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Development of an Ergonomic Desk and Support for Optimal Keyboard Angle in the Sitting and Standing Workstation

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DEVELOPMENT OF AN ERGONOMIC DESK AND SUPPORT FOR OPTIMAL KEYBOARD ANGLE IN THE SITTING AND STANDING WORKSTATION

BY

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April 17, 2023

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ABSTRACT

With the proliferation of computers in homes and workplaces, the keyboard has become an integral part of our daily lives, and it is difficult to imagine using a computer without one. Given the high prevalence of WMSDs among computer users and the growing global computer workforce, concerns exist about the escalation of computer related injury with Carpal tunnel syndrome (CTS) being one of the most reported WMSDs among office workers. The forceful and repetitive movements of the hand and wrist, prolonged use of the hand and wrist and a non-neutral or awkward wrist posture (where there is a migration from a neutral flexion/extension position) are some of the causes of CTS among office workers. If these known risks are not addressed appropriately, this injury will inhibit a person's ability to perform work effectively. The purpose of this study is to determine the optimal range of keyboard angles for sitting and standing positions based on wrist posture, forearm muscle activities and user preference. Keyboard location in relation to user position and distance will be identified for both sitting and standing postures. 30 volunteers with an above 40wpm typing speed participated in this study with wrist posture, muscle activity, typing performance, distance to place keyboard and user preference as dependent variables were measured. A 2-way ANOVA for repeated measure was performed using the SPSS software for analyzing the results of the dependent variables. Results show that, although user prefer to use positive keyboard angle, the negatively tilted keyboard is more ergonomically friendly at both sitting and standing workstations as compared to the standard keyboard angle, reducing muscle activity and awkward wrist posture while maintaining performance. Findings from this study should provide a useful framework for ergonomics practice and policy evaluation, and we expect that an office workstation can be improved for workers to reduce their risk of developing WMSDs, specifically CTS, with an ergonomic desk for sitting and standing workstations, including a universally adjustable support attached to the desk for sitting and standing workstation.

Keywords: Keyboard, work-related musculoskeletal disorders (WMSD), and Carpal tarnal syndrome (CTS).

DEDICATION

All the glory to God for making this a reality; Dreams do come through!

This is dedicated to my adorable girls. My Rock Amina, for your prayers, patience and encouragements. To Fasa and Efe, I am inspired by your believing that Daddy will get there someday even when I sometime quiver and become discouraged. This is only the beginning!

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My sincere thanks to Dr. Fouzia Baki. I am full of gratitude Ma'am for your kind words and believing in me all these years at the university of Windsor. I am grateful for my participation in the Mitacs summer project years back with your support.

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LIST OF ABBREVIATIONS/SYMBOLS

ANSI/HFES 100	American National Standard for Human Factors/Engineering of Visual Display Terminal Workstations
ANSUR II	Anthropometric survey of U.S army
ANOVA	Analysis of Variance
BLS	Bureau of Labor statistics
CAD	Computer Aided design.
CTP	Carpal Tarnal Pressure
CTS	Carpal Tunnel Syndrome
ECR	Extensor Carpi Radialis
EDC	Extensor Digitorium Communis
EMG	Electromyography
FDP	Flexor Digitorium Profundus
FDS	Flexor Digitorium Superficialis
LSD	Least Significant Difference
MVC	Maximum Voluntary Contraction
RMS	Root Mean Square
SSW	Sit/Stand Workstation
WMSD	Work-related musculoskeletal disorder
WPM	Words per minute

Chapter 1 – Introduction

1.1 Background

The keyboard serves as the primary input device for data entry tasks, acting as an interface between the user and the computer. The keyboard's layout typically consists of a set of phonetic letters commonly known as "QWERTY," along with symbols and numbers, arranged in a specific pattern. Over recent decades, a trend in computer usage has been growing around the world, and as a result, keyboard usage has also increased. With the proliferation of computers in homes and workplaces, the keyboard has become an integral part of our daily lives, and it is difficult to imagine using a computer without one. According to recent projections, the percentage of families that own a computer is expected to reach 93.3% by 2023, as shown in Figure 1.This growing increase in computer/keyboard usage could lead to an increase in the risk of various work-related musculoskeletal

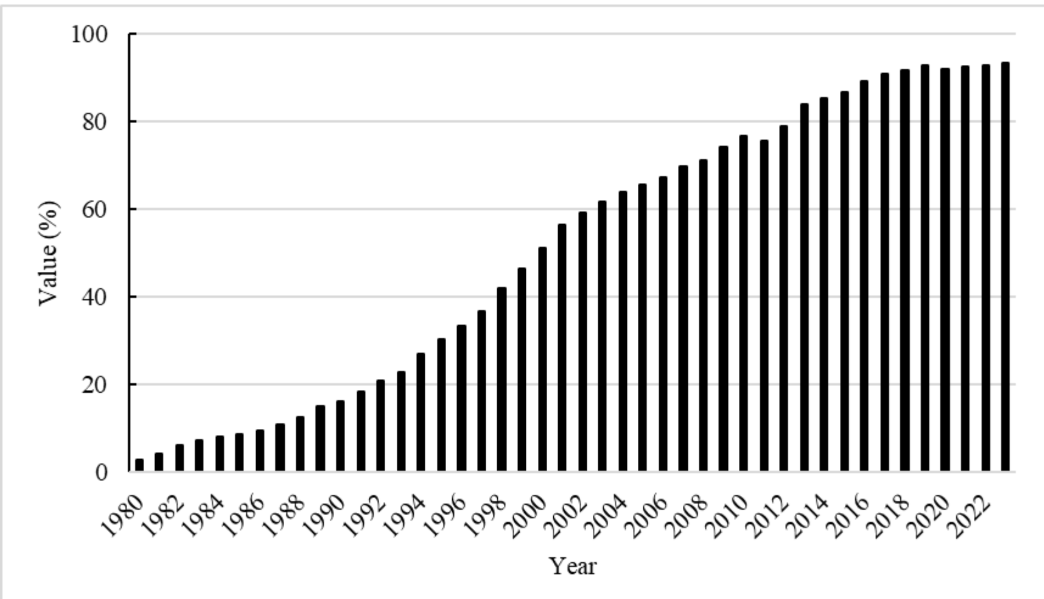

Figure 1: Total Percentage of Households With At Least One Computer (%) (Source: https://www.ibisworld.com/us/bed/percentage-of-households-with-at-least-one-computer/4068/

disorders (WMSDs), which are already prevalent among office workers (Hale et al., 1994; Norman et al., 2004; Rempel et al., 2006; Toosi et al., 2015). Given the high prevalence of WMSDs among computer users (between 40% to 80%) and the growing global computer workforce, concerns exist about the escalation of computer related injury (Tittiranonda et al., 1999; Katz et al., 2000). Carpal tunnel syndrome (CTS) is one of the most reported cases of WMSDs among office workers (Werner & Andary, 2002). The Bureau of Labor Statistics reported fewer than 27,000 cases of CTS (as cited in the center for Disease Control and Prevention, on Work-related musculoskeletal disorder and ergonomics, 2020); However, a report by Sevy and Varacallo (2022) suggests that in the U.S, CTS has an incidence rate of 1 to 3 persons per 1000 per year and a prevalence of 50 per 1000, rates similar to those of most developed countries.

1.2 Problem statement

Currently, most available keyboards in the marketplace are manufactured with the positive tilt angle as seen in Table 1, forcing users to assume an awkward posture as they extend their wrist up to an angle of 20° while performing a typing task. As documented in the allowable standards guide for sitting position shown in Table 2, 20° wrist extension surpasses recommended standards of less than 10° wrist extension while typing in the U.S. (ANSI/HFES-100), Australia (AS-3590.2), and Hong Kong.

Table 1: Available Keyboard in the Marketplace

Keyboard make/model	Keyboard tilt angle in degrees (with legs)	Keyboard tilt angle in degrees (without legs)
HP- TJE10NB	6	(-)
ASUS – MD5112	(-)	5.9
HP – 5524A TPCC002K	(-)	4.3
HP – 24-DF1129	(-)	5.2
HP – BGL5P3A	(-)	5.1
HP – EMJKHSA – P003K	(-)	4.4
ACER – KBCR21	(-)	5.7
ACER – KBAY211	6.9	5.6
DELL – 03K-0021-A00	5.6	5.0
DELL- WHITE	(-)	5.5
DELL – 056-0YRQ – AO3	5.5	4.7
LENOVO – SKMOU65071	(-)	5.4
AVERAGE ANGLES (degrees)	5.9	5.16

Table 2: Standard Guidelines of Computer Use in the Sitting Posture

	Australia (AS-3590.2)	Canada CAN/CSA-Z412-M89	United States ANSI/HFES-100	Europe ISO-9241	Hong Kong Labor guideline
Upper arm and forearm positions	-	Upper arms are approximately vertical and lower arms are horizontal. Elbows are close to body (CSA-Z412-00)	Elbow angles between 70° and 135°	-	Forearm and arm at about right angles
Hand and wrist positions	Maximum wrist extension of 10° (AS-3590.3)	Hands are in line with forearms. Wrists are straight, not bending up, down or to either side. (CSA-Z412-00)	Hands are in a reasonably straight line with the forearm. Maximum wrist extension (bent up) of 10^0 or flexion (bent down) of 30°	-	Wrist kept straight at most slightly inclined, maximum wrist incline of 10°

Note. Adapted from Woo, P., White, P., & Lai, C. W. K. (2016) "Ergonomics standards and guidelines for computer workstation design and the impact on users' health" – a review, Ergonomics.

Numerous studies have shown that when users perform a typing task, negatively sloped keyboards tend to promote minimal wrist extension and muscle activity (Gilad et al., 2005; Hedge & Morimoto 2001; Marklin et al., 2004; Rempel et al., 2007; Simoneau et al., 2003; Woods & Babski-Reeves, 2005). For example, Woods et al. (2002) conducted a study to evaluate the effects of a negatively sloped keyboard on forearm muscle activity, wrist posture, key strike force, perceived discomfort, and typing performance. The study revealed that a negatively sloped keyboard provided objective postural benefits and reduced muscle activity while improving or maintaining typing performance, as compared to a standard (positively sloped) keyboard. Simoneau et al. (2003) also found that a negative keyboard slope reduced the wrist extension angle to a more neutral position. The same study also showed a decrease in electromyographic (EMG) activity of a major wrist extensor-without impairing typing performance-for 10-digit "touch" typists. However, these previous studies were conducted in the early 2000s and did not determine the optimal range of angles for minimal wrist extension and muscle activity for standing workstations.

