliability of measures used to quantify trapezius muscle activity patterns (Jackson et al., 2009; Mathiassen, Moller, & Forsman, 2003).

The variance components and grand means were also used to find coefficients of variation (CVs) and standard errors of measurement (SEMs) (American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 1999; Denegar & Ball, 1993), using the following equations:

$$CV = \frac{\sqrt{({\sigma_B}^2 + {\sigma_W}^2)}}{\mu} \quad \text{Eq. 11}$$

$$SEM = \sqrt{{\sigma_W}^2} \quad \text{Eq. 12}$$

These two measures were used as absolute measures of reliability for the marginal sums along the amplitude and duration axes, as well as, for the EVA summary measures to examine the differences across participants within the healthy group.

2.7.2 Specific Aim 2

Dependent measures were log transformed for statistical analysis because the residuals of EVA marginal distributions from an ANOVA model were found to significantly deviate from the assumptions of normal distribution. During the natural log transformation, to account for zeros in the data, amplitude marginal sums in the third, fourth and fifth categories were collapsed to one measure (>20% RVE). Three-way analysis of variance (ANOVA) tests were performed on the marginal distributions of EVA (i.e. along the intensity and duration axes separately) for each condition, with computer task (i.e. TYPE, CLICK and FORM) and order of tasks as within-subject factors, and group (pain vs. control) as a between-subjects factor. Statistical significance was accepted at $p < 0.05$, and all statistical testing was done using JMP Pro 13 and MATLAB v9.2.0. When task effects were significant, post-hoc comparisons between the three task conditions were made using Tukey's HSD and corresponding effect sizes were reported, as described below.

For all group effects and pairwise comparisons of task effects, effect sizes were computed using Cohen's d (Cohen, 1988), using the following equation:

$$d = \frac{\bar{Y}_1 - \bar{Y}_2}{\sigma_{pooled}} \quad \text{Eq. 13}$$

where d is Cohen's d, $\bar{Y}_i$ represent independent population means, which is the mean recorded EVA measures for the two groups being compared (e.g. pain vs. no-pain), and σ_{pooled} represents the common within-population standard deviation. Cohen's d represents the standardized difference between two means.

3 Results

3.1 Performance

The results of the average completion and number of errors made by participants in each group and in each condition and task are shown Figure 4. Performance in the TYPE and CLICK tasks was quantified using completion and inaccuracy measures. For the TYPE task, the total number of words typed (Figure 4A) was used to measure completion while inaccuracy was measured as number of word errors made (Figure 4B) during the task. For the CLICK task, completion was measured as the number of boxes colored (Figure 4C) during the task, while the number of errors colored incorrectly (Figure 4D) were counted as a measured of inaccuracy. In general, participants typed and clicked slower and made fewer errors in the SP than the CP condition. The difference between self and control paced conditions seemed more for the CLICK task than TYPE task (CLICK task performance in control pace was ~3 times as high as that in self pace condition), but there were no group differences in any of the performance measures.

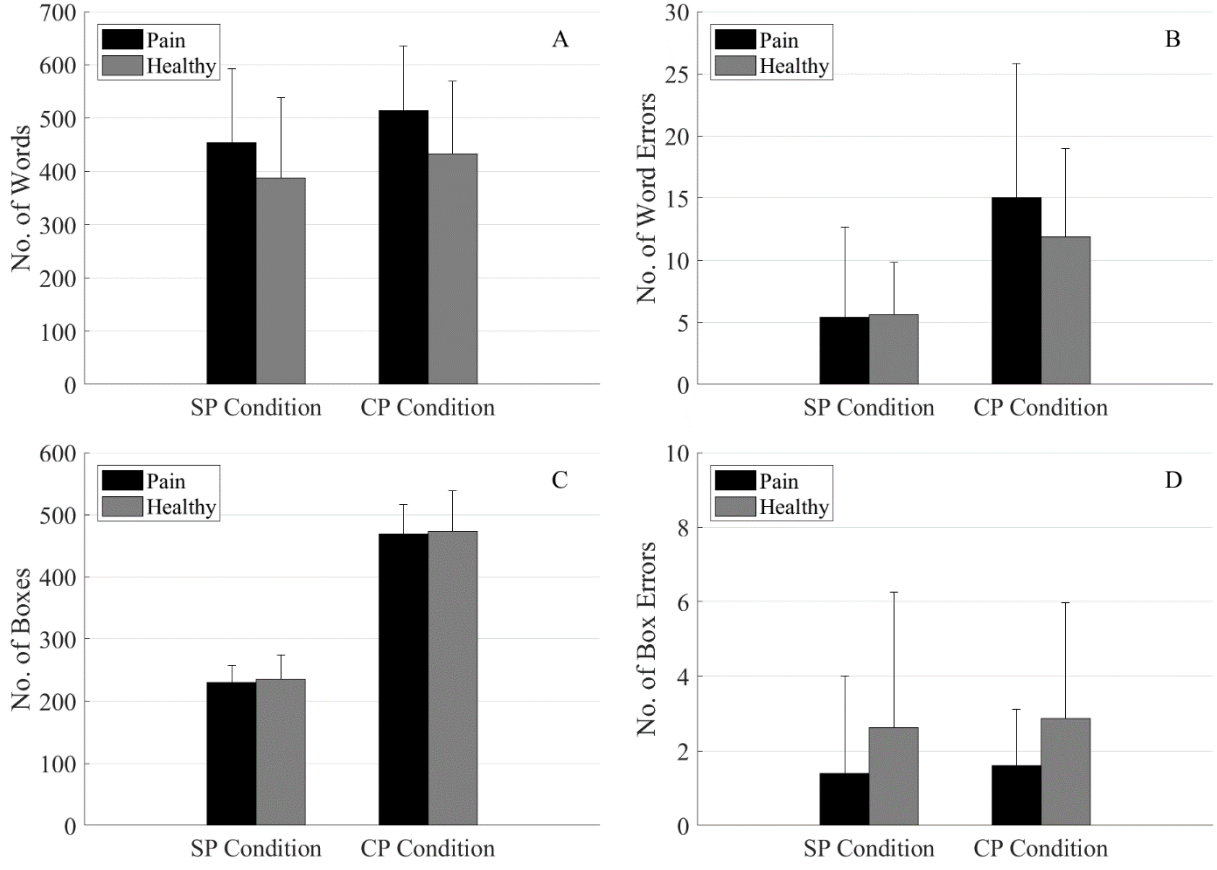

Figure 4 Number of words completed and number of errors in TYPE task (A and B, respectively), and number of boxes completed and number of errors in CLICK task (C and D, respectively) for healthy and pain groups in SP and CP condition; error bars for SD

3.2 Subjective Discomfort Ratings

The subjective discomfort ratings were taken for the neck, shoulder, upper back and lower back regions following each task for each pacing condition. A diagram of these regions are shown in the Appendix C. Figure 5 shows average discomfort ratings for each group for each condition.

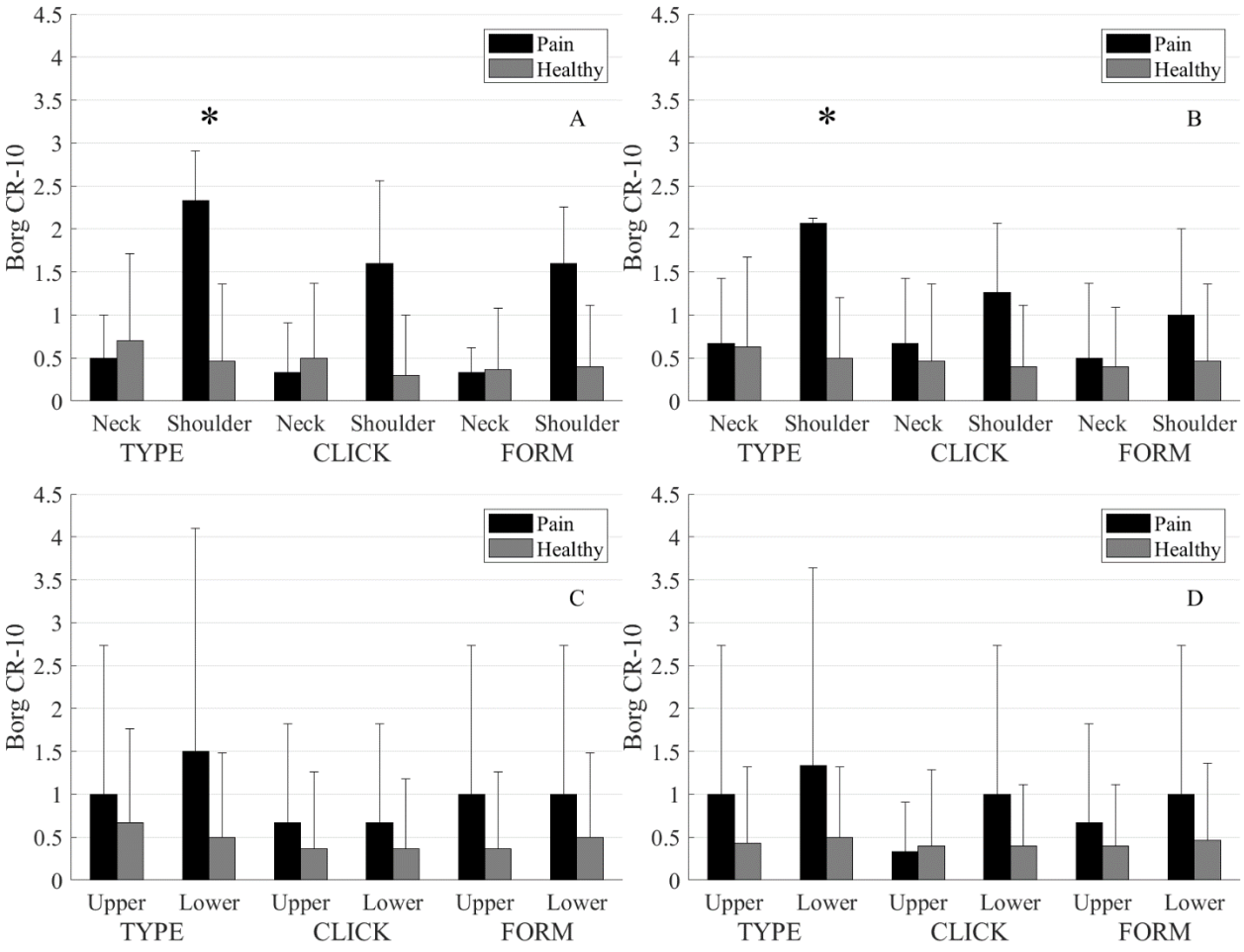

Figure 5 Discomfort ratings for SP condition (A, C) and CP condition (B, D) for neck, shoulder, and upper and lower back; error bars for SD; asterisk for statistical significance

Comparisons were done on the discomfort ratings across groups for each region for task and pacing condition. The pain group showed significantly higher discomfort in the shoulder in the TYPE task for both the SP condition ($p = 0.0087$) and the CP condition ($p < 0.0001$).

3.3 Descriptive Results of Exposure Variation Analysis

Continuous data for muscle activity was organized into EVA matrices concatenated across tasks to create 30 minutes of continuous muscle activity. The average EVA matrices computed across participants within each group in each task, as well as the concatenated EVA across all tasks, are shown in Figure 6 through Figure 9. From these figures, it can be seen that for the healthy group, muscle activity in the upper trapezius

was <50% RVE for almost the entire task period during all tasks, while on average individuals in the pain group registered muscle activity > 100% RVE for approximately 20% of working time. While examining the duration classes, individuals in the healthy group seemed to exhibit sustained muscle contractions longer than 15s (of different amplitudes) for approximately half the working time, while participants in the pain group registered such prolonged muscle activations of longer than 15 seconds for approximately ¾ of working time, specifically in the self-paced conditions of TYPE and CLICK tasks (Figures 6A and 7A).

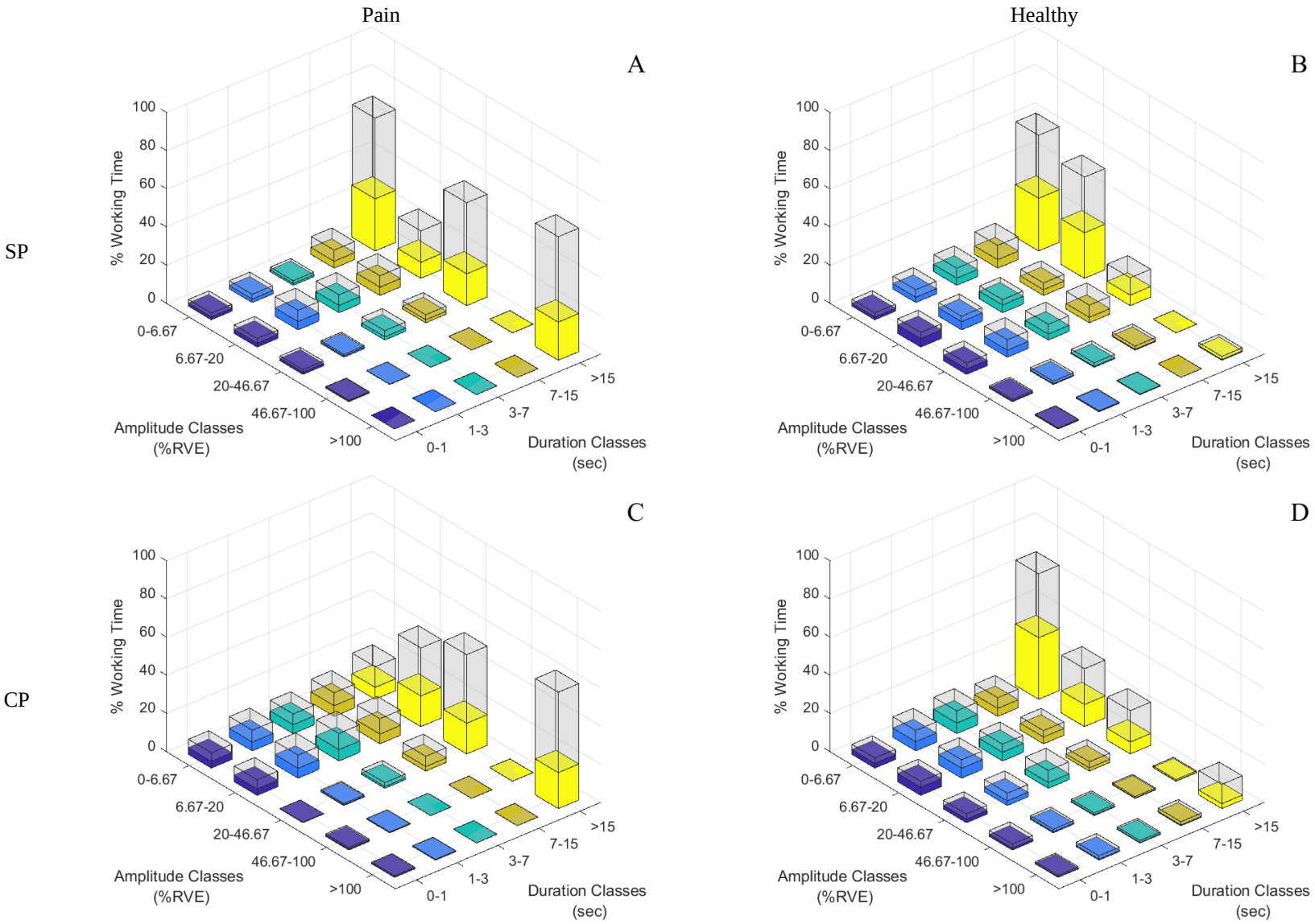

Figure 6 EVA for pain and healthy groups for SP and CP conditions for TYPE task; SD denoted with gray stacked bars