Since 2015, there has been a growing awareness of the sit/stand workstation, which has gained popularity in part due to recent desire to reduce sedentary behavior in office workplaces. There is increasing support for the introduction of active workstations through changes to the work environment (Ojo et al., 2017), with evidence suggesting that such interventions can reduce musculoskeletal discomfort and improve worker well-being (Robertson et al., 2013; Karakolis & Callagan, 2004; Wilks et al., 2006). Further, Yin et al. (2017) reported greater ECR muscle activity for standing postures and a significant difference in the wrist extension for this position, as well. Considering the different working postures performed at sitting and standing workstations, it is essential to investigate the effects of a negatively sloped keyboard for postures at both workstations in order to reduce risk factors of CTS.

1.3 Purpose

The purpose of this study is to determine the optimal range of keyboard angles for sitting and standing positions based on wrist posture, forearm muscle activities and user preference. Keyboard location in relation to user position and distance will be identified for both sitting and standing postures. Based on the results from this study, we expect to (1) propose an ergonomic desk for minimum muscle activity and wrist extension in sitting and standing positions, (2) propose a universal, adjustable support on the ergonomic desk for sitting and standing positions. The optimal range of angle is validated statistically with sitting and standing workstation by performing a 2-way ANOVA with repeated measures for the two levels of sitting and standing positions.

1.4 Hypothesis

In this study, we hypothesize that the negatively sloped keyboard will: (1) produce minimal wrist extension and muscle activity while in sitting and standing positions. (2) be assessed by users as preferable to standard keyboard angles (3) create no significant difference in the performance (speed and accuracy) between the keyboard tilt angles for sitting and standing positions (4) differ in optimal keyboard angle range for sitting and standing postures, and (5) differ in keyboard distance from desk edge for sitting and standing positions.

Chapter 2- Literature review

2.1 WMSD in the workplace

Musculoskeletal disorders are one of the most common chronic disorders that result in sprain/strain of the human musculoskeletal system. WMSD is a condition in which the work environment and performance of work are made worse due to longer work conditions (Bernard & Putz, 1997). The causes of these injuries involve repetitive and accumulative movements damaging the musculoskeletal tissues, especially of the hand and wrist while performing a typing task. These defined repetitive movements can arise from the most common activity being the daily tasks associated to an individual's occupation. As the average American between the ages of 22-65 spends 40 to 50 percent of their day at the workplace, it has been established that there is a strong correlation between musculoskeletal disorders and occupational duties (Leigh et al., 2000). Currently work-related musculoskeletal disorders (WMSDs) are considered a serious issue with major economic implications. WMSD are the most common non-fatal injury reported annually in the United States (Bernard et al., 1997). According to the data released by the Bureau of Labor Statistics (BLS) on Workplace Injuries and Illnesses of 2010, it was reported that there were 2.9 million work-related injuries in the United States (BLS 2011). An estimate by (Leigh et al., 2011) on the economic implications of WMSD found non-fatal injuries and illnesses in 2007 to be approximately $46 billion dollars. This pattern of high WMSDs incidence rates is not limited to Europe and America alone, as it has predominantly increased all around the world. However, aside from the financial burden of WMSDs, the risk has a tendency of negatively affecting the quality of life of workers. WMSDs are known to cause chronic pain, psychological stress, overexertion, and a variety of other negative health-related symptoms (Sizer et al., 2004a). Another detrimental outcome of WMSDs may be delayed return-to-work status, due to severity of this work-specific disorder that are often neglected. WMSDs are maintained primarily by damaging tissues of the musculoskeletal system in a variety of ways (Sizer et al., 2004a), which may contribute to the occurrence of a severe nature of inflammation. However, some WMSDs causes can extend beyond the physical factors related to an individual's occupation. With Psychosocial (stress) and organizational (workstation design) risk factors have been identified as contributing to the prevalence of WMSD$_S$ (Arnell & Kumar, 2002). The complex nature of the causes of WMSD$_S$ leads to complexity in the diagnosis and treatment of this disorder. Currently, treatment of WMSDs may involve strength-building exercises, electrical stimulation, hot and cold packs, and injections. It is believed that these different treatment approaches can reduce the pain, inflammation, increase strength, and promote healthy tissue healing of the affected area (Poitras & Brosseau, 2008). However, there seem to be contradictory evidence put forward by different studies. Several evidence-based studies have recommended high therapeutic exercises as an option for the treatment of WMSDs, but there are contradictory studies that found insufficient evidence supporting this finding (Novak et al., 2004; Ludewig & Borstad, 2002; Indahl et al., 2004).There are limited studies evaluating the evidence of a hot and cold packs for pain reduction, but they are considered not strong evidence (French et al., 2006). While the use of injections as a primary treatment for low back pain is limited and inconclusive to be utilized as a reliable pain intervention (Staal et al., 2008). With limited and proven intervention model for treating WMSD, intervention for the treatment of individuals with WMSD$_S$ rely on medications and pharmacological methods for pain management, which have not been firmly determined to be effective (Hurwitz et al., 2008). With this very high socioeconomic burden of WMSDs on the worker, a different approach to the treatment and intervention of WMSDs should be considered. Ergonomic approach interventions are one of many proposed interventions for the overall treatment of WMSD$_S$. The ergonomic interventions involve, but not limited to adjusting a workers' environment, behavior, and other educational and policy-based approaches to treat and prevent further damage due to WMSD$_S$.

2.2 Keyboard angle and wrist posture

Literature revealed a few articles investigating wrist flexion and the concept of negatively sloped keyboard systems. Stack (1987, 1988(a, b)) reported that a negatively sloped keyboard design by purposefully slanting the keyboard away from the user result in reducing the angle of the wrists to a near zero. There have been numerous studies on the negative sloped keyboard while typing (Hedge and Morimoto, 2001; Hedge et al., 1999; Hedge and Powers, 1995; Hedge et al., 1995; Hedge, 1994) Hedge and Powers (1995) and

Powers and Hedge (1992) found that the adjustable tilted keyboard in the negative significantly reduced wrist extension and participants did not report any negative reactions while typing. Hedge and Powers (1995) concluded that the reduction in wrist extension from use with a negatively tilted keyboard should lessen the risks of developing CTS. In more recent studies, Simoneau & Marklin (2001) analyzed wrist extension at five keyboard angles (+15°, +7.5°, 0°, -7.5°, and -15°) and at different keyboard heights. As the keyboard slope was changed from +15° to -15°, wrist extension decreased approximately 13°. Interestingly, the mean wrist extension decreased approximately 1° for every 2° of change in the downward slope. In this study, the participants selected -12° to be the average negative slope angle for the keyboard platform, resulting in a keyboard slope close to 0°. Even when the wrist is extended, lower wrist extension angles associated with negative keyboard slopes seem to be theoretically beneficial. Gilad & Harel (2000) found that the negative angle of the keyboard they studied provided a more natural positioning of the hand while typing and decreased muscle strain in the arms as measured by a change in muscle activity. Studies have also shown that when users perform a typing task, negatively sloped keyboards tend to promote minimal wrist extension and muscle activity (Gilad et al., 2005; Hedge & Morimoto 2001; Marklin et al., 2004; Rempel et al., 2007; Simoneau et al., 2003; Woods & Babski-Reeves, 2005). For example, Woods et al. (2002) conducted a study to evaluate the effects of a negatively sloped keyboard on forearm muscle activity, wrist posture, key strike force, perceived discomfort, and typing performance. The study revealed that a negatively sloped keyboard provided objective postural benefits and reduced muscle activity while improving or maintaining typing performance, as compared to a standard (positively sloped) keyboard. Simoneau et al. (2003) also found that a negative keyboard slope reduced the wrist extension angle to a more neutral position. The same study also showed a decrease in electromyographic (EMG) activity of a major wrist extensor-without impairing typing performance-for 10-digit "touch" typists.

2.3 Keyboard angles and Carpal tarnal pressure

Increased carpal tarnal pressure (CTP) seems to be a causal factor for CTS resulting in the compressive forces on the median nerve from surrounding tissues. Gelberman et al. (1984) found that fluids in the palm of the hand flow freely with the hands in neutral-to-moderate extension angle of <20° or flexion angle of <20°. Weiss et al. (1995) found that extreme extension and flexion of the wrist could lead to an elevated CTP. It has been shown that brief exposure to a CTP of 30 mm Hg in animals is sufficient to affect nerve functioning for prolonged periods of time (Lundborg et al., 1983). However, Rempel et al. (1997) found that CTP levels approached a critical value of (30 mm Hg) when passively extending the wrist up to 30°. For passive wrist movements, mean CTP values were lowest at 15° of flexion, and increased as the wrist was flexed or extended while CTP values for wrist flexion were less than corresponding values for wrist extension. Studies have also identified various wrist postures (flexion/extension, radial/ulnar deviation, forearm pronation/supination) in relation to CTP values. Weiss et al. (1995) found that the average position of the wrist for the lowest CTP was 2° ± 9° of extension and 2° ± 6° of ulnar deviation. Similarly, Rempel et al. (1992) found CTP to be lowest with the hand in 3.5° ± 5.9° of wrist flexion, 5.0° ± 7.1° ulnar deviation, and 45° of metacarpophalangeal flexion. Gilad & Harel (2000) stated that CTP was lowest with the hand in a natural working posture of up to 15° wrist extension, less than 20° wrist flexion, and moderate ulnar deviation. Considering these findings, minimizing extension or flexion could reduce CTP while performing a typing task. The overall Implications of these findings in relation to typing tasks are meaningful. Average wrist extension angles while performing a typing task have been reported to be between 13° and 33° (Hedge and Powers, 1995; Honan et al., 1996; Honan et al., 1995; Sommerich and Marras, 1994). Rempel and Horie (1994) found that the lowest CTP occurred at 0° or 15° of wrist extension. These studies concluded that wrist extension angle has a strong causal relationship with CTP and suggested minimizing wrist extension during typing.

2.4 Carpal Tunnel Syndrome

Literature on CTS has identified typical occupations of patients with this syndrome, including those who use the computer extensively and perform other tasks that are repetitive and require frequent movement (Akhondi et al., 2022; Maher et al., 2016; Mezian et al., 2016). Several studies have found that the well-known risk of CTS is caused by multiple factors, and most prominent among them are the forceful and repetitive movements of the hand and wrist (Kroemer et al., 1972; Septiawati et al., 2013), the prolonged use of the hand and wrist (You et al., 2014; Sharma et al., 2016), and a non-neutral or awkward wrist posture (Anderson et al., 1997; Hunting et al., 1981; Marklin et al., 1999; Rempel et al., 2008; Simoneau et al., 1996, 1999; Thomsen et al., 2008; Toosi et al., 2015). In an awkward posture, there is a migration from a neutral flexion/extension position (Simoneau & Marklin, 2001) and an increase in the carpal tunnel pressure in the wrist (Thomsen et al., 2008) as a result of compressed media nerve as shown in Figure 2. If these known risks are not addressed appropriately, this injury will inhibit a person's ability to perform work effectively, leading to worker disability (Turner et al., 2007), which can, in turn, impose an economic impact on employees and the country in general (Schneider et al., 2010).

Figure 2: Hand with CTS injury. Source: http://patientslounge.com/injuries/hand-wrist

2.5 Sit/stand workstation and sedentary behavior

In recent years there have been studies related to the use of standing desks as an alternative to the sedentary behavior of the office work. Compared to seated work, use of standing desks is associated with modest increases in physical activity and energy expenditure (Grunseit et al., 2013; Miyachi et al., 2015), without a reduction in cognitive performance (Russell et al., 2016; Kar and Hedge, 2016). However, occupational standing for a prolonged duration could be associated with negative health outcomes such as increase physical fatigue, musculoskeletal discomfort, and risks of cardiovascular problems (Andersen et al., 2007; Baker et al., 2018; Balasubramanian et al., 2009; Chester et al., 2002; Graf et al., 2015; Krause et al., 2000; Tüchsen et al., 2000; Waters and Dick, 2015). An increased sedentary behavior from a global perspective is a major public health concern (Matthews et al., 2014; Owen et al., 2010). A workstation that is designed primarily for the sitting position increases the office workers' physical inactivity and greater risks of obesity, type-2 diabetes, some forms of cancer, cardiovascular disease, and premature mortality (Chambers et al., 2019; Chau et al., 2013; Dunstan et al., 2012; Young et al., 2016). While hours of computer use can increase the risks for musculoskeletal disorders of upper extremities (Rempel et al., 2006; Village et al., 2005), as a typical office workplace may require workers spend approximately 8–9 h daily in sedentary behaviors (Bureau of Labor Statistics, 2009; Healy et al., 2011; Parry and Straker, 2013). Sedentary concerns may lead to an increase in absenteeism, reduced quality of work done, short-term disability, work impairment and an additional healthcare cost to the worker (Pronk and Kottke, 2009). In a study done in 2013, (Ding et al., 2016) concluded that the direct and indirect costs associated with sedentary behavior and physical inactivity were estimated to be $67.5 billion globally. Current trends suggest a global increase in sedentary behaviors and physical inactivity in the future (Ng and Popkin, 2012). Also, in response to the public health concerns of increased sedentary behaviors, the updated Physical Activity Guidelines for the U.S. acknowledges the obvious need to move more and sit less in a workplace (Piercy et al., 2018. The use of sit-stand workstations (SSWs) has also been popular in recent times. This workstation design enable the office worker to alternate between the sitting and standing posture at work, and evidential report suggest that SSWs reduce sitting time and increase standing time (Karakolis and Callaghan, 2014; Karol and Robertson, 2015), attenuate musculoskeletal discomfort and pain (Agarwal et al., 2018), and minimize self-reported fatigue (Neuhaus et al., 2014), without impacting productivity in computer-based work (Chambers et al., 2019; Kar and Hedge, 2016; Russell et al., 2016).

Chapter 3 – Method

3.1 Participants

A total of thirty healthy volunteers (fifteen men and fifteen women) with no prior cases of CTS participated in this study. The participants were current students at the University of Windsor with an above 40 WPM typing speed and a 10-digit typing skill. The average age of the participants was 23.7 (2.76 standard deviation) years old, and the average height and weight were 1715.5 (100.2) millimeters tall and 68.6 (14.3) kilograms. The average hand length and breadth of hand were 180.46(16.81) and 74.5 (9.65) millimeters, respectively. Detailed demographic and anthropometric information of the participants is presented in Table 3. Hand length and breadth of the dominant hand of the participants was measured by a NEIKO sliding caliper and defined according to the literature of anthropometric survey of the U.S army personnel standards as outlined by Gordon (1988). The protocol for the experiment was reviewed and approved by the University of Windsor office of Research Ethics Board (REB# 20-229). All participants received compensation of $10 per hour for participating in the study.

Table 3: Demographic and Anthropometric data for participants

Variables	Mean (SD)	
	Male	Female
Age (years)	24.2 (2.65)	23.26 (2.89)
Height (mm)	1781 (78.09)	1650.06 (91.46)
Weight (kg)	77.66 (11.6)	61.46 (13.57)
Hand length (mm)	188.93 (16.16)	171.93 (13.10)
Hand breadth (mm)	78.27 (10.12)	70.73 (7.76)

3.2 Apparatus

Figure 3: Portable Wooden Stand for (A) -15°, (B) -10°, (C) -5°, (D) 0° and (E) 6° respectively

For this experiment, a portable and adjustable wooden stand for the angles (-15°, -10°, -5°, 0°, and 6°) to be evaluated was designed to position the keyboard during typing, as seen in Figure 3. The wooden stand was used to vary the different tilt angles for typing tasks.

Figure 4 below shows the Mavis Beacon typing software (2020 personal edition encore software, U.S.) used to evaluate the typing performance in terms of speed and accuracy. Script is based on university daily news articles of more than 420 words.

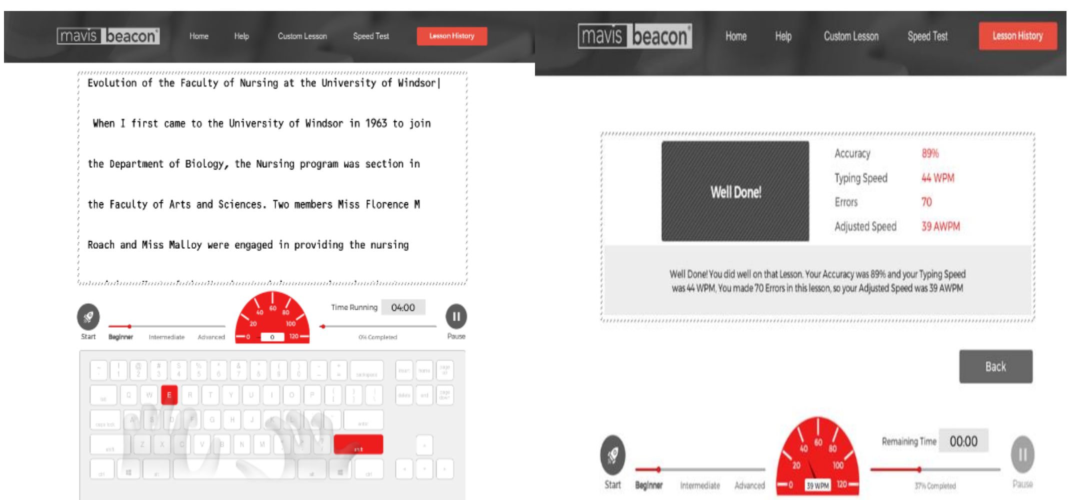

Figure 4: Mavis beacon typing software.

A surface EMG system (Trigno TM Wireless EMG, Delsys Inc., Boston, MA, USA) shown in figure 5, was used to measure muscle activity during typing for both sitting and standing positions. To measure muscle activity in the forearm, electrodes were attached to the skin above the main flexor and extensor muscles of the forearm while typing, specifically, the flexor digitorum superficialis (FDS), flexor digitorum Profundus (FDP), extensor carpi radialis (ECR), and the extensor digitorum common (EDC), based on the anatomical guide by Peroto (2011).

Figure 5: EMG console. Source: Trigno® Research+ System - Delsys

Table 4 below is a data collect form for the distance to place keyboard from the edge of the ergonomic table. The measurement was done with a simple measuring tape.

Table 4: Data collection form for distance to keyboard from edge of workstation

Tilt Angles (degrees)	Preferred distance for sitting posture (mm)	Preferred distance for standing posture (mm)
-15^0		
-10^0		
-5^0		
0^0		
6^0		

The form as shown in table 5 below was also used in collecting data for user perceived preference while typing. The 7-point Likert scale was implemented with (1) being the lowest and (7) highest.

Table 5: Data collection form for preference in relation to tilt angle

Position	Tilt angles (degrees)	Very highly preferred (7)	Highly preferred (6)	Somewhat preferred (5)	Slightly preferred (4)
Sitting	-15				
Standing					
Sitting	-10				
Standing					
Sitting	-5				
Standing					
Sitting	0				
Standing					
Sitting	6				
Standing					

Position	Tilt angles (degrees)	Preferred (3)	Not preferred (2)	Will recommend (1)
Sitting	-15			
Standing				
Sitting	-10			
Standing				
Sitting	-5			
Standing				
Sitting	0			
Standing				
Sitting	6			
Standing				

A biaxial electrogoinometer (B6357, Biometrics Ltd. Newport, UK) as shown in figure 6 below was used to measure wrist posture for flexion, extension, ulnar deviation and radial deviation of the wrist while typing. Movement in the sagittal (longitudinal) plane involves a reduction in the wrist angle, is considered flexion and denotes the negative direction, while an increase in this angle is considered extension and denotes the positive direction. The radial deviation is wrist movement toward the radial bone, and ulnar deviations is wrist movement toward closer to the ulnar bone, which respectively denote negative and positive direction.