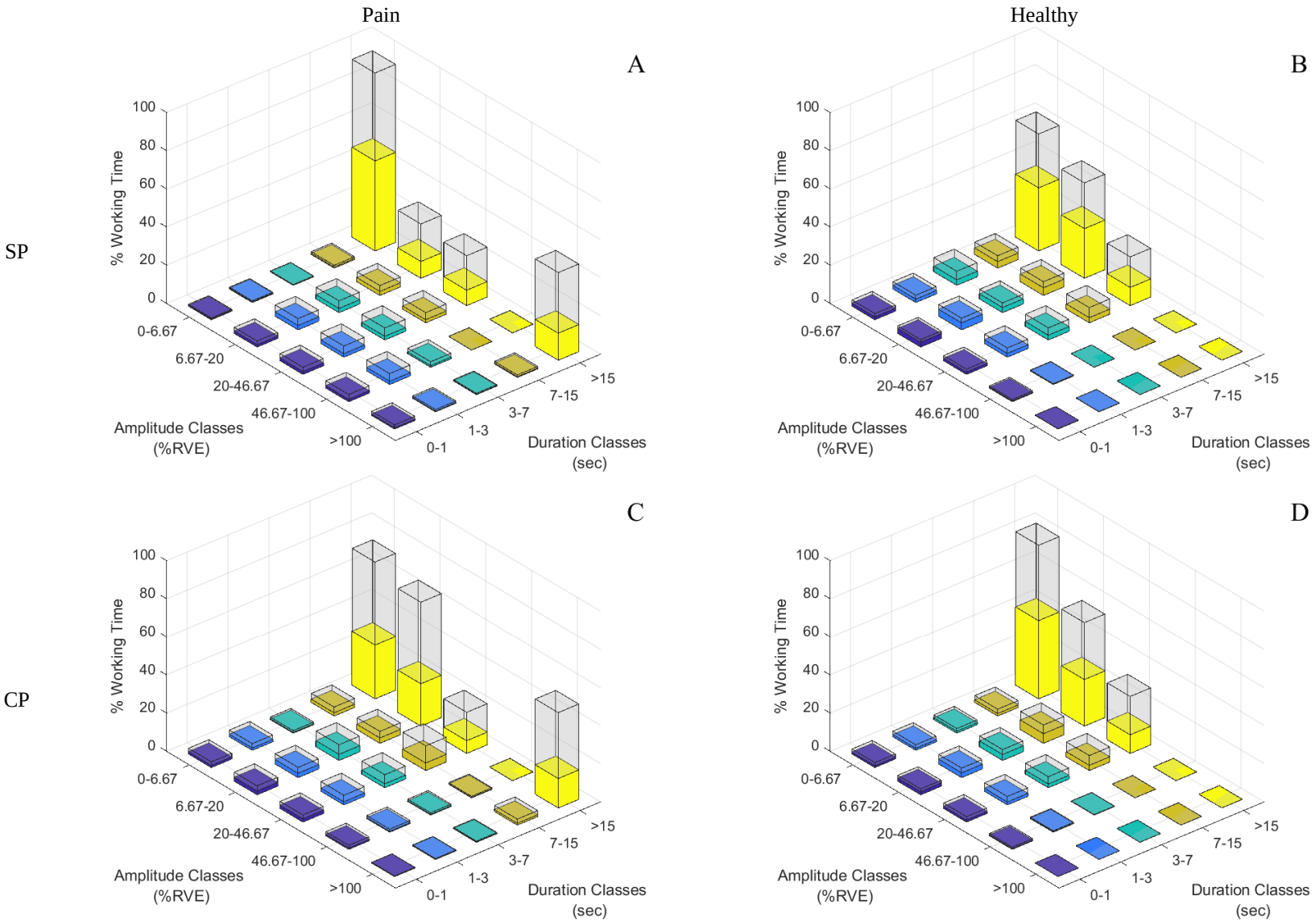

Figure 7 EVA for pain and healthy groups for SP and CP conditions for CLICK task; SD denoted with gray stacked bars

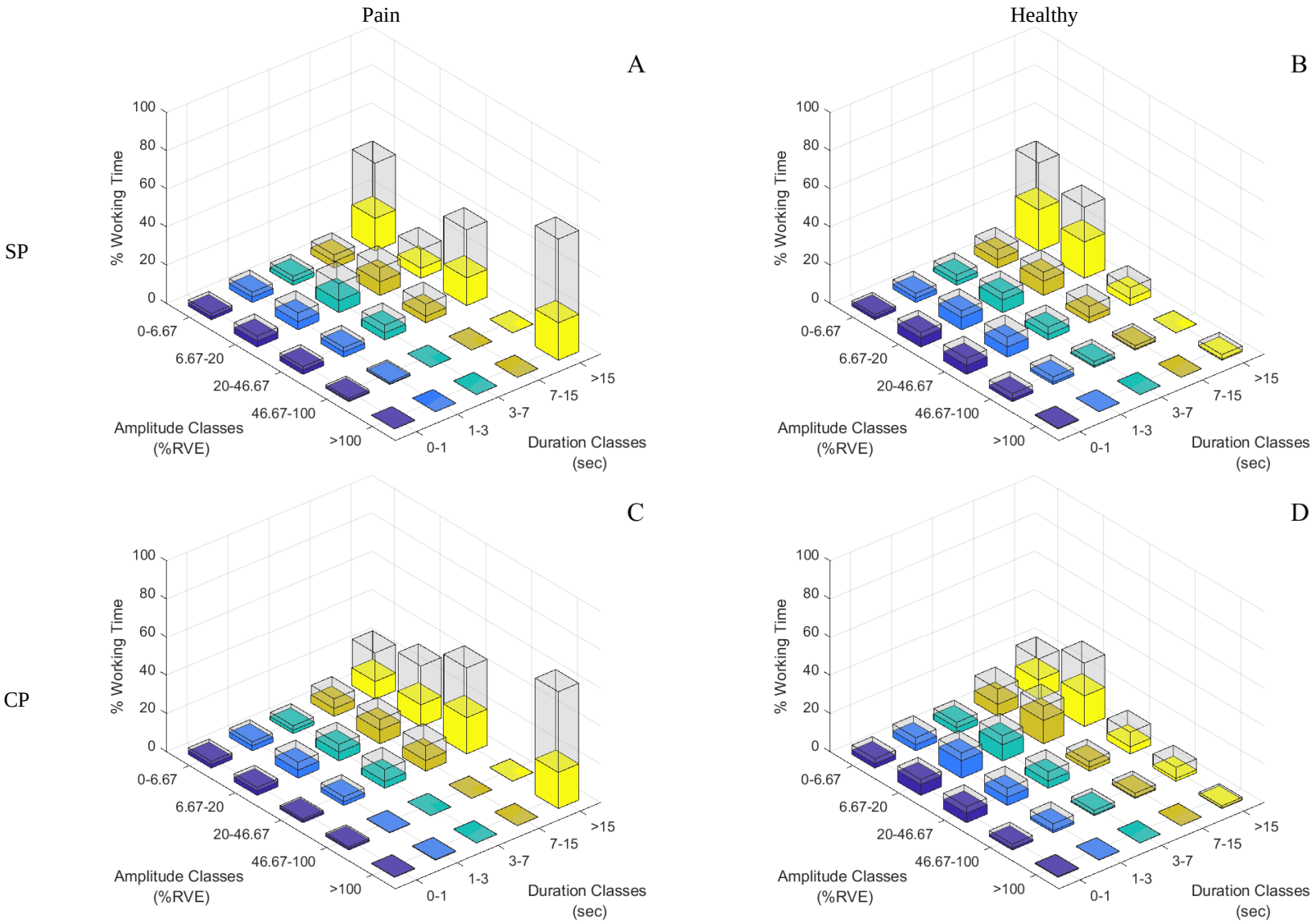

Figure 8 EVA for pain and healthy groups for SP and CP conditions for FORM task; SD denoted with gray stacked bars

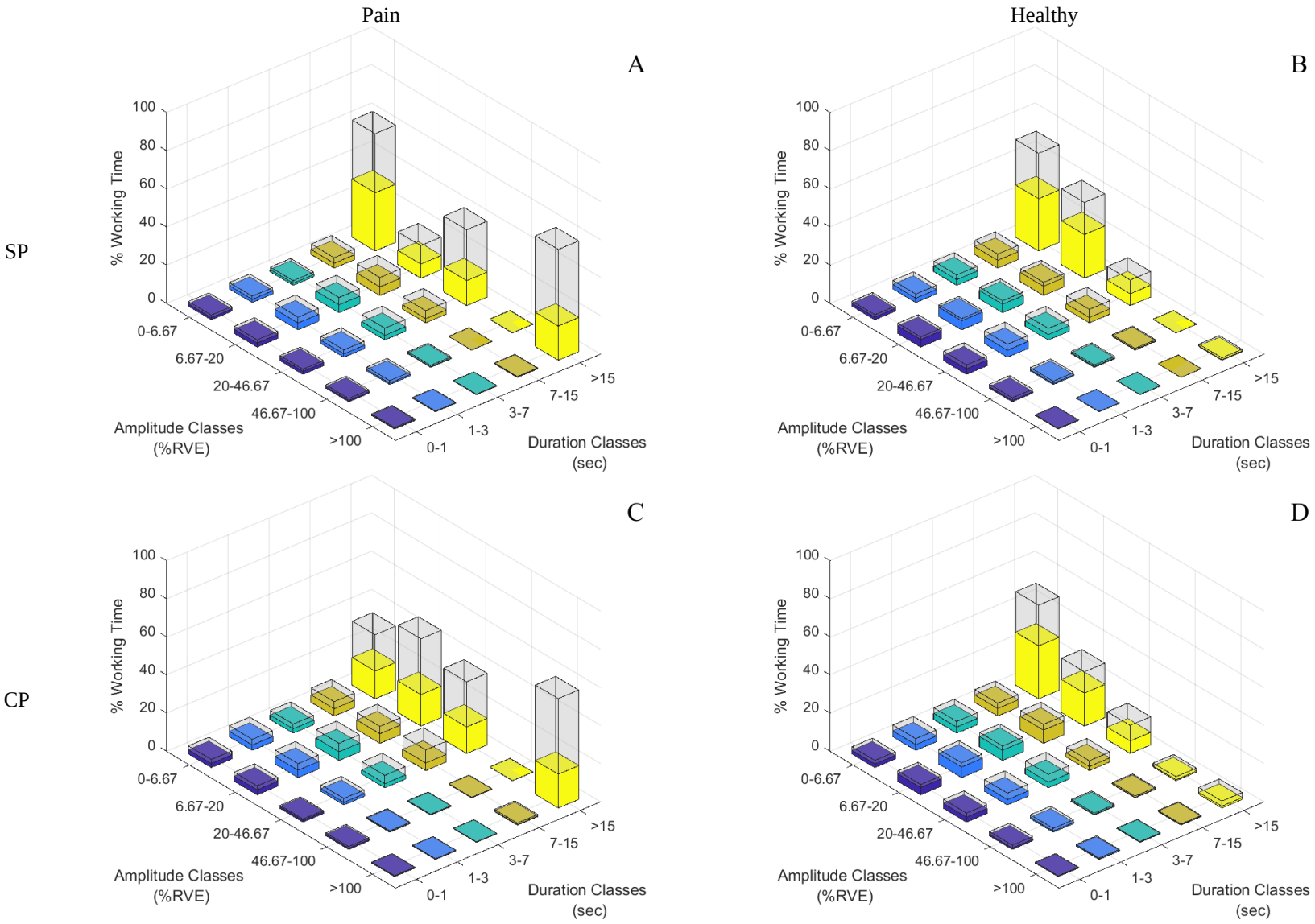

Figure 9 EVA for pain and healthy groups for SP and CP conditions for all tasks; SD denoted with gray stacked bars

3.4 Aim 1: Reliability Tests

Between-subjects and within-subjects variance components were calculated for the EVA amplitude and duration marginal sums, as well as, the EVA summary measures for each pacing condition, using data from the healthy subjects. From these, intra-class correlation coefficients (ICCs), coefficients of variation (CVs) and standard errors of measurements (SEMs) were calculated. Results are shown in Table 4, and the ICCs are color-coded according to whether ICCs were in the poor (i.e. 0-0.4), fair to good (i.e. 0.4-0.75) and excellent (i.e. 0.75-1.0) ranges and interpreted to indicate low, moderate and high reliability, respectively (Fleiss, 1986).

The ICCs for self-paced condition were generally high except for the 5^{th} amplitude marginal sum and the overall amplitude SD. This was expected, since most participants in the healthy control group did not register any muscle activity in the 5^{th} amplitude category. Hence, the between-subjects variance component of the 5^{th} amplitude sum was zero, leading to an ICC of 0. To account for this in subsequent analyses, we combined amplitude categories 3-5 and reported the reliability tests on that combined category, which showed high reliability. In the control-paced condition, most measures showed moderate-high reliability except the 4^{th} amplitude marginal sum and the 4^{th} duration marginal sum.

As for the coefficients of variance that were computed, in the SP condition, CVs for all marginal sums were all moderate-high, whereas the CV of the EVA summary measures (means and SDs) were low (i.e. 0.1-0.4). This implies that the dispersion in EVA measures across subjects, when compared to the mean in any category was high for the marginal distributions and small for the summary measures. There were similar results for the CP condition, implying similarly that there was more variance in the marginal distributions compared to the EVA summary measures.

SEM, a measure of reproducibility was computed for all measures in both pacing conditions, and generally seemed to be similar across pacing conditions. The only notable exceptions to this was the first and second EVA amplitude marginal sums, for which the SEM in the CP condition was almost twice as high as that in the SP condition. This seems to be particularly striking since the mean values of the two measures are not different between the SP and CP conditions.