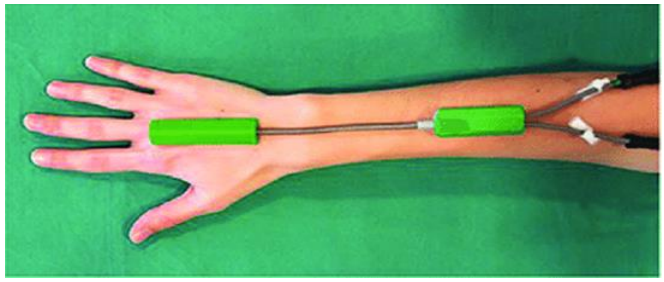

Figure 6: Placement of goniometer (Image source: (PDF) Ergonomics in Laparoscopic Surgery (researchgate.net)

3.3 Experimental procedure

A Two-factor within-subject design was used to evaluate the effects of two independent variables of tilt angles with five levels (-15°, -10°, -5°, 0° and 6°) and posture with two levels (sitting and standing) on muscle activities and wrist postures. Participants were presented with an introduction to the study, including the purpose and procedures, and were given the opportunity to ask questions regarding the experiment. Consent was obtained from participants prior to continuation of the experiment, and participants were asked to complete a demographic questionnaire for age, gender, and previous wrist or forearm injuries. Their anthropometric data was also collected, including height, weight, length of hand, and breadth of hand, as shown in Table 3. Participants then had the surface EMG sensor insertion area prepared by shaving the area if hairy and cleaning the surface before placing sensors on participant's dominant hand. Participants were asked to practice typing on the wooden adjustable stand with the typing software until they felt comfortable with it. During the experiment, each participant underwent a total of 10 conditions (5 tilt angles at 2 levels) of typing trials that were randomized as shown in Figure 7. Each trial took about 8 minutes with a rest time of at least 4 minutes in between trials, and participants were asked whether they needed more rest time before continuing with the next trial in order to minimize effects of muscle fatigue. At the end of each trial, each participant was asked to fill out a preference sheet for keyboard angles using a 7-point Likert Scale. The experimentation was carried out with 30 participants, and all trials for each participant were finished within 3 hours.

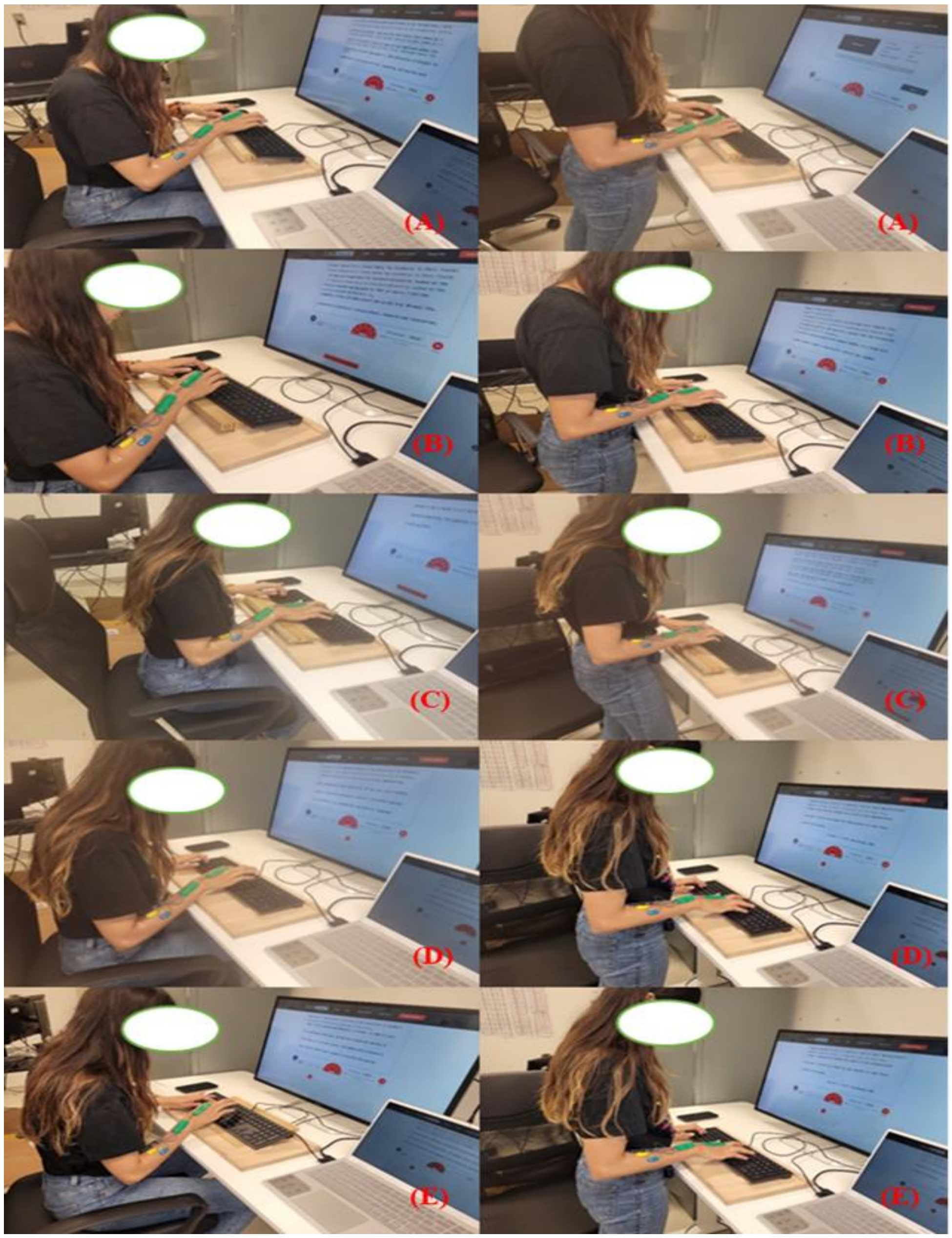

Figure 7: Participant Typing on (A) -15°, (B) -10°, (C)-5°, (D) 0° and (E) 6° for the sitting and standing positions respectively.

3.4 Data acquisition

An EMG system (Trigno TM Wireless EMG, Delsys Inc., Boston, MA, USA) was used to collect the raw EMG data using the Delsys EMG data acquisition software. In order to normalize EMG signals of each muscle, the Primus RS™ (BTE technologies, Maryland. U.S.A) machine was used to determine each participant's maximum voluntary contraction (MVC). Participants were instructed to maintain maximum force for 5 s, and MVC was computed using EMG data for the 3 second span between seconds 1 and 4. Three MVC trials were performed for each muscle group with each participant to ensure maximum force measurements were representative, and a rest period of at least 2 minutes was provided between trials. EMG signals were pre-amplified with a gain of 9.09, which had a common mode rejection ratio of 95 dB and a baseline noise of 0.5 mV Root Mean Square (RMS). The signals were then filtered using a band-pass frequency between 20 Hz and 450 Hz and digitized at a frequency of 1 kHz. The RMS values were computed using a 100 ms time constant. Electrodes were placed in the direction of muscle fibers on each participant's dominant hand after standard skin preparation (Martinez & Malkin, 1995). Location of the electrodes for insertion over each prominent muscle, as illustrated in Perotto (2011), are shown in Figure 8, with precise insertion as follows:

- FDP was located on volar surfaces of the bases of the distal phalanges of the four fingers.
- FDS was located where the tendons inserted in the volar surface of the 2^{nd} phalanx.
- ECR was placed in two locations:
    - The dorsal surface of base of second metacarpal (Longus), and
    - The dorsal surface of the third metacarpal (Brevis).
- EDC was inserted on the dorsal surface of base of second and fifth phalanges of finger.

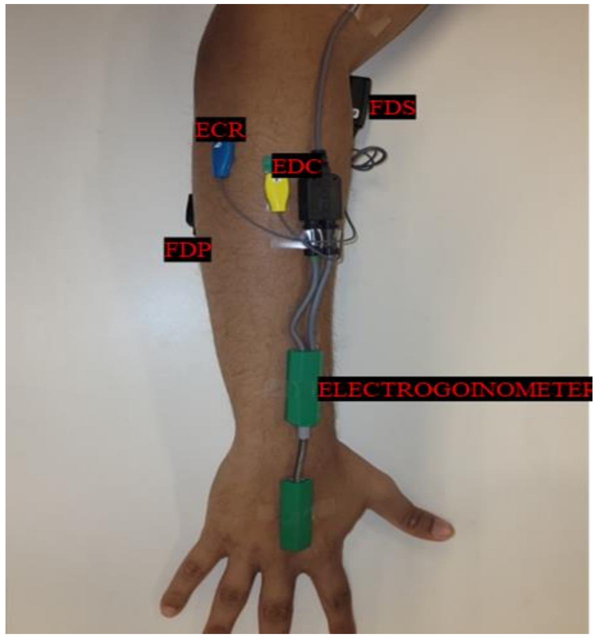

Figure 8: Insertion Area for Extensor and Flexor Muscles of the Forearm

The electrogoinometer data were wirelessly transmitted to a receiver (Trigno TM Wireless EMG, Delsys Inc., Boston, MA, USA) and sampled at 1000 Hz. After calibration based on the literature (Thota et al., 2022), the sensor was affixed to the back of the wrist in coronal planes using skin adhesive tape. One end of the twin-axis electrogoinometer was attached in line with the third metacarpal bone, while the other end was attached to the midline dorsal side of the lower arm. EMG and electrogoinometer measurements were taken simultaneously, with the measurement signals transmitted to a personal computer (PC) via analog-to-digital (A/D) computer interface hardware.

3.5 Statistical analysis

Summary statistics for EMG and wrist posture were analyzed using SPSS software version 25.0 (IBM Corp., Armonk, NY). A repeated-measures ANOVA was conducted to determine the effects of keyboard angles and sitting/standing posture on EMG, wrist posture, preference, performance, and keyboard location. Post hoc analysis was performed using a follow-up LSD test to determine significant differences among keyboard angles. Statistical significance was set at $p < 0.05$ for all tests.

Chapter 4 - Results

4.1 EMG muscle activity

Table 6 shows statistical results from the two-way repeated measures analysis, which revealed no significant differences and no significant interaction effect in EDC, FDP, and FDS muscles for posture and keyboard angle (P > 0.05). ECR muscles did show a statistically significant difference ($p < 0.05$), but only for main effects. A post-hoc analysis for ECR is presented in Table 7. The minimum RMS EMG value was observed at -15°, -10°, -5°, and 0°. For posture, the lower RMS EMG value was observed in participants' standing posture (3.52%) rather than sitting (3.97%).

Table 6: Results from two-way repeated measure ANOVA for EMG muscle activity

Muscle	Variable	DF	MS	F	SIG.	Muscle	Variable	DF	MS	F	SIG.
	P	1	13.59	3.91	0.049		P	1	1.96	0.27	0.604
ECR	A	4	11.28	3.25	0.013	EDC	A	4	4.06	0.56	0.692
	P×A	4	4.29	1.23	0.296		P×A	4	0.27	0.04	0.997
	P	1	8.84	1.82	0.178		P	1	3.25	0.38	0.539
FDP	A	4	4.20	0.87	0.485	FDS	A	4	2.25	0.26	0.902
	P×A	4	0.84	0.17	0.952		P×A	4	0.33	0.04	0.997

Table 7: Post Hoc Analysis for the ECR muscle activity

			Grouping	
Angle	Mean	N	A	B
-15	3.55	30	■	■
-10	3.12	30	■	
-5	3.64	30	■	■
0	3.83	30	■	■
6	4.31	30		■

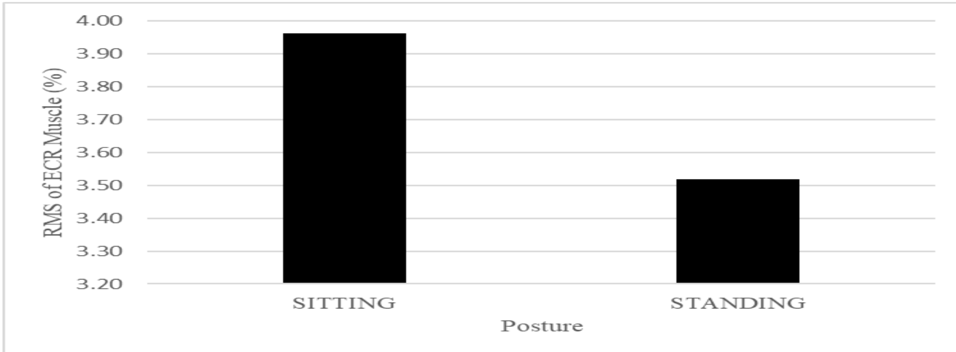

Figure 9:Difference in ECR muscle activity for Posture

4.2 Wrist posture

Overall, goniometer measurements showed that ranges of -8.97~36.10 flexion(-)/ extension(+) and -3.20~39.69 5–37 radial(-)/ulnar(+) deviation were used for typing tasks. A two-way repeated measures analysis of variance showed that the tilt angle was significant only for wrist extension movement, as shown in Table 8. Table 9 shows the significant differences among the tilt angles. The smallest wrist extension was observed at -5°, followed by -15° and -10°. Figure 11 illustrates in bar graphs both ulnar deviation and wrist extension for the typing tasks with various keyboard angles used in this study. Participants extended their wrist over 10° (12.63° at 6° and 17.95° at 0°) only at the tilt angles of 0° and 6°. The ulnar deviation results showed no significant main effects or interaction effects ($P > 0.05$), indicating that wrist deviation was within 10° in all conditions, as shown in Figure 9.

Table 8: Result from two-way ANOVA for Extension and Ulnar Deviation

Wrist Posture	Variable	df	MS	F	Sig.
	P	1	246.17	3.66	0.057
Wrist Extension	A	4	1160.38	17.25	0.000
	P×A	4	33.47	0.50	0.738
	P	1	19.10	0.47	0.494
Ulnar Deviation	A	4	41.52	1.02	0.398
	P×A	4	9.38	0.23	0.921

Table 9: Post Hoc Analysis for Wrist Extension

			Grouping		
Angle	Mean	N	A	B	C
-15	7.47	23			■
-10	7.61	23			■
-5	5.62	23			■
0	12.63	23		■	
6	17.94	23	■		

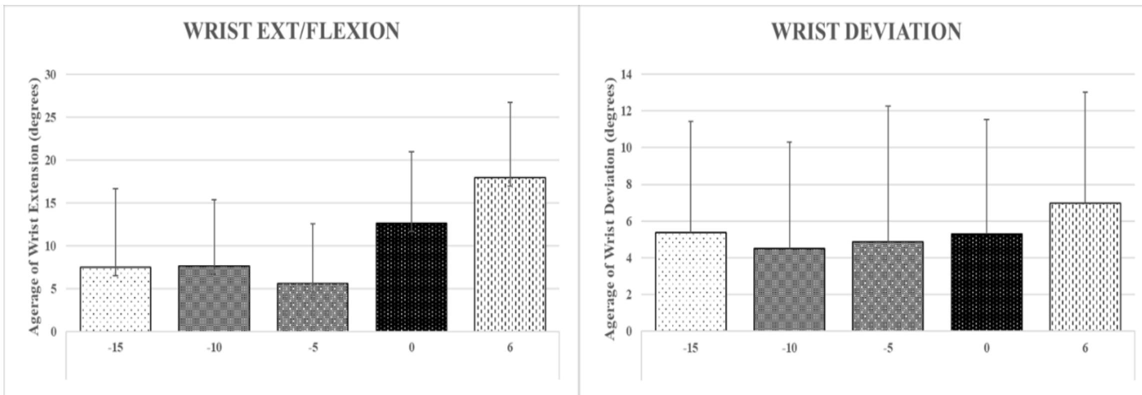

Figure 10: Mean Values for extension and wrist deviation with Tilt Angles

4.3 User preference

ANOVA results of participants user preference for varying the tilt angles and posture showed that there is significant difference of the user preference for tilt angles as well as the interaction effect of posture and keyboard angles as show in Table 10 ($P < 0.05$). The interaction plot showed that the most preference angle was 6° for sitting and 0° for standing postures in Figure 10. The least preferred angle was -15° for both sitting and standing postures.

Table 10: Results of a two-way ANOVA for User Preference

	Variable	df	MS	F	Sig.
User preference	P	1	1.61	1.83	0.177
	A	4	32.16	36.45	0.000
	P×A	4	2.59	2.93	0.021

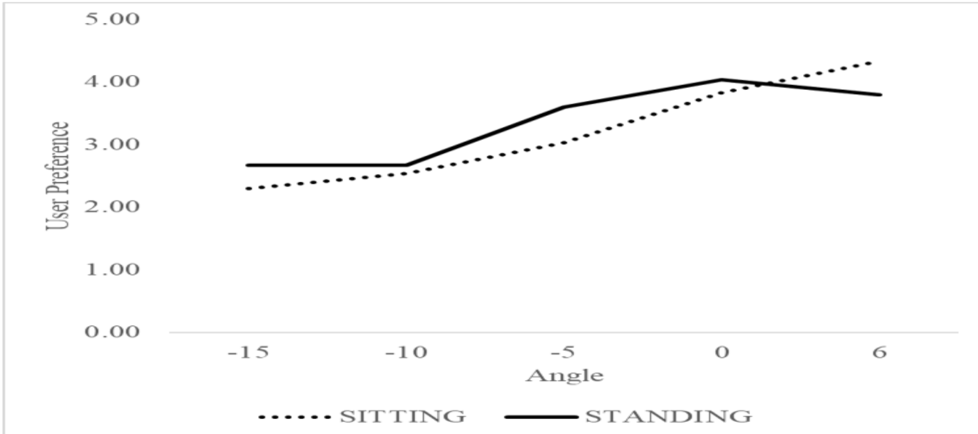

Figure 11: Interaction effect plot of posture and keyboard angles for User preference

4.4 Typing performance

Overall, typing speed ranged from 45.4 to 46.6 WPM (words per minute), and typing accuracy ranged from 88.8% to 89.8%, as shown in Figure 11. Table 11 shows that there was no significant difference in average typing speed and accuracy among the five angles and two postures ($P > 0.05$).

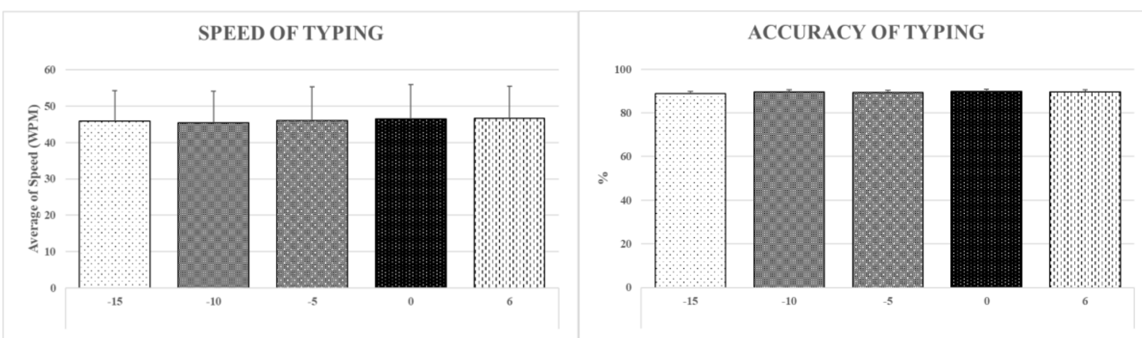

Figure 12: Graph of speed and accuracy versus tilt angles

Table 11: Results of two-way ANOVA for Speed and Accuracy

Performance	Variable	df	MS	F	Sig.
Speed	P	1	0.00	0.00	0.995
	A	4	15.68	0.19	0.941
	P×A	4	6.85	0.08	0.987
Accuracy	P	1	14.96	1.76	0.185
	A	4	7.54	0.89	0.471
	P×A	4	6.51	0.77	0.547

4.5 Distance of Keyboard Placement

The average distance to place the keyboard from the end of the desk was 134.07 mm and 135.85 mm for the sitting and standing postures, respectively. As illustrated in Table 12, there was no significant difference between the sitting and standing postures regarding mean distance of keyboard placement while typing ($P > 0.05$). This result also indicates that there was no significant difference in keyboard placement distance for the various tilt angles ($P > 0.05$).