Table 4 Means, between-subjects (BS) and within-subjects (WS) variances, ICC[1] CV and SEM of amplitude (AMS 1-5) and duration marginal sums (DMS 1-5) and EVA summary measures for healthy participants in the self-pace (SP) and control-pace (CP) conditions; 95% confidence intervals (CI) are presented

Variable (% WT)	SP Condition						CP Condition					
	Mean	BS [95% CI]	WS [95% CI]	ICC	CV	SEM	Mean	BS [95% CI]	WS [95% CI]	ICC	CV	SEM
AMS 1	38.13	761.5 [128.99 - 3386.91]	126.1 [57.55 - 462.96]	0.86 [0.69 - 0.88]	0.78	11.23	39.87	444.0 [0 - 2755.39]	497.1 [226.82 - 1824.63]	0.47 [0 - 0.6]	0.77	22.30
AMS 2	40.93	361.5 [56.79 - 1613.11]	62.6 [28.58 - 229.91]	0.85 [0.67 - 0.88]	0.50	7.91	39.1	97.1 [0 - 759.76]	194.1 [88.53 - 712.2]	0.33 [0 - 0.52]	0.44	13.93
AMS 3	18.42	271.3 [0 - 1406.17]	153.2 [69.91 - 562.41]	0.64 [0 - 0.71]	1.12	12.38	17.03	295.2 [0 - 1510.83]	156.3 [71.3 - 573.53]	0.65 [0 - 0.72]	1.25	12.50
AMS 4	2.04	10.9 [0 - 54.87]	5.2 [2.36 - 18.96]	0.68 [0 - 0.74]	1.97	2.27	2.52	10.9 [0 - 109.86]	35.0 [15.97 - 128.47]	0.24 [0 - 0.46]	2.69	5.92
AMS 5	0.49	0.0 [NaN - NaN]	2.8 [1.29 - 10.41]	0.00 [NaN - NaN]	3.45	1.68	1.48	8.4 [0 - 63.95]	15.7 [7.18 - 57.78]	0.35 [0 - 0.53]	3.33	3.97
AMS 3-5	20.95	416.1 [0 - 2025.93]	163.9 [74.79 - 601.67]	0.72 [0 - 0.77]	1.15	12.8	21.03	590.0 [0 - 2749.99]	166.1 [75.79 - 609.68]	0.78 [0 - 0.82]	1.31	12.89
DMS 1	9.53	9.9 [0 - 50.93]	5.4 [2.45 - 19.73]	0.65 [0 - 0.72]	0.41	2.32	9.99	20.2 [2.06 - 91.47]	4.2 [1.91 - 15.38]	0.83 [0.52 - 0.86]	0.49	2.05
DMS 2	11.67	12.6 [0 - 62.41]	5.5 [2.52 - 20.29]	0.70 [0 - 0.75]	0.36	2.35	12.61	26.9 [2.87 - 121.37]	5.5 [2.5 - 20.14]	0.83 [0.53 - 0.86]	0.45	2.34
DMS 3	11.44	8.2 [0 - 51.76]	9.8 [4.45 - 35.79]	0.46 [0 - 0.59]	0.37	3.12	12.78	24.7 [0 - 119.23]	9.3 [4.23 - 34]	0.73 [0 - 0.78]	0.46	3.04
DMS 4	12.3	8.9 [0 - 73.72]	19.9 [9.1 - 73.19]	0.31 [0 - 0.5]	0.44	4.47	14.11	2.9 [0 - 25.45]	7.3 [3.33 - 26.75]	0.28 [0 - 0.49]	0.23	2.70
DMS 5	55.06	175.3 [0 - 867.16]	76.5 [34.9 - 280.74]	0.70 [0 - 0.76]	0.29	8.75	50.51	248.2 [0 - 1160.95]	72.1 [32.89 - 264.62]	0.77 [0 - 0.81]	0.35	8.49
Amplitude Mean	1.86	0.2 [0.01 - 1.09]	0.1 [0.03 - 0.21]	0.81 [0.3 - 0.84]	0.29	0.24	1.87	0.3 [0 - 1.44]	0.1 [0.06 - 0.48]	0.69 [0 - 0.75]	0.35	0.36
Duration Mean	3.92	0.1 [0 - 0.53]	0.04 [0.02 - 0.15]	0.73 [0 - 0.78]	0.10	0.20	3.95	0.2 [0.02 - 0.89]	0.04 [0.02 - 0.15]	0.83 [0.51 - 0.85]	0.13	0.20
Total Mean	4.37	0.1 [0.01 - 0.23]	0.01 [0 - 0.04]	0.83 [0.53 - 0.86]	0.06	0.10	4.52	0.1 [0 - 0.51]	0.1 [0.04 - 0.31]	0.51 [0 - 0.62]	0.10	0.29
Amplitude SD	27.04	1.4 [0 - 55.12]	26.8 [12.21 - 98.18]	0.05 [0 - 0.36]	0.20	5.17	32.31	10.2 [0 - 53.51]	6.0 [2.74 - 22.02]	0.63 [0 - 0.71]	0.15	2.45
Duration SD	19.78	53.7 [0 - 264.95]	23 [10.48 - 84.32]	0.70 [0 - 0.76]	0.44	4.79	21.67	74.8 [0 - 348.9]	21.2 [9.69 - 77.98]	0.78 [0 - 0.82]	0.56	4.61
Total SD	8.61	6.5 [0 - 32.54]	3.1 [1.43 - 11.51]	0.67 [0 - 0.74]	0.36	1.77	10.62	7.1 [1.42 - 31.28]	1.0 [0.47 - 3.82]	0.87 [0.75 - 0.89]	0.35	1.02

[1] ICCs were shaded with green to represent high reliability (0.75-1.0), yellow for moderate reliability, (0.4-0.75) and red for low reliability (0-0.4)

3.5 Aim 2: Differences in EVA Measures between Groups

3.5.1 Marginal Sums

The amplitude marginal sums and duration marginal sums are shown in Figure 10. In general, the pain group showed longer times in higher duration classes compared to the healthy group.

The results of the ANOVAs for each pacing condition are shown in Table 5 and 6. There were over 100 occurrences of zeros in the data, mostly concentrated in the higher amplitude marginal sums (classes 3-5). Hence, prior to being log-transformed, the third, fourth and fifth amplitude marginal sums were combined, to create one category of >20% RVE. After this procedure, there were 9 remaining zeros in the amplitude marginal sums, and 12 in the duration marginal sums. These remaining zeros were changed to the lowest naturally occurring measure in the data (i.e. 0.0001).

For the SP condition, on average, the healthy group spent 80% more working time in the 2nd amplitude marginal class (i.e. 6.67-20% RVE) compared to the pain group, and this difference was also detected as being statistically significant ($p = 0.0001$, Table 5). From Figure 10A, it seems that this was accounted for by the pain group spending more time in the final amplitude category compared to the healthy group. However, this was not tested in the statistical test since we had concatenated the 3rd-5th amplitude classes. There was no statistical difference in amplitude marginal sums of the concatenated category between the pain and healthy groups. As for the duration marginal sums, the pain group, on average, spent 3% less time in each of the first four duration marginal classes (i.e. 0-1, 1-3, 3-7, and 7-15 s) compared to the healthy group (see Figure 10C), and these differences were statistically significant ($p = 0.01$; $p = 0.002$; $p = 0.001$; $p = 0.03$; Table 5). The results in the CP condition were quite similar in the direction of effects, but not all the effects were as strong or statistically significant (refer to Figures 10B, 10D and Table 6). Cohen's d was computed as a measure of effect size (as per Equation 13), and these are shown for the group effects that were statistically significant, in Table 5 and 6. It must be taken into account that Cohen's d was computed for the log-transformed values. There were a few statistically significant effects of computer-task (TYPE vs. CLICK vs. FORM) in the results reported in Table 5 and 6, and these are presented and interpreted in Section 3.5.3.

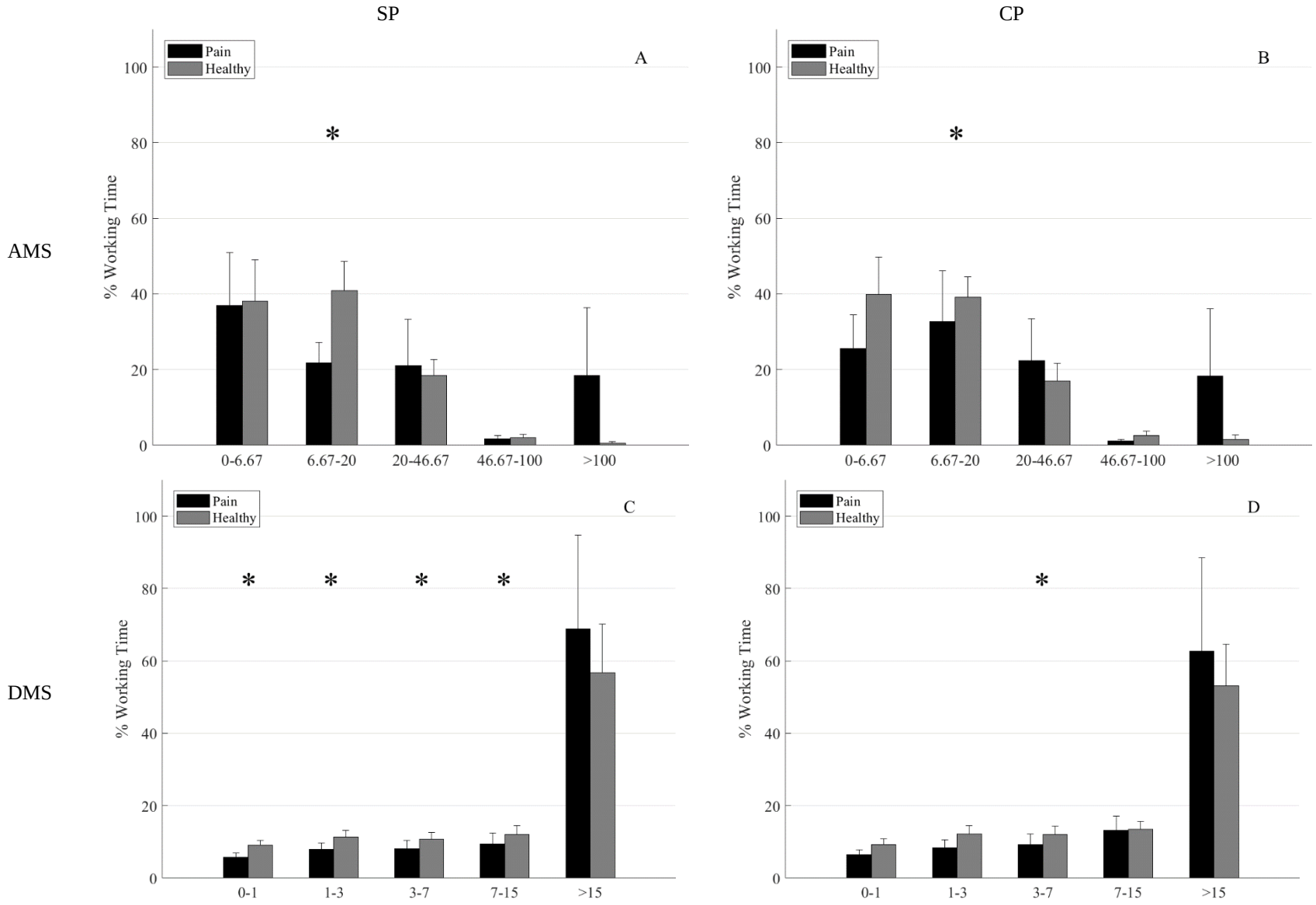

Figure 10 Distribution of EVA amplitude marginal sums and duration marginal sums for all tasks for each condition

Table 5 ANOVA test results for marginal sums for SP condition; significance marked with asterisk and bolded; d is Cohen's d

	Source	DF	F Ratio	P-value
AMS 1	Order	2	0.33	0.72, d = 0.81
	Group	1	0.05	0.83
	Task	2	0.48	0.62
	Group*Task	2	0.21	0.81
AMS 2	Order	2	0.17	0.84
	Group	1	17.19	**0.0001*, d = 4.95**
	Task	2	1.52	0.23
	Group*Task	2	1.36	0.27
AMS 3-5	Order	2	1.26	0.29
	Group	1	0.15	0.70, d = 0.88
	Task	2	3.57	**0.03***
	Group*Task	2	0.26	0.77
DMS 1	Order	2	2.25	0.11
	Group	1	8.48	**0.01*, d = 2.67**
	Task	2	2.71	0.08
	Group*Task	2	0.77	0.47
DMS 2	Order	2	2.74	0.07
	Group	1	10.93	**0.002*, d = 4.93**
	Task	2	0.82	0.45
	Group*Task	2	1.67	0.20
DMS 3	Order	2	3.49	**0.04***
	Group	1	12.26	**0.001*, d = 7.26**
	Task	2	0.74	0.48
	Group*Task	2	0.19	0.83
DMS 4	Order	2	3.57	**0.03***
	Group	1	5.01	**0.03*, d = 4.97**
	Task	2	0.14	0.87
	Group*Task	2	0.02	0.98
DMS 5	Order	2	0.74	0.48
	Group	1	1.30	0.26, d = 0.45
	Task	2	2.98	0.06
	Group*Task	2	0.23	0.80

3.5.2 EVA Summary Measures:

EVA summary measures include means and SDs along each EVA axis and overall mean and SD across all EVA cells. These were computed for each participant in each task and pacing condition. The results of EVA means along each EVA axis are plotted as 2-D plots in Figure 11, and are shown for each participant group, task, and pacing condition. On average, the pain group showed larger amplitude means in every condition and task, and showed longer duration means in every condition and task except for the CLICK task in the CP condition (Figure 11D). The results of EVA SD along each EVA axis and the overall SD of all cells are shown in Figure 12. In general, the SDs were higher in the pain group than in the healthy group for both amplitude and duration classes, and the difference between groups seemed higher in the control paced (Figure 12B) than the self-paced condition (Figure 12A). The results of statistical analysis of the

summary measures for each condition are shown in Table 7 and 8. In the SP condition, the pain group had a significantly larger duration mean (p = 0.05) and total mean (p = 0.002) compared to the healthy group. In the CP condition, on the other hand, the pain group showed a significantly larger amplitude mean (p = 0.04) and total mean (p = 0.01). The pain group also had significantly larger amplitude SD (p = 0.02), duration SD (p = 0.04) and total SD (0.01) compared to the healthy group in the SP condition, and larger SD on the amplitude axis (p = 0.02) and across all the cells (p = 0.04) in the CP condition.