Table 12: Results of two-way ANOVA for Distance of Keyboard Placement

	Variable	df	MS	F	Sig.
Distance	P	1	92.96	0.13	0.717
	A	4	965.99	1.36	0.246
	P×A	4	123.32	0.17	0.952

Chapter 5 - Discussion

In this study, differences in users' wrist posture, muscle activity, and keyboard location among five keyboard tilt angles in sitting and standing postures were measured in order to find the optimal keyboard angles for reducing the risk factors of CTS for keyboard typing. The first hypothesis proposed that a negatively sloped keyboard would produce the minimum wrist extension and muscle activity for sitting and standing postures. As shown in Table 8, changing the tilt angle of a computer keyboard in the downward slope from its typical, built-in positive angle resulted in a reduction of wrist extension to a near neutral position. This result demonstrates that, when the keyboard tilt angle was changed from 6° to -5°, the mean wrist extension is decreased from 17.94° to 5.62°. This finding is in general agreement with previous studies that wrist extension angle decreases as a keyboard slope downward (Gilad et al., 2005; Hedge & Morimoto 2001; Marklin et al., 2004; Simoneau et al., 2004; Woods et al., 2002; Woods & Babski-Reeves, 2005). This finding is consistent with other studies on CTS, which found that wrist extension angles closer to neutral are beneficial to office workers with respect to nerve conduction injuries affecting the wrist (Kier et al., 1998; Rempel et al., 1997). In terms of muscle activity, although all measured muscles showed reduced change in muscle activity from positive to negative tilt angles, a statistically significant reduction occurred only in ECR muscle activity ($p < 0.05$). One possible explanation may be that extensor muscles play a primary role in typing tasks, considering that another study (Simoneau, 2003) found significant muscle activity reduction only in the extensor carpi ulnaris (ECU) muscle, indicating no significant difference in flexor carpi ulnaris (FCU) or flexor carpi radialis (FCR) muscles. In addition, Wood et. al. (2000) found that while ECU muscle activity was reduced from 13.38% to 11.39% by changing the keyboard angle from 7° to -20°, FCU muscle activity increased from 3.59% to 4.21% when keyboard tilt angle increased from 7° to -20°.

With respect to the second hypothesis, we had an unexpected finding that most preferred keyboard angles were positive keyboard (6° for sitting and 0° for standing postures). With the assumption that negative keyboard angles will produce minimal muscle activity and wrist awkward postures, we expected that user will prefer the negative angles for typing. A possible explanation for this finding may be because the participants are still not familiar with negative keyboard angles even though we believe that they have enough time for training session to be familiar with our typing environment. Since most participants use keyboards in their daily work for more than 5 years, it might not be sufficient with a 30 mins training session to change their overall preferred keyboard settings. Although a post experiment questionnaire was not carried out for user preference, visual display feedback can also play a significant role in user preference. The forearm, shoulder and neck posture can have a mild effect on tilt angles when elbow is at an angle of 90^0. The height of the desk can influence the shoulder posture while the neck and forearm posture can be affected by the height of the monitor on the desk.

In our third hypothesis, we proposed no significant difference in performance (speed and accuracy) between tilt angles for sitting and standing positions. The two-way ANOVA result for performance shown in table 11 reveals no significant difference ($P > 0.05$) for posture and tilt angles and no interaction effects. This finding is consistent with previous studies by (Rempel et al., 2007; Simoneau et al., 2003; Woods & Babski-Reeves, 2005). Thus, negatively tilted keyboards have no adverse effect in terms of typing performance as compared with standard keyboards.

In our fourth hypothesis, we proposed that the optimal range of keyboard angle would be different between sitting and standing postures. However, although there was significant difference in ECR muscle activity between sitting and standing positions, as shown in Table 6, ECR muscle activity was higher at positive angles (0° and 6°) as compared with negative keyboard angles, as shown in Table 7. In addition, there was no significant difference in wrist posture, performance or keyboard location between sitting and standing postures. Thus, overall, the optimal keyboard angle range will not be affected by the type of workstation in use.

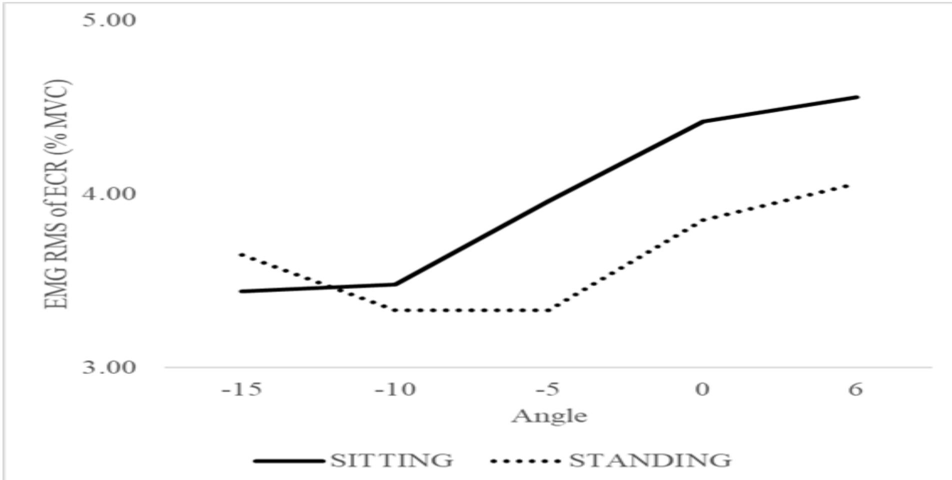

Figure 13: ECR muscle and Posture

The final hypothesis of this study was that the distance to place the keyboard while typing would differ between sitting and standing workstations. However, results in Table 12 indicate a non-significant difference ($P > 0.05$) for both postures at all tilt angles as main effects and the interaction effects between the independent variables. Since preferred keyboard distance is subjective, empirical evidence substantiating this result remains to be established by future studies.

Chapter 6 - Conclusion

Based on our results, we conclude that, although user prefer to use positive keyboard angle, the negatively tilted keyboard is more ergonomically friendly at both sitting and standing workstations as compared to the standard keyboard angle, reducing muscle activity and awkward wrist posture while maintaining performance. The proposed range for an optimal keyboard angle is between -5° (based on wrist extension) and -10° (based on muscle activity). The proposed 3d model of an ergonomic sit/standing desk with accompanying keyboard support is shown Figure 14 and 15.

6.1 Proposed designs

Figure 13 below is a proposed CAD design for the ergonomic table for the side, front, top and isometric views with dimensions. The proposed design allows for the placement of the adjustable unit and distance from the edge of table.

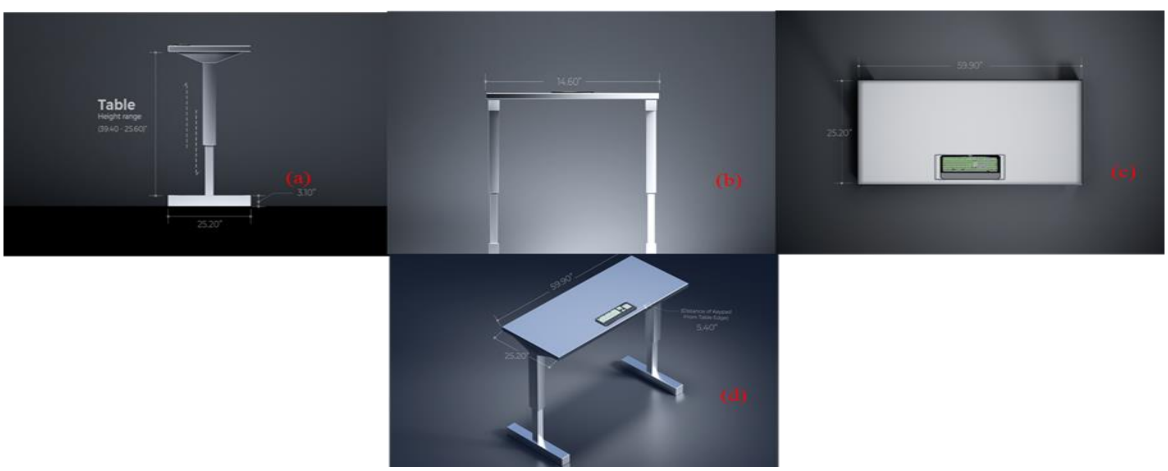

Figure 14: CAD design of proposed ergonomic desk

6.2 Universal Adjustable unit

Figure 14 below is a CAD design of the portable universal adjustable unit that can be used for both sitting and standing positions. The device is designed to be tilted to negative angles for a typing task. The figures below represent the side, front, top and isometric views with appropriate dimensions.

Although this study has presented an ergonomic desk with embedded adjustable support and a portable adjustable unit, the portable adjustable unit can be an option for keyboard users with multiple keyboards. In terms of cost effectiveness, it is cheaper to use the portable unit for various keyboards rather than adjusting individual keyboard for the desired keyboard tilt angle.

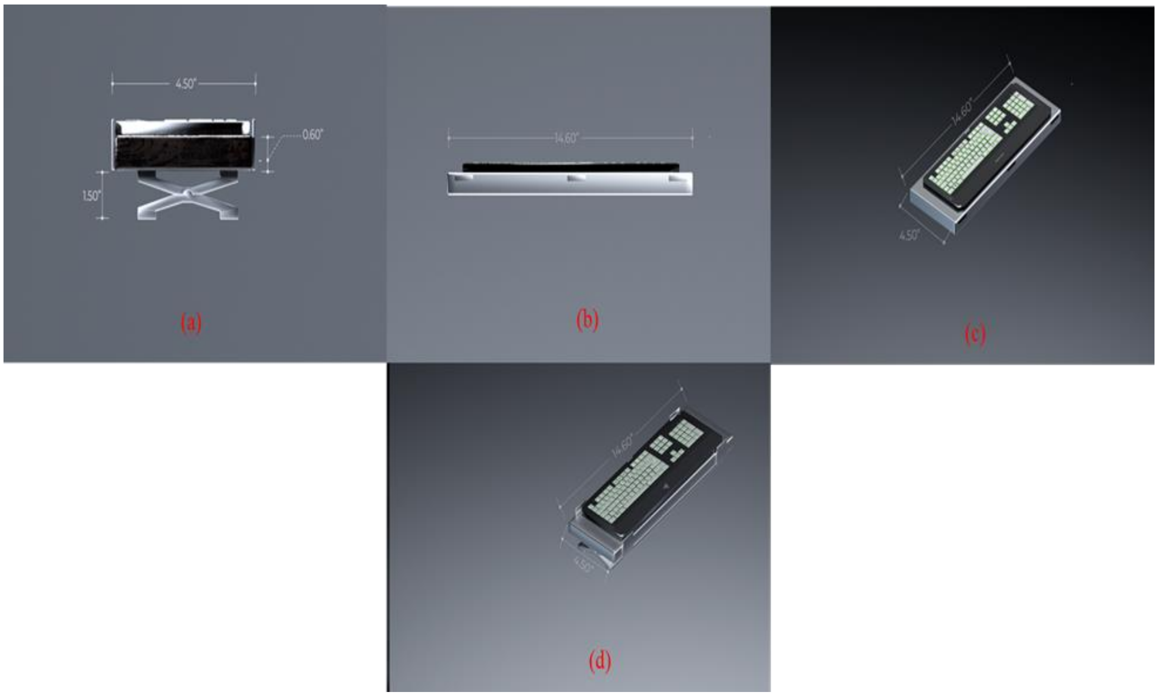

Figure 15: CAD design of Universal adjustable unit

A cost-benefits analysis can be utilized to determine an adequate cost with a possible mass production of the above proposals.

This study also presents some limitations that should be noted for future work. First, this study only considered the posture of the wrist, ignoring the posture of the arm and shoulder. Although participants were asked to adjust the height of the desk in order to keep their forearm at about 90° (as elbow angle) on the desk and to maintain natural shoulder posture during the experiment, awkward postures of the forearm and shoulder are possible and may lead to a higher risk of WMSDs in performing a typing task. However, Gilad et. al. (2000) found that participants report less discomfort in neck, shoulder and forearm as compared with those who use a flat keyboard. Further, it is more important to set the proper height to keep the neutral posture of neck, shoulder and forearm than to adjust keyboard slope. Thus, this limitation may potentially have only very modest effect on the results. The second limitation of this study is that we focused only on the dominant hand. Considering that typing is symmetrical and that there was no significant difference between hands in terms of muscle activity and wrist posture in the previous study, this limitation should not change the conclusions of the present study. Another limitation is that we did not consider how hand dimensions might affect wrist extension angle. Based on the ANSUR II survey (2021), since the range of hand length is 16.00 cm (1st percentile female) to 21.80 cm (99th percentile male), this limitation may have only a very modest effect on the results of the present study.

Findings from this study should provide a useful framework for ergonomics practice and policy evaluation, and we expect that an office workstation can be improved for workers to reduce their risk of developing WMSDs, specifically CTS, with an ergonomic desk for sitting and standing workstations, including a universally adjustable support attached to the desk for sitting and standing positions workstation.

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APPENDICES

Acknowledgement Participant

This Acknowledgement made on the ____ day of __________, 2021. I, ___________________________ a participant and in relation to the carrying on of research project(s) **DEVELOPMENT OF AN ERGONOMIC DESK FOR OPTIMAL KEYBOARD ANGLE IN THE SITTING AND STANDING WORKSTATION.** I do hereby acknowledge that I have received, been informed, understand, and will comply and adhere with all safety plans, procedures communicated to me by the principal investigator for the safe conduct of the above research project(s). I agree and acknowledge that I am aware of any known or unknown risks of conducting work in relation to the above stated research project. As a participant, I am aware that if at any time, I feel that the risks have increased, or circumstances have changed that I may terminate my contribution to the research project and will advise my principal investigator that I cannot conduct any further contributions until such risks or circumstances have changed that I may safely conduct the research. There will be no repercussions on my decision to continue or terminate my involvement with the above stated research project. IN WITNESS WHEREOF, the parties hereto have hereunto executed this Acknowledgement as of the effective date stated above. The Principal Investigator leading the research study has reviewed the safety plan with me.

☐ Yes ☐ No **I HAVE READ THIS ACKNOWLEDGEMENT FORM CAREFULLY. BY SIGNING THIS ACKNOWLEDGEMENT, I FULLY UNDERSTAND ITS CONTENT, AND VOLUNTARILY AGREE TO ITS TERMS.**

Dated at Windsor, this_______ day of , ______2022.

Signature ___________________________________

Consent Forms and Background Information for Participants

Data Collection of forearm muscle activity and wrist extension produced from typing on a keyboard with different slopes.

CONSENT TO PARTICIPATE IN RESEARCH

You are asked to participate in a research study conducted by Mr. Victor Eghujovbo, under the guidance of Faculty supervisor Dr. Eunsik Kim, from the Mechanical, Automotive & Materials Engineering Department at the University of Windsor. The data collected from this research will be used to assist a thesis project.
If you have any question or concerns about the research, please feel free to contact:

Dr. Eunsik Kim:
E-Mail: eunsik.kim@uwindsor.ca
Phone #: 519-253-3000 ext. 5409

Victor Eghujovbo
E-mail: eghujov@uwindsor.ca

PURPOSE OF THE STUDY
The purpose of this study is to build a 3D printable support that will be attached to the universal keyboard to achieve the optimal angle ranges by collecting the data from the participants. This is to help decrease wrist extension and prevent musckuloskeltal disorders such as; carpel tunnel syndrome and tenosynovitis.

PROCEDURES
If you volunteer to participate in this study, you will be asked to:

1. Male and female must wear a short-sleeved T-shirt.
2. Must arrive to the lab in room 1220 Centre for Engineering Innovation
3. Sign the consent form.
4. Must sit and stand in a certain position when typing.
5. Will be asked to type out a TED script of 600 words within 8 minutes for each trial (angle of keyboard). There will be five angles (-4 degrees, -8 degrees, -12 degrees, -16 degrees, 6 degrees) tested for two postures (sitting and standing), which is a total of 10 trials.
6. Will be given a 4-minute rest time in between trials.

7. The procedure will take approximately 2 hours and 35 minutes to complete per participant.

POTENTIAL RISKS AND DISCOMFORTS

Possible risks exist with this study:

1. Physical Risks – Participants will have to be in certain posture while typing for sitting and standing computer workstations. The experiment will take around 2 hours and 35 minutes and that may lead to discomfort.

2. Emotional Risk – Participant may feel uncomfortable because they are required to wear short sleeved shirts and may feel exposed which can make them uncomfortable. May be the first time they participate in such an experiment which will probably cause them to be nervous about what they will be doing in the experiment, when they should be in the lab and where they will be participating.

3. There may be a social risk when it comes to data being collected from the participant. They may want their information kept private, such as their name, height, age, and gender.

4. This study may involve psychological issues since participants will be video recorded for posture. They may feel uncomfortable and feel exposed in the study.

To prevent these risks:

1. Investigators will teach the participants the form they will take when typing in a standing or sitting computer workstation. Also, the participants will be given a 4-minute break in between trials.
2. Participants might feel uncomfortable revealing their forearm and the investigator applying the electrodes on their forearm. In this case an investigator of the same gender will attach the electrodes on the participant forearm to prevent discomfort. Participants will be informed of where and when the experiment will take place to prevent nervousness and stress.
3. If the participant chooses to have their information hidden, they will be considered anonymous.
4. When the participant is video recorded only their posture will be recorded and not their face.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

You will not directly benefit from the research study; however, you will be ccontributing to the testing of keyboard angles to help with the development of a 3D printable keyboard which can reduce wrist extension and musculoskeletal disorders.

COMPENSATION FOR PARTICIPATION

Participants will be paid $10/hour for the session. There will only be one session and it is expected that the session will last around 3 hours.

CONFIDENTIALITY

Any information that is obtained in connection with this study will remain confidential and will not be disclosed. All participants will stay confidential if requested for the study. Digital recording of the forearm muscle activity generated is the only information that will be collected along with the wrist extension angle.

PARTICIPATION AND WITHDRAWAL

The investigator may withdraw you from this research if circumstances arise which warrant doing so. If the participant feels as though they would like to withdraw their results from the study, they will have until two weeks after participation in the study to withdraw their results. In order to withdraw results, participants must email Dr. Eunsik Kim or Ms. Howraa Nash notifying them of requisition of withdrawal.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

Feedback of the results of the individual participant will be available to the participant if they request for their information. The participant will only be given their personal results of the experiment. The University of Windsor's REB provides a platform where the research can upload a summary of their studies. If participants are interested in seeing overall results of the study, they can follow this link: **https://scholar.uwindsor.ca/research-result-summaries/.**

SUBSEQUENT USE OF DATA

These data may be used in subsequent studies, in publications and in presentations.

RIGHTS OF RESEARCH PARTICIPANTS

If you have questions regarding your rights as a research participant, contact: The Office of Research Ethics, University of Windsor, Windsor, Ontario, N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

SIGNATURE OF RESEARCH PARTICIPANT/LEGAL REPRESENTATIVE

I understand the information provided for the study **[*insert title*]** as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____

Name of Participant

Signature of Participant — Date

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

Signature of Investigator — Date

Data Collection of Forearm Muscle Movement and Wrist Extension when typing

University of Windsor

BACKGROUND INFORMATION OF RESEARCH FOR PARTICIPANT

Most jobs require people to work on computers and type for most of the day. Because conventional computer keyboards have a built-in positive slope, it requires the user to extend the wrist approximately 20 degrees while typing (Simoneau & Marklin, 2001). Raising of the legs on the back of the conventional keyboard will also increase the positive slope angle as well as the wrist angle (Simoneau & Marklin, 2001). The reason why the keyboard has a positive slope is because it complies with the current U.S. guidelines for visual display terminal (VDT) workstation layout (ANSI/ HFS 100, 1988) (Simoneau & Marklin, 2001). It states that the keyboard angle must be between 0 degrees and +25 degrees (Simoneau & Marklin, 2001). When the wrist is extended for a long period of time it can cause the user to develop musculoskeletal disorders such as carpel tunnel syndrome and tenosynovitis (Simoneau & Marklin, 2001).