Table 6 ANOVA test results for marginal sums for CP condition; significance marked with asterisk and bolded; d is Cohen's d

	Source	DF	F Ratio	P-value
AMS 1	Order	2	0.12	0.89
	Group	1	0.00	0.97 d = 0.01
	Task	2	0.18	0.84
	Group*Task	2	0.35	0.71
AMS 2	Order	2	0.60	0.55
	Group	1	3.90	**0.05*, d = 0.15**
	Task	2	1.43	0.25
	Group*Task	2	0.04	0.96
AMS 3-5	Order	2	0.34	0.71
	Group	1	1.55	0.22, d = 0.27
	Task	2	1.75	0.18
	Group*Task	2	0.55	0.58
DMS 1	Order	2	2.16	0.12
	Group	1	0.97	0.33, d = 0.09
	Task	2	3.32	**0.04***
	Group*Task	2	0.02	0.98
DMS 2	Order	2	2.92	0.06
	Group	1	0.63	0.43, d = 0.09
	Task	2	2.14	0.13
	Group*Task	2	0.26	0.77
DMS 3	Order	2	2.95	0.06
	Group	1	5.10	**0.03*, d = 0.39**
	Task	2	0.46	0.63
	Group*Task	2	0.10	0.90
DMS 4	Order	2	2.26	0.11
	Group	1	3.62	0.06, d = 0.33
	Task	2	0.46	0.64
	Group*Task	2	0.09	0.91
DMS 5	Order	2	1.81	0.17
	Group	1	0.95	0.33, d = 0.09
	Task	2	1.80	0.17
	Group*Task	2	0.64	0.53

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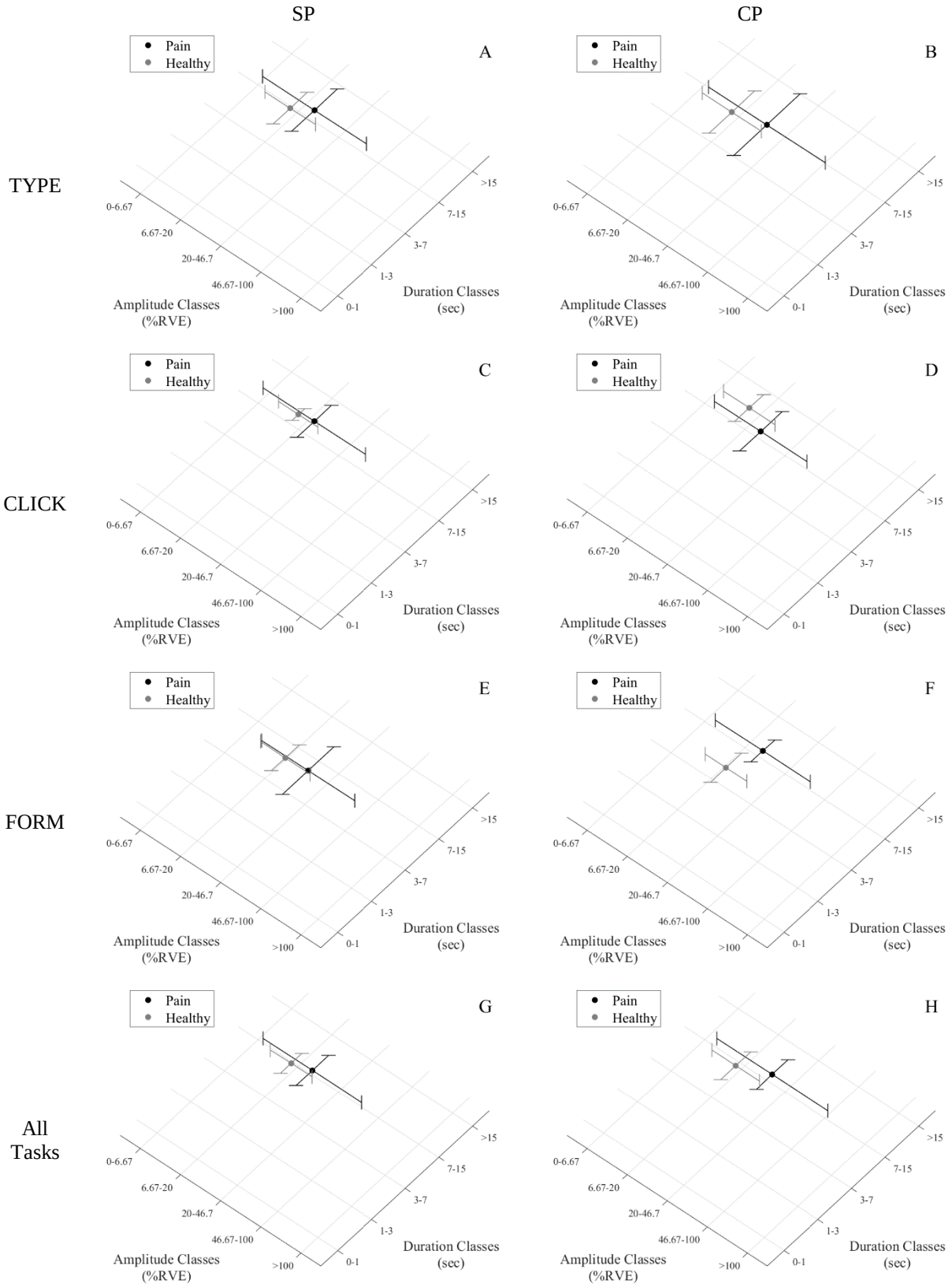

Figure 11 EVA Means for each task and for tasks combined in SP and CP conditions; error bars show SD within group

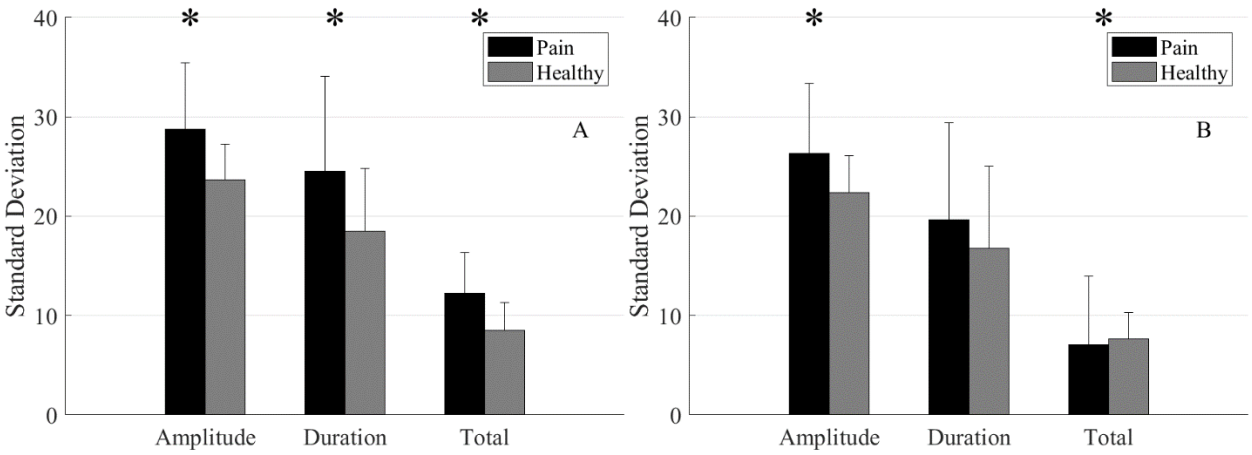

Figure 12 SD summary measures for all tasks for A) SP condition and B) CP condition; error bars for SD across participants

Table 7 ANOVA test results for EVA summary measures for SP condition; significance marked with asterisk and bold; Cohen's d

	Source	DF	F Ratio	P-value
Amplitude Mean	Order	2	0.20	0.82
	Group	1	1.86	0.18, d = 0.40
	Task	2	0.78	0.46
	Group*Task	2	0.14	0.87
Duration Mean	Order	2	1.54	0.22
	Group	1	4.02	**0.05*, d=0.21**
	Task	2	2.26	0.11
	Group*Task	2	0.25	0.78
Total Mean	Order	2	1.62	0.21
	Group	1	10.63	**0.002*, d=0.31**
	Task	2	0.96	0.39
	Group*Task	2	0.09	0.91
Amplitude SD	Order	2	0.93	0.40
	Group	1	5.65	**0.02*, d=0.38**
	Task	2	1.65	0.20
	Group*Task	2	0.31	0.74
Duration SD	Order	2	1.32	0.28
	Group	1	4.42	**0.04*, d=1.00**
	Task	2	1.78	0.18
	Group*Task	2	0.38	0.69
Total SD	Order	2	2.25	0.12
	Group	1	6.91	**0.01*, d=0.75**
	Task	2	1.88	0.16
	Group*Task	2	0.07	0.93

Table 8 ANOVA test results for EVA summary measures for CP condition; significance marked with asterisk and bold; Cohen's d

	Source	DF	F Ratio	P-value
Amplitude Mean	Order	2	0.01	0.99
	Group	1	4.53	**0.04*, d = 0.05**
	Task	2	0.73	0.48
	Group*Task	2	0.038	0.96
Duration Mean	Order	2	0.58	0.57
	Group	1	3.00	0.09, d = 0.02
	Task	2	3.54	**0.04***
	Group*Task	2	1.12	0.33
Total Mean	Order	2	0.41	0.67
	Group	1	6.45	**0.01*, d = 0.02**
	Task	2	1.79	0.18
	Group*Task	2	0.62	0.54
Amplitude SD	Order	2	1.91	0.16
	Group	1	5.35	**0.02*, d = 0.03**
	Task	2	2.24	0.12
	Group*Task	2	0.31	0.73
Duration SD	Order	2	0.33	0.72
	Group	1	3.23	0.08, d = 0.06
	Task	2	3.76	**0.03***
	Group*Task	2	1.66	0.20
Total SD	Order	2	2.07	0.14
	Group	1	4.63	**0.04*, d = 0.04**
	Task	2	4.17	**0.02***
	Group*Task	2	0.73	0.49

3.5.3 Task Differences

The tasks were compared (for each condition), and the results are shown in Table 9. In the SP condition, the FORM task showed a larger percentage of working time in the 3rd through 5th amplitude marginal classes ($p = 0.01$) compared to the CLICK task. Additionally, the FORM task had larger percentages of working time in the 1st duration marginal class (0-1 s) compared to the TYPE task in the SP condition ($p = 0.05$), and compared to the CLICK task in both the SP and CP conditions ($p = 0.05$; $p = 0.02$). In the CP condition, participants spent more percent working time in the 2nd duration marginal class (i.e. 1-3 s) while completing the FORM task compared to the CLICK task. Participants showed higher duration means in the CLICK task compared to the FORM task for both the SP condition ($p = 0.05$) and the CP condition ($p = 0.02$). Lastly, the CLICK task showed consistently higher SDs – amplitude ($p = 0.04$), duration ($p = 0.01$) and total ($p = 0.01$) compared to the FORM task in the CP condition.

Table 9 Post-hoc testing on tasks in SP condition; d is Cohen's d

Condition	Variable	Comparisons		Difference	Std Err	[95% CI]	P-value
SP	AMS 3-5	CLICK	FORM	-3.12	1.17	[0.78 – 5.46]	0.01 d = 7.65
	DMS 1	FORM	TYPE	0.82	0.40	[0.02 – 1.63]	0.05 d = 2.01
		FORM	CLICK	0.79	0.40	[-0.01 – 1.60]	0.05 d = 1.95
	DMS 5	CLICK	FORM	0.48	0.20	[0.07 – 0.88]	0.02 d = 1.17
	Duration Mean	CLICK	FORM	-0.11	0.05	[0.00 – 0.22]	0.05 d = 0.21
CP	DMS 1	FORM	CLICK	1.52	0.62	[0.27 – 2.76]	0.02 d = 0.29
	DMS 2	FORM	CLICK	1.56	0.79	[-0.03 – 3.14]	0.05 d = 0.29
	Duration Mean	CLICK	FORM	0.16	0.07	[0.03 – 0.30]	0.02 d = 0.03
	Amplitude SD	CLICK	FORM	0.15	0.07	[0.01 – 0.30]	0.04 d = 0.03
	Duration SD	CLICK	FORM	0.64	0.23	[0.17 – 1.10]	0.01 d = 0.12
	Total SD	CLICK	FORM	0.40	0.14	[0.12 – 0.68]	0.01 d = 0.08

Similar measurements were taken for the other muscle locations – descending trapezius, transverse trapezius and ascending trapezius. While the DT and TT locations showed low to moderate reliability, the AT location showed moderate to high reliability in the duration marginal sums and EVA summary measures. Absolute reliability measures also had generally good results. All three locations showed very little differences between healthy and pain groups, and these results are found in Appendix D.

4 Discussion

The main goal of this thesis was to explore the variation in patterns of trapezius muscle activity using Exposure Variation Analysis (Mathiassen & Winkel, 1991) in order to estimate the reliability of EVA measures commonly used in the literature for healthy subjects (aim 1), and discriminate between healthy individuals and those suffering from chronic neck-shoulder pain (aim 2) during the performance of computer tasks..

While performance in completion was similar for both participant groups across both pacing conditions in the TYPE task, participants completed ~ 3 times more boxes during the CP condition compared to the SP condition in the CLICK task. Thus, for the CLICK task, in addition to CP condition representing a controlled task, CP may also be perceived as a faster pace condition compared to the SP condition. Overall, the completion rate was similar across healthy and pain groups, and the number of errors were very small (less than 2%) in both groups, indicating that our sample consisted of experienced computer workers and that pain did not affect performance in these short-term controlled computer tasks. This is in accordance with the findings from an earlier study (Johnston, Jull, Darnell, Jimmieson, & Souvlis, 2008) of no significant difference between healthy and pain groups in the number of words typed per minute in typing tasks.

While all participants were pain-free at the beginning of the experiment (by design), the pain group in general reported increased perceived shoulder and lower back discomfort compared to the healthy group. On the other hand, neck and upper back pain was similar across groups and consistent across tasks and conditions.

4.1 Exposure Variation Analysis

The amplitude and duration classes of EVA in this study were chosen based on established literature on low exposure continuous work (e.g. Mathiassen, Moller, et al., 2003; Mathiassen & Winkel, 1991; Samani et al., 2009a). Participants in the pain group spent higher percentages of time in higher amplitude levels compared to their healthy counterparts, i.e. the EVA matrices for the pain group were skewed towards higher amplitudes and those of healthy participants were skewed toward lower amplitude classes. There is some support for this in the literature: computer workers suffering from pain in their upper trapezius spent less time in amplitude classes that constitute as EMG gaps in both their left and right trapezius while typing compared to their healthy counterparts (Hägg & Åström, 1997). As EMG gaps are defined as periods of exposures less than 1% MVE (or 6.67% RVE) for at least 0.3 seconds continuously, the lack of EMG gaps suggest that pain participants had lower percent working times at lower exposure levels. Another previous

study which included mouse and keyboard tasks performed for 20 minutes, reported that EVA amplitude classes were skewed neither to lower nor higher exposures among healthy subjects (Delisle, Larivière, Plamondon, & Imbeau, 2006). The majority of the working time was spent between 1-7% MVE, which would correlate with 6.67-46.67% RVE in our study (or the 2nd and 3rd amplitude classes). This is also in accordance with our results from the healthy control group.

However, findings on duration marginal sums from the Delisle (2006) study showed most activity to be sustained continuously for less than 7 seconds, whereas our results from healthy subjects indicated about half the working time to be spent in the final duration category of >15 seconds. This means that in our study, the muscle activity of healthy participants was in certain amplitude categories for more than 15 seconds continuously (5th duration class). From examining Figures 6-9 more closely, our healthy participants spent nearly 50% of the time within the 5th duration class by being in the first amplitude category of 0-6.67% RVE, and most of the remaining time in the second amplitude category of 6.67-20% RVE. Our study differed from this referenced study (Delisle et al., 2006) in two primary methodological aspects: since the previous study was conducted to understand the specific effects of different workstation designs, participants' postures were carefully controlled by the authors (e.g. forearms resting on arm-rests to offload shoulder muscle activity, mouse and keyboard placed at certain fixed distances, etc.). In contrast, while we designed the task set-up to meet standard ergonomics recommendations, we allowed the participants to adopt their natural and comfortable postures (we did not constrain them in any way). As a second difference, we controlled the working pace quite tightly by including demands that were changed by the minute. The Delisle study, on the other hand, only reports that participants performed roughly 20 minutes of computer tasks that included mouse and keyboard work and say that on average, participants used the mouse for 20% of working time. It is reasonable to expect that our strictly paced (and fast) tasks led to our participants spending a majority of working time (>70%) in the higher duration classes. Hence, we believe that these differences in the extent of control in postures and working pace could have led to the described differences in EVA duration marginal sums between our present study and that of Delisle et al. (2006). Our results of a considerable percentage of the working time in the fifth duration class is, on the other hand, supported by another previous study (Hägg & Åström, 1997), showing workers with chronic neck-shoulder pain spend longer durations of time at similar exposure levels compared to their healthy counterparts.

As for EVA summary measures, EVA means, referred to as the centroid of the EVA matrix, measure the central tendency of the muscle activity levels during the tasks. Delisle et al. (2006) and Dumas et al (2008) found lower mean indices compared to the present study. While this is probably due to the differences in

marginal distributions spoken of earlier for the Delisle study, the latter study, however, found similar mean durations as our study. EVA standard deviation (SD) has been suggested to be a measure of dispersion across exposure levels, thus quantifying variability in exposure during a continuous task. Most previous studies of computer work found similar SD indices in healthy populations as our current study (Ciccarelli et al., 2011; Delisle et al., 2006; Dumas et al., 2008).

4.2 Aim 1: Reliability Tests

The reliability of EVA measures during occupational tasks such as computer work is not known. To our knowledge, this is the first study to investigate the reliability of common EVA measures during simulated computer work. Although our study indicated good ICCs for most measures, indicating that the between-subject's variance was relatively high compared to the sum of the between-subjects and within-subjects variances, we would also like to point out that the confidence intervals on the variance components were quite wide, probably owing to the small number of subjects tested. For instance, if one were to examine the lower confidence intervals of the between-subjects variance components in Table 4, healthy individuals seem remarkably similar in most EVA measures, as indicated by the lower 95th percentile of the confidence interval of the between-subjects variance component being zero (contrary to the point estimate of the between-subjects variance component, and hence ICC, being high). Some exceptions to this general finding were narrow confidence intervals in the lowest two amplitude marginal sums (i.e. 0-6.67% and 6.67-20% RVE) in the self-paced condition and the lowest two duration marginal sums (i.e. 0-1 and 1-3 seconds) in the control-paced condition. On the other hand, the within-subjects (i.e. between-days) variance component had both non-zero point estimates, and non-zero lower confidence intervals for most EVA measures, indicating a high certainty in concluding that participants used different strategies on different days.

While the ICCs are measures of relative reliability, CV and SEM represent measures of absolute reliability (Searle, Casella, & McCulloch, 1992). Coefficient of variation (CV) measures the gross variability between subjects compared to the grand mean, and good and excellent CVs indicate a high precision in the measure (Searle, Casella, & McCulloch, 2009). For both pacing conditions, CVs were good to excellent for the amplitude and duration marginal sums. Lower amplitude classes showed lower CV values (i.e. 0.4-0.8) compared to higher classes, with the combined 3rd-5th amplitude marginal sum having a CV of 1.15 in the self-paced condition and 1.31 in the control-paced condition. On closer examination of Table 4, it becomes apparent that this difference in CV between lower and higher amplitude classes is driven mainly by the difference in mean values of these classes (i.e. the denominator of the CV), and not the variance per se. This does not seem to be the case for the duration marginal sums, as the CVs seem more uniform across all duration classes.

The standard error of measurement, or SEM, is another measure of absolute reliability (using the measure's same unit of measurement) and provides a measure of reproducibility (American Educational Research Association et al., 1999; Hallman, Srinivasan, & Mathiassen, 2015). High SEMs represent high variation across repeated measures obtained from each participant. SEM generally seemed to be similar across pacing conditions. The only notable exceptions to this were the first and second EVA amplitude marginal sums, for which the SEM in the CP condition was almost twice as high as that in the SP condition. This seems to be particularly striking since the mean values of the two measures are not different between the SP and CP conditions. This implies that the participants may have used different motor strategies across different days in using the upper trapezius muscle while completing control-paced simulated computer tasks. As mentioned before, the performance of CLICK task in the control paced condition was twice as fast as that in the self-paced condition – hence the faster pace imposed during the CP condition may have significantly influenced this finding. The duration marginal sums showed lower SEM values for both pacing conditions (with the exception of the 5^{th} duration marginal sum), which indicates that healthy participants spent similar durations of time at various exposure levels across task and pacing conditions. The EVA summary means showed very low SEM values compared to the marginal distributions, which was expected since these are summary measures, thus suggesting that healthy participants did not vary by much in their average amplitude level and duration period across days. However, healthy participants did vary in the dispersion of amplitudes and durations across days, as shown by moderate SEM values for the EVA SD measures.

In summary, on completion of the first aim, we recommend that use of EVA duration marginal sums may be more ***reliable*** than amplitude marginal sums, for comparing different individuals or groups, especially when applied to low intensity work like computer work. This is based on our finding of high ICCs, low CVs and low SEMs for duration marginal sums than amplitude marginal sums. Better reliability was obtained for the self-paced than control-paced condition, indicating that it may be better to allow individuals to perform tasks at their natural and comfortable pace, rather than constraining/forcing everyone to adopt a specific pace. Furthermore, EVA summary measures also exhibited good reliability, however, whether the summary measures are sensitive enough to discriminate between groups is yet to be determined (aim 2).

Previous literature on reliability of EVA for muscle activation patterns has been done on sign language interpreters, with poor reliability results (Delisle, Larivière, Imbeau, & Durand, 2005), and for violinists with moderate reliability (Reynolds, Leduc, Kahnert, & Ludewig, 2014).

4.3 Aim 2: Differences in EVA Measures between Groups

While some studies have examined the muscle-activation differences between workers with and without pain during computer work, those studies have used methods other than EVA (Johnston et al., 2008; Madeleine, 2010; Richter, Mathiassen, Slijper, Over, & Frens, 2009). To our knowledge, only one study has compared differences between healthy workers and those with chronic neck-shoulder pain during computer work using EVA (Hägg & Åström, 1997).

Participants in the pain group spent more working time in larger amplitude categories compared to their healthy counterparts. This is inferred by the pain group having shown significantly lower times in the second amplitude category compared to the healthy group (Figure 10), higher time in the 5th amplitude category (Figure 10, however when amplitude categories 3-4 were merged, this effect could not be statistically tested directly), and also higher EVA mean on the amplitude axis (Figure 11). A study by Johnston et al. (2008) found that pain group participants did not differ significantly from their healthy counterparts in mean muscle activation level of the upper trapezius. It is possible that a summary measure such as the mean, extracted from the whole task, may not have detected the above differences in amplitude categories from within the task. However, another study (Szeto et al., 2005) showed higher activity levels in the upper trapezius muscle for the pain compared to healthy group, and higher activity in the cervical erector spinae for the control group compared to pain, suggesting that different muscle activation strategies were used by individuals in the two groups to perform typing tasks.

The relationship between pain and altered muscle activation patterns is complex. Research using experimental muscle pain models has demonstrated that muscle pain influences motor control and load sharing among muscles (e.g. Falla, Graven-Nielsen, & Farina, 2006). Accordingly, evidence of altered muscle coordination in the acute stages of neck pain following a traumatic event have been demonstrated before (Sterling, Jull, Vicenzino, & Kenardy, 2004). However, in low load repetitive muscle activity associated with computer work, chronic pain may sensitize muscles leading to alterations in movement, force production and greater EMG activity. This was evident in the outcome of a six-month prospective study by Madeleine et al. (2003) who found sensory and motor control differences of higher EMG activity in trapezius, deltoid and infraspinatus muscles, decreased arm movement amplitude and lower force levels, in food processing workers with neck/shoulder complaints at commencement of employment and after 6 months. Inhibition of deep musculature (deep neck flexors) and associated dominant patterns of activation of the superficial musculature (superficial neck flexors and upper trapezius) has also been previously reported in chronic neck pain (e.g. Jull, 2000; Jull, Kristjansson, & Dall'Alba, 2004).

Another factor for consideration (and an alternate explanation) is that the static loading of the proximal structures (head, neck and shoulder region) during sustained repetitive work is associated with over-activity of low-threshold type I motor units (Hägg, 1991). This over-activity in muscles of the neck and upper extremity is thought to be sufficient to cause degenerative changes resulting in fatigue and pain occurring at a subliminal level (Sjøgaard et al., 2000). Visser and van Dieën (2006) suggest that the homeostatic disturbances in muscles secondary to low load muscle activity may result in an accumulation of metabolites, thus stimulating nociceptors, which in turn can disturb proprioception, thereby affecting motor control. As the loss in sensory feedback is not immediately perceived during low force production (Lundberg et al., 2002; Sjøgaard & Jensen, 2006), the worker continues to work without adequate rest resulting in further over-activity of the motor units and homeostatic disturbances. This is a possible circular pathway to explain the chronic nature of symptoms, and the associated motor (Johnston et al., 2008) and sensory deficits observed in these workers (Johnston, Jimmieson, Souvlis, & Jull, 2007).

Johnston et al. (2008) also reported that workers with pain had more difficulty returning to rest after each computer task compared to healthy workers (Johnston et al., 2008). Altered patterns of neuromuscular activation, resulting in loss of joint stability and normal movement control, may cause people with pain to exhibit hyper-activity and not relax as much as asymptomatic individuals. EVA allows for testing this speculation, that the inability for relaxing the upper trapezius muscle, may be one of the key characteristic differences between those with and without chronic pain during low-exposure tasks (Johnston et al., 2008). Previous studies (e.g. Falla, Bilenkij, & Jull, 2004) have also proposed similar hypotheses. In our study, this point would be reflected by more time in the longer duration categories for the pain group, as it would represent the inability for the muscle to switch to different exposure levels (i.e. amplitude classes). We found that pain group participants did indeed spend significantly lower working time in lower duration classes compared to healthy participants, and registered a higher duration mean in the EVA summary measures. This would suggest that healthy computer workers switch between amplitude categories more often than those with pain, which may be indicative of more variable muscle patterns that would lead to the increased likelihood of de-recruitment and subsequent substitution of type I motor units.

EVA SD along the amplitude axis (see Figure 12A and Figure 12B) represents the dispersion or variability across amplitude levels, and the pain group exhibited greater EVA SD than the healthy group. The onset of acute pain may induce a dynamic reorganization of the coordination among muscles to reduce the use of the painful muscle while maintaining task performance (Falla, Farina, & Graven-Nielsen, 2007; Forsman, Birch, Zhang, & Kadefors, 2001). However, once the pain stage has progressed to a chronic level, varying exposure levels which are indicative of motor strategies employing motor unit de-recruitment and

substitution (Westgaard & de Luca, 1999), are expected to be shown to a reduced extent among those with chronic pain. Hence it has been hypothesized in the past that those who suffer from chronic neck-shoulder pain may exhibit decreased variability in order to cope with pain (Madeleine, Voigt, et al., 2008). Although this seems to be contrasting with our finding of greater amplitude SD in the pain group, caution should be used in interpreting our findings from EVA: Higher EVA SD along the amplitude axis in the pain group indicates that overall, the variance in exposure was higher in the pain group. However, since EVA does not preserve the time-line of that information, whether this variable exposure was truly an effect of a variable muscle/motor-unit recruitment strategy is not clear. For instance, a participant in the pain group could have hypothetically employed a low activation level in the beginning and a high level at the end, which may have led to a high SD in EVA amplitude categories overall, while a participant in the control group could have continually alternated activity between high and low amplitude levels more frequently and registered a lower EVA amplitude SD. Thus, muscle recruitment strategies may be better captured by the EVA duration measures.

A larger duration mean represents a tendency towards longer continuous durations in muscle activity. It is in itself a measure of variation in that those with smaller duration means will, by definition, switch through more amplitude levels in a set period of time (i.e. total working time). Short spikes in both low and high exposures, which facilitate de-recruitment and subsequent substitution in type I motor units, are distributed across the amplitude axis while both occur at the lowest duration marginal class. Thus, we emphasize that EVA duration mean in itself is a measure of variation in muscle recruitment patterns, and the fact that the pain group shows higher means than the control group indicates that the pain group is employing a less variable muscle recruitment pattern. While previous literature has suggested the EVA duration SD as a measure of variation (Delisle et al., 2006; Larivière, Delisle, & Plamondon, 2005), this may be more relevant for tasks, which involve high amplitude levels, and in which reducing exposures may be a primary concern (as compared to computer work where reduction in exposure amplitude levels is not a primary concern). EVA total SD was significantly higher in the pain group in the self-paced and lower in the pain group in the control-paced condition, thus requiring caution in interpretation. In general, greater EVA total SD has been used to indicate greater distribution of muscle activation across the different amplitude and duration categories. Whether a greater EVA total SD is a desired outcome in tasks such as computer work (as opposed to most of the activity being concentrated in the low activity-short duration part of the EVA matrix) is an open question.

4.4 Limitations

Our study, and the methods employed, have some limitations. EVA, as a tool to categorize continuous data, removes the sequence of the data. Hence, the order of occurrence of categories is lost in the EVA matrix, and this is critical for further understanding patterns of temporal variation in muscle recruitments.

While a logarithmic scale has been recommended for low exposure loads (Mathiassen & Winkel, 1991), more recent studies on computer work have adopted slight different scales with increased resolution at the lowest exposure level to facilitate EMG gap detection (Ciccarelli et al., 2013; Delisle et al., 2006; Hägg & Åström, 1997). We expect that further resolution of amplitudes in the range of 5-50% RVE (which is where most of the activity is present during computer work) may help in better elucidation of differences in motor strategies and muscle activation patterns between the healthy and pain groups. Emphasis should also be placed on further understanding the relationship between the duration marginal distribution and variation in muscle activity, as they seem to clearly show measurable differences between computer workers with and without pain.

As in most previous studies using EVA, there is a dependency across the amplitude and duration axes. Because all cells within EVA add to 100%, there is an innate dependence across the cells and marginal distributions. Summary measures are more reliable and discriminate than marginal sums and using means and SD, can represent a distribution similar to that of the marginal sums. However, there is still uncertainty on the significance of the duration SD and total SD as they relate to variation in computer work. While some researchers propose eliminating one class of data (Mathiassen & Winkel, 1996), this could potentially cause a loss in important data (Reynolds et al., 2014). A potential approach may be to use principal component analysis (PCA), which transforms data that includes correlated variables into a smaller set of uncorrelated variables, as has been attempted by a few studies (Samani, Kawczyński, Chmura, & Madeleine, 2012; Samani, Mathiassen, & Madeleine, 2013; Samani & Madeleine, 2014).

Finally, because of the low sample size, which could be attributed to the strict inclusion and exclusion criteria for the pain group used in this study, there was low power across the study. Because of this and the inclusion of order effects, the pacing conditions were tested separately, and the effect of pace was not directly analyzed. The data were not normally distributed and needed to be log-transformed. However, this required a correction for any zeros in the data. This was accomplished by combining larger amplitudes (>20% RVE), which may have increased the reliability with a consequent loss in sensitivity.

4.5 Conclusion

Reliability of EVA amplitude marginal sums ranged from moderate to high in the self-paced condition and low to moderate in the control-paced condition. The duration marginal sums had moderate reliability in the self-paced condition and moderate to high in the control-paced condition. The summary measures (means and SDs) were moderate to high in both the self-paced and control-paced condition. Group comparisons revealed that individuals with chronic pain spent longer durations of work time in higher EVA duration categories, exhibited larger means along the amplitude, duration and in the resultant, and higher EVA SD in the amplitude and duration axes as compared to their healthy counterparts. To our knowledge, this is the first study to report on the reliability of EVA applied specifically to computer work. Furthermore, EVA was used to assess differences in muscle activation patterns as individuals with and without chronic pain engaged in computer work. Individuals in the pain group seemed to exhibit prolonged sustained activation of the trapezius muscle to a significantly greater extent than controls, even though they did not experience pain during the performance of the computer tasks (as obtained through self-reports). Thus, these altered muscle recruitment patterns observed in the pain subjects, even in the absence of task-based pain/discomfort, are suggestive of chronic motor control changes occurring in adaptation to pain, and may have implications for the etiology of neck and upper-limb musculoskeletal disorders. Whether the differences in muscle activation patterns reported between symptomatic and asymptomatic computer workers are adaptive or maladaptive strategies occurring in individuals with chronic pain needs to be investigated using prospective studies, in order to gain a mechanistic understanding of why some individuals are more susceptible to the development of upper extremity musculoskeletal symptoms.

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Appendix A: Questionnaires

Baseline Questionnaire

Department of Industrial and Systems Engineering

Date: _____ Subject Code Number: ____

GENERAL

1. Age: _____
2. Gender: _____
3. Height: _____ (inches) Weight: _____ (in lbs)
4. Dominant Hand: Left / Right
5. Bottom to pelvis (ASIS) height: _____ (cm)
6. Popliteal height : _____ (cm)
7. Elbow rest height : _____ (cm)

COMPUTER WORK

1. Job Title: _____
2. How long have you been using a computer? _____ yrs, _____ mths
3. How often do you normally work on a computer?

Seldom	Once a Week	2-3 Times a Week	Almost All of the Time

4. On any typical day, how many hours do you spend working on the computer? ____ hrs
5. Do you think you can perform 1-2 hours of computer work without substantial discomfort? Y/N

Baseline Questionnaire

Department of Industrial and Systems Engineering

Date: _____ Subject Code Number: _____

PAIN

1. **Have you experienced pain in your neck or shoulder for 30 days or more in the last 1 year?** Y / N

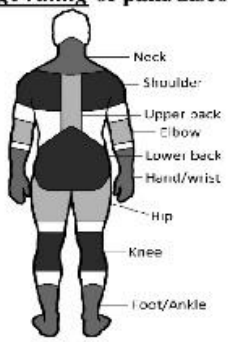
2. **Do you have any diagnosed cardiovascular or neurological or musculoskeletal conditions?** Y / N

3. **Have you had any surgery in your neck/shoulder region?**

   If yes, please describe the purpose and time of the procedure: _____

4. **Using the regions shown in the picture, please indicate the *average rating* of pain/discomfort in each region of the body over the *last 3 month period*.**

0 None at all
0.5 Very weak (barely noticeable)
1 Very weak
2 Weak/light
3 Moderate
4 Pretty Strong
5 Strong
6
7 Very strong
8
9
10 Very, very strong (almost maximum)



Scale	0	0.5	1	2	3	4	5	6	7	8	9	10
a) Neck	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
b) Shoulders	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
c) Elbows	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
d) Wrists/Hands	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
e) Upper Back	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
f) Lower Back	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
g) Hips	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
h) Knees	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
i) Feet	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Baseline Questionnaire

Department of Industrial and Systems Engineering

Date: _____ Subject Code Number: _____

5. How often have you had pain in the *last 3 months*?

	Never	Seldom	Once a week	2-3 times a week	Almost all the time
a) Neck	☐	☐	☐	☐	☐
b) Shoulders	☐	☐	☐	☐	☐
c) Elbows	☐	☐	☐	☐	☐
d) Wrists/hands	☐	☐	☐	☐	☐
e) Upper back	☐	☐	☐	☐	☐
f) Lower back	☐	☐	☐	☐	☐
g) Hips	☐	☐	☐	☐	☐
h) Knees	☐	☐	☐	☐	☐
i) Feet	☐	☐	☐	☐	☐

Baseline Questionnaire
Department of Industrial and Systems Engineering

Date: _____ Subject Code Number: _____

PAIN MANAGEMENT

Answer the following section *only* if you have reported to have substantial pain in your neck or shoulder (check with the researcher if you are not sure whether you need to answer this section)

1. Do you take any medication for pain treatment? Y / N

   If yes, please list them: _____

2. Have you taken any of these medications in the last 24 hours? Y / N

   If yes, please list them: _____

3. Do you receive physical therapy for pain management? Y / N

   If yes, how often: _____

4. Do you visit a chiropractor for pain management? Y / N

   If yes, how often: _____

5. Have you had any surgeries for treatment of pain? Y / N

   If yes, please list them: _____

6. Do you practice any other pain management solutions? Y / N

   If yes, please list them: _____

7. How much does your pain interfere with daily activities?

Seldom	Once a Week	2-3 Times a Week	Almost All of the Time

8. How much does your pain interfere with your regular computer work?

Not at all	Somewhat	Substantial	Very much

Appendix B: Task Instructions

Self-Pace TYPE Task

Instructions

- You will now complete a typing task.
- You will need to copy the text in the Word Document in your task window.
- Please work at your **natural, comfortable pace** (as you would during regular work).
- Please also be sure to be **as accurate as possible**.

- When you have finished reading, select this link to open Microsoft Word. Then click anywhere on this screen and begin typing in the word document.

Control-Pace TYPE Task

Instructions

- You will now complete a typing task.
- You will need to copy the series of text in the Word Document in your task window.
- We want you to type at **65 WPM**. This is imposed with a **beep** and a **red arrow** that appears at the beginning of each passage for each minute.
  - If you find yourself going faster than the required pace, *please proceed to the next paragraph (without stopping)*, but make sure to adjust your pace as you type that paragraph to better match the required work pace.
  - If you find yourself going slower (ex. Not finishing the required passage in the given minute), when the cursor moves *please move to the next paragraph* – no matter how much of the previous paragraph is incomplete. Try to speed up this time so that it doesn't happen again.
  - It is critical that you **don't stop typing** no matter what once the task starts. We want you to be typing through the whole 10 minutes of measurements.
- When you have finished reading, select this link to open Microsoft Word. Then click anywhere on this screen and begin typing in the word document.

Self-Pace CLICK Task

Instructions

- You will be presented with a series of images and legends of colors for each image.
- You will need to use the *'eyedropper' tool* to select the appropriate color and the *'fill' tool* to color areas with the corresponding number of letter.
  - Please keep the image *zoom = 100%.*
- Please work at your **natural, comfortable pace** (as you would during regular work).
- Please also be sure to be **as accurate as possible**.

- When you have finished reading, tap the 'space bar' and click the link to begin.

Control-Pace CLICK Task

Instructions

- You will be presented with a series of images and legends of colors for each image.
- You will need to use the *'eyedropper' tool* to select the appropriate color and the *'fill' tool* to color areas with the corresponding number of letter.
  - Please keep the image *zoom = 100%.*
- At the bottom of each image, there are **red boxes** around one or more colors in the legend. We expect you to complete each box within a given minute. This is imposed with a **beep** that sounds at the beginning of each minute.
  - If you find yourself going faster than the required pace, *please proceed to the next red box (without stopping)*, but make sure to adjust your pace as you work to better match the required work pace.
  - If you find yourself going slower (ex. Not finishing the required box in the given minute), when the beep sounds *please move to the next red box* – no matter how much of the previous red box is incomplete. Try to speed up this time so that it doesn't happen again.
  - It is critical that you **don't stop working** no matter what once the task starts. We want you to be working through the whole 10 minutes of measurements.
- When you have finished reading, tap the 'space bar' and click the link to begin.

Self-Pace FORM Task

Instructions

- You will be presented with a form.
- You will need to begin working on the form.
- When you click each link, a PDF will open.
- Please work at your **natural, comfortable pace** (as you would during regular work).
- Please also be sure to be **as accurate as possible**.

- When you have finished reading, tap the 'space bar' to begin and click on the first link to begin.

Control-Pace FORM Task

Instructions

- You will be presented with series of links to forms.
- We expect you to complete each form within a given minute. This is imposed with a **beep** and a **red arrow** that appears next to the next link each minute.
- When you click each link, a PDF will open.
  - If you find yourself going faster than the required pace, *please proceed to the next form (without stopping)*, but make sure to adjust your pace as you work to better match the required work pace.
  - If you find yourself going slower (ex. Not finishing the required form in the given minute), when the beep sounds *please move to the next form* – no matter how much of the previous form is incomplete. Try to speed up this time so that it doesn't happen again.
  - It is critical that you **don't stop working** no matter what once the task starts. We want you to be working through the whole 10 minutes of measurements.
- When you have finished reading, tap the 'space bar' to begin and click on the first link to begin.

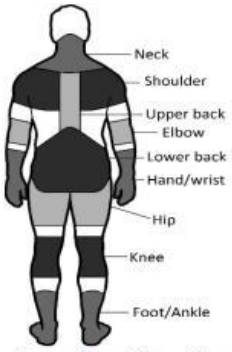
Appendix C: Borg CR-10 Scale and Body Regions of Discomfort

DISCOMFORT QUESTIONNAIRE
Department of Industrial and Systems Engineering

Date: _____ Subject Code Number:

Using the regions shown in the picture, please indicate the rating of pain/discomfort in each region of the body *right now*.

0 None at all
0.5 Very weak (barely noticeable)
1 Very weak
2 Weak/light
3 Moderate
4 Pretty Strong
5 Strong
6
7 Very strong
8
9
10 Very, very strong (almost maximum)



Scale	0	0.5	1	2	3	4	5	6	7	8	9	10
a) Neck	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
b) Shoulders	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
c) Elbows	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
d) Wrists/Hands	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
e) Upper Back	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
f) Lower Back	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
g) Hips	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
h) Knees	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
i) Feet	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Appendix D: Data Results at other Muscle Locations

Reliability for DT Muscle

Variable	SP Condition						CP Condition					
	Mean	BS [95% CI]	WS [95% CI]	ICC	CV	SEM	Mean	BS [95% CI]	WS [95% CI]	ICC	CV	SEM
AMS 1	38.59	1182.5 [361.58 - 5075.4]	96.1 [43.85 - 352.71]	0.92 [0.89 - 0.94]	0.93	9.80	39.22	952.6 [0 - 4451.84]	274.5 [125.25 - 1007.54]	0.78 [0 - 0.82]	0.89	16.57
AMS 2	42.38	671.3 [143.28 - 2952.19]	92.9 [42.39 - 341.03]	0.88 [0.77 - 0.9]	0.65	9.64	38.96	117.9 [0 - 1209]	391.1 [178.42 - 1435.27]	0.23 [0 - 0.46]	0.58	19.78
AMS 3	16.11	156.1 [0 - 850.19]	110.4 [50.38 - 405.30]	0.59 [0 - 0.68]	1.01	10.51	15.39	162.3 [0 - 914.67]	131.5 [59.97 - 482.45]	0.55 [0 - 0.65]	1.11	11.47
AMS 4	2.80	10.5 [0 - 139.45]	52.0 [23.74 - 190.97]	0.17 [0 - 0.42]	2.83	7.21	4.32	10.8 [0 - 247.32]	110.0 [50.17 - 403.58]	0.09 [0 - 0.38]	2.54	10.49
AMS 5	0.12	0 [0 - 0.15]	0.1 [0.02 - 0.20]	0.18 [0 - 0.43]	2.07	0.23	2.11	2.6 [0 - 123.23]	61.0 [27.85 - 224.02]	0.04 [0 - 0.35]	3.79	7.81
AMS 3-5	19.03	367.8 [43.08 - 1657.58]	72.8 [33.22 - 267.21]	0.83 [0.56 - 0.86]	1.10	8.53	21.82	384.7 [0 - 2401.90]	438.5 [200.06 - 1609.39]	0.47 [0 - 0.60]	1.31	20.94
DMS 1	10.85	0 [NaN - NaN]	40.6 [18.51 - 148.91]	0.00 [NaN - NaN]	0.59	6.37	10.69	11.4 [0 - 83.35]	19.5 [8.92 - 71.75]	0.37 [0 - 0.54]	0.52	4.42
DMS 2	12.49	13.2 [0 - 108.16]	29.0 [13.25 - 106.59]	0.31 [0 - 0.5]	0.52	5.39	12.14	10.8 [0 - 89.44]	24.3 [11.07 - 89.08]	0.31 [0 - 0.50]	0.49	4.93
DMS 3	11.67	8.2 [0 - 77.68]	23.6 [10.79 - 86.78]	0.26 [0 - 0.47]	0.48	4.86	11.60	1.6 [0 - 40.62]	18.5 [8.42 - 67.73]	0.08 [0 - 0.37]	0.39	4.30
DMS 4	13.05	11.3 [0 - 86.75]	21.8 [9.93 - 79.92]	0.34 [0 - 0.52]	0.44	4.67	13.38	8.3 [0 - 53.19]	10.1 [4.62 - 37.2]	0.45 [0 - 0.59]	0.32	3.18
DMS 5	51.93	135.3 [0 - 1219.17]	357.4 [163.04 - 1311.57]	0.27 [0 - 0.48]	0.43	18.90	52.19	115.6 [0 - 841.99]	197 [89.90 - 723.20]	0.37 [0 - 0.54]	0.34	14.04
Amplitude Mean	1.83	0.3 [0.09 - 1.23]	0.02 [0.01 - 0.09]	0.92 [0.88 - 0.93]	0.30	0.16	1.91	0.4 [0 - 1.90]	0.2 [0.09 - 0.75]	0.64 [0 - 0.72]	0.40	0.45
Duration Mean	3.83	0.1 [0 - 0.79]	0.3 [0.12 – 1.00]	0.20 [0 - 0.44]	0.15	0.52	3.84	0.1 [0 - 0.64]	0.2 [0.07 - 0.60]	0.34 [0 - 0.52]	0.13	0.40
Total Mean	4.30	0 [NaN - NaN]	0.2 [0.08 - 0.66]	0.00 [NaN - NaN]	0.08	0.42	4.35	0.02 [0 - 0.54]	0.2 [0.11 - 0.92]	0.07 [0 - 0.37]	0.12	0.50
Amplitude SD	29.38	22.3 [0 - 151.11]	31.8 [14.49 - 116.58]	0.41 [0 - 0.56]	0.25	5.64	28.15	13.2 [0 - 103.48]	26.4 [12.03 - 96.79]	0.33 [0 - 0.52]	0.22	5.14
Duration SD	18.73	37.0 [0 - 317.41]	89.0 [40.62 - 326.76]	0.29 [0 - 0.49]	0.60	9.44	18.34	36.5 [0 - 253.09]	55.2 [25.21 - 202.76]	0.40 [0 - 0.56]	0.52	7.43
Total SD	9.19	6.0 [0 - 41.70]	9.2 [4.19 - 33.74]	0.39 [0 - 0.55]	0.42	3.03	8.82	5.4 [0 - 33.47]	5.9 [2.71 - 21.79]	0.48 [0 - 0.61]	0.38	2.44

Reliability for TT Muscle

Variable	SP Condition						CP Condition					
	Mean	BS [95% CI]	WS [95% CI]	ICC	CV	SEM	Mean	BS [95% CI]	WS [95% CI]	ICC	CV	SEM
AMS 1	2.15	0 [NaN - NaN]	25.4 [11.58 - 93.13]	0 [NaN - NaN]	2.18	5.04	0.79	0 [NaN - NaN]	4.0 [1.82 - 14.62]	0 [NaN - NaN]	2.40	2.00
AMS 2	53.86	94.0 [0 - 3109.61]	1476.0 [673.4 - 5417.07]	0.06 [0 - 0.36]	0.74	38.42	48.90	339.5 [0 - 3876.47]	1340.2 [611.48 - 4918.95]	0.2 [0 - 0.44]	0.84	36.61
AMS 3	38.05	113.4 [0 - 2603.87]	1157.9 [528.3 - 4249.84]	0.09 [0 - 0.38]	0.94	34.03	44.02	487.7 [0 - 3635.45]	876.4 [399.86 - 3216.60]	0.36 [0 - 0.53]	0.84	29.60
AMS 4	5.81	0 [NaN - NaN]	234.7 [107.08 - 861.36]	0 [NaN - NaN]	2.58	15.32	6.20	0 [NaN - NaN]	246.4 [112.41 - 904.29]	0 [NaN - NaN]	2.44	15.70
AMS 5	0.12	0 [NaN - NaN]	0.1 [0.04 - 0.35]	0 [NaN - NaN]	2.41	0.31	0.09	0 [NaN - NaN]	0.1 [0.04 - 0.29]	0 [NaN - NaN]	2.93	0.28
AMS 3-5	43.99	0 [NaN - NaN]	1644.0 [750.08 - 6033.95]	0 [NaN - NaN]	0.90	40.55	50.32	305.0 [0 - 3833.33]	1394.4 [636.21 - 5117.87]	0.18 [0 - 0.43]	0.82	37.34
DMS 1	11.70	34.2 [0 - 322.6]	98.2 [44.81 - 360.45]	0.26 [0 - 0.47]	0.98	9.91	8.33	28.4 [0 - 159.29]	22.7 [10.34 - 83.20]	0.56 [0 - 0.66]	0.86	4.76
DMS 2	11.25	43.6 [0 - 295.24]	62.1 [28.33 - 227.94]	0.41 [0 - 0.56]	0.91	7.88	9.86	30.5 [0 - 198.06]	38.9 [17.74 - 142.74]	0.44 [0 - 0.58]	0.84	6.24
DMS 3	10.55	32.4 [0 - 178.1]	23.9 [10.9 - 87.71]	0.58 [0 - 0.67]	0.71	4.89	9.63	31.8 [0 - 168.40]	20.0 [9.11 - 73.30]	0.61 [0 - 0.70]	0.75	4.47
DMS 4	10.53	0 [NaN - NaN]	42.0 [19.16 - 154.13]	0 [NaN - NaN]	0.56	6.48	12.14	23.3 [0 - 134.66]	20.6 [9.41 - 75.70]	0.53 [0 - 0.64]	0.55	4.54
DMS 5	55.98	553.1 [0 - 2909.21]	335.5 [153.06 - 1231.24]	0.62 [0 - 0.7]	0.53	18.32	60.04	424.9 [0 - 2387.85]	340.6 [155.41 - 1250.20]	0.56 [0 - 0.66]	0.46	18.46
Amplitude Mean	2.48	0 [NaN - NaN]	0.3 [0.13 - 1.07]	0 [NaN - NaN]	0.20	0.54	2.56	0 [0 - 0.47]	0.3 [0.12 - 0.94]	0 [0 - 0.34]	0.20	0.51
Duration Mean	3.88	0.4 [0 - 2.42]	0.4 [0.18 - 1.42]	0.52 [0 - 0.63]	0.23	0.62	4.06	0.3 [0 - 1.61]	0.2 [0.11 - 0.86]	0.55 [0 - 0.65]	0.18	0.48
Total Mean	4.65	0.1 [0 - 1.27]	0.4 [0.17 - 1.37]	0.27 [0 - 0.48]	0.15	0.61	4.84	0.1 [0 - 0.77]	0.3 [0.12 - 0.99]	0.20 [0 - 0.44]	0.12	0.52
Amplitude SD	35.31	30.4 [0 - 213.55]	47.5 [21.69 - 174.49]	0.39 [0 - 0.55]	0.25	6.90	36.04	26.1 [0 - 158.03]	27.2 [12.41 - 99.80]	0.49 [0 - 0.61]	0.20	5.21
Duration SD	22.22	108.9 [0 - 630.19]	97.1 [44.31 - 356.42]	0.53 [0 - 0.64]	0.65	9.85	22.92	124.0 [0 - 692.10]	96.9 [44.22 - 355.72]	0.56 [0 - 0.66]	0.65	9.84
Total SD	11.37	17.2 [0 - 96.88]	13.8 [6.3 - 50.66]	0.56 [0 - 0.66]	0.49	3.72	11.88	17.9 [0 - 95.71]	11.6 [5.31 - 42.68]	0.61 [0 - 0.69]	0.46	3.41

Reliability for AT Muscle

Variable	SP Condition						CP Condition					
	Mean	BS [95% CI]	WS [95% CI]	ICC	CV	SEM	Mean	BS [95% CI]	WS [95% CI]	ICC	CV	SEM
AMS 1	0.58	0 [NaN - NaN]	3.6 [1.66 - 13.32]	0 [NaN - NaN]	3.26	1.91	1.17	0 [NaN - NaN]	19.5 [8.91 - 71.68]	0 [NaN - NaN]	3.77	4.42
AMS 2	42.91	375.6 [0 - 3257.33]	923.2 [421.22 - 3388.47]	0.29 [0 - 0.49]	0.84	30.38	36.56	199.3 [0 - 2695.07]	1014.3 [462.76 - 3722.61]	0.16 [0 - 0.42]	0.95	31.85
AMS 3	32.56	290.2 [0 - 2520.67]	715.5 [326.45 - 2626.08]	0.29 [0 - 0.49]	0.97	26.75	36.56	24.2 [0 - 1427.93]	720.3 [328.64 - 2643.68]	0.03 [0 - 0.35]	0.75	26.84
AMS 4	23.17	1140.9 [401.08 - 4837.13]	60.4 [27.56 - 221.7]	0.95 [0.94 - 0.96]	1.50	7.77	24.40	716.0 [76.24 - 3235.77]	146.5 [66.82 - 537.52]	0.83 [0.53 - 0.86]	1.20	12.10
AMS 5	0.79	0.7 [0 - 3.73]	0.3 [0.16 - 1.26]	0.69 [0 - 0.75]	1.32	0.58	1.31	0 [0 - 10.62]	5.7 [2.6 - 20.9]	0.01 [0 - 0.34]	1.83	2.39
AMS 3-5	56.52	377.9 [0 - 3278.13]	929.4 [424.03 - 3411.07]	0.29 [0 - 0.49]	0.64	30.49	62.27	159.2 [0 - 2585.55]	1045.1 [476.84 - 3835.84]	0.13 [0 - 0.4]	0.56	32.33
DMS 1	8.69	24.5 [0 - 129.66]	15.3 [6.99 - 56.21]	0.62 [0 - 0.7]	0.73	3.91	10.08	25.8 [0 - 149.61]	23.1 [10.53 - 84.72]	0.53 [0 - 0.64]	0.69	4.80
DMS 2	10.95	48.0 [0 - 222.94]	13.0 [5.94 - 47.77]	0.79 [0 - 0.82]	0.71	3.61	12.12	61.4 [10.06 - 273.42]	10.4 [4.74 - 38.09]	0.86 [0.68 - 0.88]	0.70	3.22
DMS 3	9.72	30.2 [5.92 - 133.3]	4.5 [2.05 - 16.52]	0.87 [0.74 - 0.89]	0.61	2.12	12.76	37.0 [0 - 175.91]	12.3 [5.61 - 45.1]	0.75 [0 - 0.80]	0.55	3.51
DMS 4	11.65	40.2 [10.09 - 174.93]	4.6 [2.11 - 16.96]	0.90 [0.83 - 0.91]	0.57	2.15	12.95	16.5 [0 - 94.86]	14.4 [6.58 - 52.9]	0.53 [0 - 0.64]	0.43	3.80
DMS 5	58.99	582.1 [137.84 - 2544.13]	72.1 [32.91 - 264.76]	0.89 [0.81 - 0.91]	0.43	8.49	52.10	519.8 [0 - 2423.69]	146.8 [66.99 - 538.92]	0.78 [0 - 0.82]	0.50	12.12
Amplitude Mean	2.81	0.3 [0 - 1.38]	0.1 [0.06 - 0.49]	0.68 [0 - 0.74]	0.23	0.36	2.88	0.2 [0 - 1.1]	0.2 [0.08 - 0.61]	0.54 [0 - 0.64]	0.21	0.41
Duration Mean	4.01	0.3 [0.01 - 1.57]	0.1 [0.04 - 0.31]	0.80 [0.27 - 0.84]	0.16	0.29	3.85	0.4 [0 - 1.72]	0.1 [0.05 - 0.43]	0.75 [0 - 0.8]	0.18	0.34
Total Mean	4.93	0.4 [0.01 - 1.84]	0.1 [0.05 - 0.37]	0.80 [0.23 - 0.83]	0.14	0.32	4.85	0.3 [0 - 1.4]	0.1 [0.07 - 0.52]	0.66 [0 - 0.73]	0.13	0.38
Amplitude SD	32.79	60.0 [0 - 300.19]	28 [12.78 - 102.77]	0.68 [0 - 0.74]	0.29	5.29	29.99	49.6 [0 - 259.82]	29.4 [13.42 - 107.99]	0.63 [0 - 0.71]	0.30	5.42
Duration SD	22.68	157.1 [53.68 - 667.66]	9.3 [4.23 - 34.01]	0.94 [0.93 - 0.95]	0.57	3.04	19.54	104.6 [0 - 517.92]	46.0 [20.98 - 168.78]	0.69 [0 - 0.75]	0.63	6.78
Total SD	11.12	25.3 [5.92 - 110.6]	3.2 [1.45 - 11.66]	0.89 [0.8 - 0.9]	0.48	1.78	9.49	15.4 [0 - 78.12]	7.7 [3.53 - 28.37]	0.67 [0 - 0.73]	0.51	2.78

ANOVA for DT Muscle

			SP Condition		CP Condition	
	Source	DF	F Ratio	P-value	F Ratio	P-value
AMS 1	Order	2	0.34	0.71	0.98	0.38
	Group	1	0.60	0.44, d = 0.23	0.15	0.70, d = 0.11
	Task	2	0.35	0.71	14.15	**<.0001***
	Group*Task	2	0.05	0.95	0.68	0.51
AMS 2	Order	2	0.15	0.86	1.13	0.33
	Group	1	12.33	**0.001*, d = 0.44**	0.41	0.52, d = 0.14
	Task	2	1.33	0.27	4.27	**0.02***
	Group*Task	2	1.04	0.36	0.14	0.87
AMS 3-5	Order	2	1.98	0.15	0.12	0.89
	Group	1	0.11	0.74, d = 0.06	2.00	0.16, d = 0.27
	Task	2	2.97	0.06	7.12	**0.002***
	Group*Task	2	0.46	0.63	1.10	0.34
DMS 1	Order	2	1.08	0.35	0.31	0.74
	Group	1	0.56	0.46, d = 0.03	0.25	0.62, d = 0.08
	Task	2	2.67	0.08	2.85	0.07
	Group*Task	2	0.02	0.98	1.50	0.23
DMS 2	Order	2	0.90	0.41	0.09	0.91
	Group	1	3.01	0.09, d = 0.14	0.04	0.83, d = 0.03
	Task	2	3.27	**0.05***	1.28	0.29
	Group*Task	2	1.84	0.17	0.35	0.70
DMS 3	Order	2	1.25	0.30	0.89	0.42
	Group	1	0.66	0.42, d = 0.09	2.06	0.16, d = 0.30
	Task	2	3.09	**0.05***	4.19	**0.02***
	Group*Task	2	1.25	0.29	1.27	0.29
DMS 4	Order	2	0.99	0.38	0.28	0.76
	Group	1	0.19	0.67, d = 0.06	0.08	0.77, d = 0.07
	Task	2	1.16	0.32	2.81	0.07
	Group*Task	2	0.02	0.98	1.28	0.28
DMS 5	Order	2	1.60	0.21	0.58	0.56
	Group	1	0.75	0.39, d = 0.03	3.79	0.06, d = 0.20
	Task	2	3.56	**0.04***	5.19	**0.01***
	Group*Task	2	0.30	0.74	5.33	**0.01***
Amplitude Mean	Order	2	0.28	0.76	0.28	0.76
	Group	1	1.11	0.30, d = 0.02	2.60	0.11, d = 0.04
	Task	2	0.75	0.48	9.12	**0.0004***
	Group*Task	2	0.22	0.81	0.15	0.86
Duration Mean	Order	2	1.30	0.28	0.21	0.81
	Group	1	0.63	0.43, d = 0.01	0.80	0.38, d = 0.01
	Task	2	3.66	**0.03***	6.05	**0.004***
	Group*Task	2	0.17	0.84	3.65	**0.03***
Total Mean	Order	2	0.74	0.48	0.49	0.61
	Group	1	4.83	**0.03*, d = 0.01**	0.96	0.33, d = 0.01
	Task	2	2.22	0.12	1.65	0.20
	Group*Task	2	0.37	0.69	2.01	0.14
Amplitude SD	Order	2	1.25	0.29	0.88	0.42
	Group	1	0.05	0.83, d = 0.003	0.71	0.40, d = 0.01
	Task	2	0.91	0.41	0.46	0.64
	Group*Task	2	0.43	0.65	1.18	0.31
Duration SD	Order	2	1.13	0.33	0.95	0.39
	Group	1	0.19	0.66, d = 0.02	0.01	0.93, d = 0.01
	Task	2	3.42	**0.04***	1.57	0.22
	Group*Task	2	1.19	0.31	0.09	0.91
Total SD	Order	2	1.29	0.28	1.01	0.37
	Group	1	0.06	0.81, d = 0.01	0.24	0.63, d = 0.01
	Task	2	2.24	0.12	2.97	0.06
	Group*Task	2	0.70	0.50	0.10	0.91

ANOVA for TT Muscle

			SP Condition		CP Condition	
	Source	DF	F Ratio	P-value	F Ratio	P-value
AMS 1	Order	2	0.04	0.96	0.14	0.87
	Group	1	0.29	0.59, d = 0.16	0.14	0.71, d = 0.11
	Task	2	0.15	0.86	0.04	0.96
	Group*Task	2	0.22	0.81	0.14	0.87
AMS 2	Order	2	0.04	0.96	0.08	0.92
	Group	1	3.42	0.07, d = 0.77	2.63	0.11, d = 0.73
	Task	2	0.07	0.93	0.02	0.98
	Group*Task	2	0.06	0.95	0.05	0.95
AMS 3-5	Order	2	0.42	0.66	0.14	0.87
	Group	1	3.98	**0.05*, d = 0.33**	5.42	**0.02*, d = 0.37**
	Task	2	0.81	0.45	0.32	0.73
	Group*Task	2	0.53	0.59	0.75	0.48
DMS 1	Order	2	0.77	0.47	0.33	0.72
	Group	1	0.41	0.53, d = 0.09	1.74	0.19, d = 0.21
	Task	2	1.20	0.31	0.71	0.50
	Group*Task	2	0.03	0.98	0.35	0.70
DMS 2	Order	2	0.80	0.45	0.60	0.55
	Group	1	0.25	0.62, d = 0.12	2.62	0.11, d = 0.46
	Task	2	1.39	0.26	1.28	0.29
	Group*Task	2	0.24	0.79	0.43	0.65
DMS 3	Order	2	0.71	0.50	0.33	0.72
	Group	1	0.27	0.60, d =0.15	3.86	**0.05*, d = 0.63**
	Task	2	0.96	0.39	0.57	0.57
	Group*Task	2	0.37	0.69	1.09	0.34
DMS 4	Order	2	0.18	0.84	0.12	0.89
	Group	1	0.35	0.55, d =0.17	0.82	0.37, d = 0.33
	Task	2	0.79	0.46	2.05	0.14
	Group*Task	2	0.28	0.76	0.34	0.72
DMS 5	Order	2	0.17	0.85	1.96	0.15
	Group	1	0.15	0.70, d = 0.05	0.20	0.66, d = 0.06
	Task	2	0.90	0.41	1.25	0.29
	Group*Task	2	0.48	0.62	0.68	0.51
Amplitude Mean	Order	2	0.26	0.78	0.26	0.77
	Group	1	11.69	**0.001*, d = 0.06**	9.95	**0.003*, d = 0.06**
	Task	2	0.26	0.77	0.16	0.85
	Group*Task	2	0.19	0.83	0.30	0.75
Duration Mean	Order	2	0.54	0.58	0.21	0.81
	Group	1	0.01	0.91, d = 0.002	0.05	0.82, d = 0.004
	Task	2	1.02	0.37	1.29	0.28
	Group*Task	2	0.34	0.72	0.46	0.63
Total Mean	Order	2	0.31	0.73	0.22	0.80
	Group	1	2.29	0.14, d = 0.02	1.34	0.25, d = 0.01
	Task	2	0.58	0.56	0.50	0.61
	Group*Task	2	0.29	0.75	0.42	0.66
Amplitude SD	Order	2	0.40	0.68	1.01	0.37
	Group	1	0.00	0.99, d = 0.0003	0.14	0.71, d = 0.005
	Task	2	0.58	0.56	1.37	0.26
	Group*Task	2	0.03	0.97	0.11	0.89
Duration SD	Order	2	0.23	0.80	0.17	0.85
	Group	1	0.10	0.75, d = 0.02	0.21	0.65, d = 0.03
	Task	2	2.31	0.11	1.35	0.27
	Group*Task	2	0.35	0.71	0.13	0.88
Total SD	Order	2	0.59	0.56	0.14	0.87
	Group	1	0.00	0.98, d = 0.001	0.69	0.41, d = 0.03
	Task	2	2.08	0.14	1.31	0.28
	Group*Task	2	0.19	0.83	0.17	0.84

ANOVA for AT Muscle

			SP Condition		CP Condition	
	Source	DF	F Ratio	P-value	F Ratio	P-value
AMS 1	Order	2	0.01	0.99	0.14	0.87
	Group	1	0.40	0.53, d = 0.19	2.60	0.11, d = 0.48
	Task	2	0.09	0.91	0.55	0.58
	Group*Task	2	0.04	0.96	0.21	0.82
AMS 2	Order	2	0.08	0.92	0.00	1.00
	Group	1	0.36	0.55, d = 0.28	0.02	0.90, d = 0.07
	Task	2	0.11	0.90	0.15	0.86
	Group*Task	2	0.14	0.87	0.03	0.97
AMS 3-5	Order	2	0.46	0.64	0.63	0.54
	Group	1	2.86	0.10, d = 0.21	1.60	0.21, d = 0.19
	Task	2	3.70	**0.03***	1.96	0.15
	Group*Task	2	0.05	0.95	0.01	0.99
DMS 1	Order	2	0.04	0.96	0.28	0.76
	Group	1	3.14	0.08, d = 0.39	1.25	0.27, d = 0.29
	Task	2	0.74	0.48	0.16	0.86
	Group*Task	2	0.08	0.92	0.03	0.97
DMS 2	Order	2	0.17	0.84	0.45	0.64
	Group	1	2.72	0.10, d = 0.48	1.71	0.20, d = 0.46
	Task	2	1.10	0.34	0.44	0.65
	Group*Task	2	0.26	0.77	0.05	0.95
DMS 3	Order	2	1.10	0.34	1.02	0.37
	Group	1	3.54	0.07, d = 0.56	0.26	0.61, d = 0.19
	Task	2	1.97	0.15	0.76	0.47
	Group*Task	2	0.62	0.54	0.64	0.53
DMS 4	Order	2	0.00	1.00	0.00	1.00
	Group	1	0.85	0.36, d = 0.29	1.23	0.27, d = 0.39
	Task	2	1.04	0.36	0.43	0.66
	Group*Task	2	0.17	0.84	0.12	0.88
DMS 5	Order	2	1.09	0.34	0.26	0.77
	Group	1	0.21	0.65, d = 0.07	1.91	0.17, d = 0.32
	Task	2	1.02	0.37	1.52	0.23
	Group*Task	2	0.41	0.67	2.86	0.07
Amplitude Mean	Order	2	0.11	0.90	0.07	0.93
	Group	1	2.11	0.15, d = 0.03	2.62	0.11, d = 0.04
	Task	2	4.13	**0.02***	3.35	**0.04***
	Group*Task	2	0.27	0.77	0.02	0.98
Duration Mean	Order	2	0.25	0.78	0.45	0.64
	Group	1	4.92	**0.03*, d = 0.04**	3.66	0.06, d = 0.04
	Task	2	3.12	**0.05***	3.06	0.06
	Group*Task	2	0.22	0.80	1.80	0.17
Total Mean	Order	2	0.06	0.94	0.13	0.88
	Group	1	1.08	0.30, d = 0.01	0.25	0.62, d = 0.01
	Task	2	0.18	0.83	0.14	0.87
	Group*Task	2	0.15	0.86	0.71	0.50
Amplitude SD	Order	2	0.27	0.76	0.17	0.84
	Group	1	1.99	0.16, d = 0.03	0.88	0.35, d = 0.03
	Task	2	3.80	**0.03***	1.79	0.18
	Group*Task	2	0.40	0.67	0.08	0.93
Duration SD	Order	2	0.35	0.71	1.30	0.28
	Group	1	1.65	0.20, d = 0.09	0.18	0.67, d = 0.03
	Task	2	6.30	**0.003***	2.67	0.08
	Group*Task	2	0.52	0.60	0.74	0.48
Total SD	Order	2	0.35	0.70	0.27	0.76
	Group	1	2.22	0.14, d = 0.06	0.59	0.45, d = 0.04
	Task	2	6.20	**0.004***	2.27	0.11
	Group*Task	2	0.16	0.85	0.30	0.75

Task Differences for DT Muscle

Condition	Variable	Comparisons		Difference	Std Err	[95% CI]	P-value
SP	Amp Marg 345	FORM	CLICK	3.04	1.25	[1.3 - 0.5]	0.02 d = 0.53
	Dur Marg 1	FORM	TYPE	0.71	0.34	[0.3 - 0]	0.04 d = 0.12
	Dur Marg 2	FORM	CLICK	1.51	0.59	[0.6 - 0.3]	0.01 d = 0.26
	Dur Marg 3	FORM	CLICK	1.91	0.78	[0.8 - 0.4]	0.02 d = 0.33
	Dur Marg 5	CLICK	FORM	0.6	0.26	[0.3 - 0.1]	0.02 d = 0.1
	Dur Marg 5	TYPE	FORM	0.59	0.26	[0.3 - 0.1]	0.03 d = 0.1
	Mean Dur	TYPE	FORM	0.16	0.07	[0.1 - 0]	0.02 d = 0.03
	Mean Dur	CLICK	FORM	0.15	0.07	[0.1 - 0]	0.03 d = 0.03
	Mean	TYPE	FORM	0.1	0.05	[0 - 0]	0.04 d = 0.02
	SD Dur	TYPE	FORM	0.66	0.27	[0.3 - 0.1]	0.02 d = 0.11
	SD Dur	CLICK	FORM	0.56	0.27	[0.3 - 0]	0.04 d = 0.1
CP	Amp Marg 1	FORM	TYPE	9.2	1.86	[1.9 - 5.5]	<.0001 d = 1.91
	Amp Marg 1	CLICK	TYPE	7.41	1.77	[1.8 - 3.9]	0.0001 d = 1.54
	Amp Marg 345	TYPE	CLICK	4.34	1.16	[1.2 - 2]	0.0004 d = 0.9
	Dur Marg 3	FORM	CLICK	3.68	1.27	[1.3 - 1.1]	0.01 d = 0.77
	Dur Marg 5	CLICK	TYPE	1.92	0.6	[0.6 - 0.7]	0.002 d = 0.4
	Mean Amp	TYPE	CLICK	0.55	0.13	[0.1 - 0.3]	0.0001 d = 0.11
	Mean Amp	TYPE	FORM	0.41	0.14	[0.1 - 0.1]	0.005 d = 0.09
	Mean Dur	CLICK	TYPE	0.25	0.07	[0.1 - 0.1]	0.002 d = 0.05

Task Differences for TT Muscle

Condition	Variable	Comparisons		Difference	Std Err	[95% CI]	P-value
SP	SD Dur	CLICK	FORM	0.61	0.29	[0.3 - 0]	0.04 d = 0.14
	SD	CLICK	FORM	0.35	0.17	[0.2 - 0]	0.05 d = 0.08

Task Differences for AT Muscle

Condition	Variable	Comparisons		Difference	Std Err	[95% CI]	P-value
SP	Amp Marg 345	FORM	CLICK	1.46	0.59	[0.6 - 0.3]	0.02 d = 0.38
	Amp Marg 345	TYPE	CLICK	1.31	0.59	[0.6 - 0.1]	0.03 d = 0.35
	Dur Marg 3	FORM	CLICK	2.83	1.44	[1.4 - 0]	0.05 d = 0.75
	Mean Amp	FORM	CLICK	0.24	0.09	[0.1 - 0.1]	0.01 d = 0.06
	Mean Amp	TYPE	CLICK	0.19	0.09	[0.1 - 0]	0.04 d = 0.05
	Mean Dur	CLICK	FORM	0.21	0.09	[0.1 - 0]	0.02 d = 0.06
	SD Amp	CLICK	FORM	0.26	0.09	[0.1 - 0.1]	0.01 d = 0.07
	SD Dur	CLICK	FORM	1.12	0.32	[0.3 - 0.5]	0 d = 0.3
	SD Dur	CLICK	TYPE	0.69	0.32	[0.3 - 0]	0.04 d = 0.18
	SD	CLICK	FORM	0.63	0.18	[0.2 - 0.3]	0 d = 0.17
	SD	CLICK	TYPE	0.37	0.18	[0.2 - 0]	0.05 d = 0.1
CP	Mean Amp	FORM	CLICK	0.2	0.09	[0.1 - 0]	0.03 d = 0.07
	Mean Amp	TYPE	CLICK	0.19	0.09	[0.1 - 0]	0.04 d = 0.06
	Mean Dur	CLICK	TYPE	0.18	0.09	[0.1 - 0]	0.04 d = 0.06
	Mean Dur	CLICK	FORM	0.18	0.09	[0.1 - 0]	0.04 d = 0.06
	SD Dur	CLICK	FORM	0.71	0.31	[0.3 - 0.1]	0.03 d = 0.23
	SD	CLICK	FORM	0.4	0.19	[0.2 - 0]	0.04 d = 0.13