The purpose of this project is to find the optimal keyboard angle ranges to reduce wrist extension for sitting and standing computer workstations. The objective of the project is to build a 3D printable support that will be attached to the universal keyboard to achieve the optimal angle ranges. The development and implementation of this support would be very beneficial to all potential users. To achieve results for the study, measurements of the forearm and wrists will be taken. Materials that will be used in this experiment are a keyboard, adjustable table, and electrodes. Also, recording and analyzing electromyographic (EMG) activity in the forearm muscles, measuring the wrist-based angle on a 2-axis goniometer sensor, and assessing user preferences. The goal of the study is to improve the ergonomics of the work environment.

PARTICIPANT PERSONAL INFORMATION

Full Name:

____

Last First MI

Gender: __________

Age: _____ yrs **Height: ___ft ___in**

REB Approval

Today's Date: September 15, 2021
Principal Investigator: Ms. Howraa Nash
REB Number: 38738
Research Project Title: REB# 20-229: "Development of a 3D printable support to optimize keyboard slope for sitting and standing workstations Capstone Project"
Clearance Date: September 14, 2021
Annual Renewal Date: September 14, 2022

This is to inform you that the University of Windsor Research Ethics Board (REB), which is organized and operated according to the Tri-Council Policy Statement and the University of Windsor Guidelines for Research Involving Human Participants, has granted approval to your research project.

An Annual Renewal/Progress Report must be submitted 1 year after the clearance date for renewal of the project. The PI may request a modification in this annual reporting date to align with other annual reporting requirements. The REB may ask for monitoring information at some time during the project's approval period. A Final Report must be submitted at the end of the project to close the file.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the REB. Approval for modifications to an ongoing study can be requested using a Request to Revise Form.

Investigators must also report promptly to the REB:
a) changes increasing the risk to the participant(s) and/or affecting the conduct of the study;
b) all adverse and unexpected events that occur to participants;
c) new information that may affect the risks to the participants or the conduct of the study.

Forms for submissions, notifications, or changes are available on the REB website: www.uwindsor.ca/reb. If your data are going to be used for another project, it is necessary to submit a secondary use of data application to the REB.

Sincerely,

Suzanne McMurphy, Ph.D., MSS, MLSP
Chair, Research Ethics Board
University of Windsor
2146 Chrysler Hall North
519-253-300 ext. 3948
Email: ethics@uwindsor.ca

EMG for Muscle Activity Data

90th Percentile of muscle activity

	-15^0		-10^0		-5^0		0^0		6^0	
ECR (n=30)	sitting	standing	sitting	standing	sitting	standing	sitting	standing	sitting	standing
Minimum	0.98	1.26	0.98	0.97	0.94	0.86	1.12	0.98	0.95	1.14
Maximum	8.26	10.46	9.67	7.68	9.75	7.85	9.67	7.87	9.48	12.2
Average	3.72	3.95	3.77	3.6	4.31	3.56	4.74	3.46	4.86	4.38
Standard Deviation	1.61	1.94	1.96	1.75	2.4	1.74	2.48	1.52	2.57	2.38
EDC (n=30)										
Minimum	0.97	0.87	0.86	0.89	0.9	0.72	0.67	0.75	0.75	0.86
Maximum	16.18	12.89	13.4	12.67	12.87	13.67	11.46	12.4	13.68	18.45
Average	3.23	3.22	2.99	3.051	2.62	2.67	2.72	3.09	3.2	3.62
Standard Deviation	3.31	2.98	2.89	2.91	2.35	2.46	2.23	2.46	3.05	3.64
FDS (n=30)										
Minimum	0.79	0.86	0.88	0.75	0.87	0.75	0.75	0.76	0.78	1.14
Maximum	7.87	8.57	7.97	8.18	9.23	11.98	10.23	11.2	11.65	12.56
Average	3.38	3.61	3.33	3.47	3.38	3.52	3.36	3.96	3.75	4.38
Standard Deviation	2.06	2.2	1.87	1.96	2.05	2.39	2.32	2.52	2.45	2.85
FDP (n=30)										
Minimum	1.25	1.25	0.99	1.24	0.95	1.29	1.43	1.42	1.49	1.26
Maximum	12.87	13.7	12.76	13.1	14.18	13.5	13.42	13.2	12.2	12.54
Average	3.99	4.34	4.31	4.6	4.05	4.14	4.08	4.38	4.52	4.57
Standard Deviation	2.79	3.05	3.1	3.39	3.17	3.02	2.79	3.1	2.94	3.01

50^{th} Percentile of muscle activity

	-15^0		-10^0		-5^0		0^0		6^0	
ECR (n=30)	sitting	standing	sitting	standing	sitting	standing	sitting	standing	sitting	standing
Minimum	0.97	1.23	0.87	0.95	0.94	0.85	1.09	0.96	0.71	1.1
Maximum	8.1	8.3	9.42	6.84	9.46	7.47	8.52	6.98	13.41	9.47
Average	3.47	3.66	3.45	3.34	4.06	3.46	4.45	3.26	3.02	4.06
Standard Deviation	1.57	1.7	1.94	1.63	2.44	1.67	2.29	1.39	3	2.11
EDC (n=30)										
Minimum	0.73	0.84	0.84	0.74	0.72	0.68	0.56	0.67	0.71	0.76
Maximum	15.4	12.63	11.78	12.12	12.54	13.21	11.27	11.7	13.41	16.34
Average	2.91	3.05	2.74	2.84	2.45	2.51	2.56	2.9	3.02	3.34
Standard Deviation	3.16	2.87	2.62	2.82	2.28	2.38	2.21	2.37	3	3.26
FDS (n=30)										
Minimum	0.65	0.76	0.76	0.7	0.7	0.66	0.7	0.7	0.6	0.6
Maximum	7.48	8.28	7.47	7.56	8.69	11.89	9.85	10.99	10.7	11.96
Average	3.12	3.37	3.13	3.25	3.14	3.37	3.19	3.73	3.49	3.14
Standard Deviation	2.01	2.16	1.79	1.87	1.99	2.38	2.29	2.49	2.34	2.69
FDP (n=30)										
Minimum	1.14	1.19	0.87	1.16	0.92	1.24	1.3	1.36	1.28	1.14
Maximum	11.9	12.32	12.46	12.87	13.99	13.48	13.31	13.05	12.17	12.3
Average	3.75	3.99	4.07	4.37	4.31	3.89	3.83	4.19	4.25	4.31
Standard Deviation	2.64	2.86	3.02	3.29	3.16	2.88	2.75	3.06	2.84	2.87

10th Percentile of muscle activity

ECR (n=30)	-15⁰		-10⁰		-5⁰		0⁰		6⁰	
	sitting	standing	sitting	standing	sitting	standing	sitting	standing	sitting	standing
Minimum	0.95	1.17	0.65	0.92	0.92	0.81	0.99	0.9	0.9	0.99
Maximum	6.5	6.56	8.11	6.83	8.7	7.12	8.44	6.43	8.51	8.54
Average	3.13	3.35	3.19	3.054	3.53	3.08	4.06	3.01	4.23	3.73
Standard Deviation	1.41	1.5	1.78	1.53	2	1.61	2.06	1.32	2.37	1.93
EDC (n=30)										
Minimum	0.65	0.48	0.65	0.66	0.62	0.5	0.44	0.48	0.63	0.55
Maximum	14.5	12.01	10.21	11.34	12.01	12.78	11.09	10.56	12.59	12.1
Average	2.67	2.7	2.43	2.55	2.23	2.31	2.41	2.66	2.82	2.97
Standard Deviation	2.98	2.62	2.3	2.56	2.19	2.34	2.19	2.19	2.87	2.68
FDS (n=30)										
Minimum	0.55	0.64	0.65	0.65	0.6	0.54	0.54	0.65	0.56	0.5
Maximum	7.37	7.63	7.31	7.03	8.21	10.77	8.56	10.42	10.1	11.2
Average	2.85	3.02	2.9	2.97	2.9	3.11	2.89	3.44	3.26	3.87
Standard Deviation	1.93	1.9	1.75	1.8	1.94	2.25	2.19	2.38	2.26	2.57
FDP (n=30)										
Minimum	1.05	1.04	0.69	1.08	0.83	1.11	1.15	1.16	1.07	1.03
Maximum	9.87	11.53	12.06	12.55	13.74	13.09	12.76	13	11.76	12
Average	3.4	3.66	3.77	4.096	3.6	3.61	3.54	3.94	3.98	3.98
Standard Deviation	2.33	1.94	2.88	3.18	3.11	2.75	2.63	3.01	2.75	2.73

Average Muscle Activity data

Tilt angles (degrees)	-15⁰		-10⁰		-5⁰		0⁰		6⁰	
Postures	Si	St	Si	St	Si	St	Si	St	Si	St
ECR	3.44	3.65	3.47	3.33	3.96	3.33	4.42	3.24	4.56	4.06
EDC	2.94	3	2.72	2.81	2.45	2.5	2.56	2.89	3.02	3.31
FDP	3.12	3.33	3.12	3.23	3.14	3.34	3.15	3.72	3.5	4.13
FDS	3.72	4	4.05	4.36	3.82	3.88	3.82	4.17	4.25	4.29

Note: Si = Sitting; St = Standing

Wrist Posture Data

Flexion/extension muscle activity data

Tilt angles (degrees)	-15^0		-10^0		-5^0		0^0		6^0	
Postures	Si	St	Si	St	Si	St	Si	St	Si	St
Minimum Wrist flexion/extension	5.18	5.68	5.32	6.21	2.44	6.42	9.59	12.39	14.84	17.32
Mean wrist flexion/extension	6.96	7.97	7.5	7.85	2.48	7.97	-4.45	13.76	18.84	18.24
Maximum Wrist flexion/extension	8.59	9.55	8.99	9.8	4.86	9.57	13.13	15.56	19.32	21.07

Note: Si = Sitting; St = Standing

Ulnar deviation data

Tilt angles (degrees)	-15^0		-10^0		-5^0		0^0		6^0	
Postures	Si	St	Si	St	Si	St	Si	St	Si	St
Maximum Wrist Ulnar deviation	7.05	6.64	5.74	4.97	5.37	9.75	6.51	6.73	7.01	8.98
Mean Wrist Ulnar deviation	5.52	5.36	4.83	4.37	4.17	3.6	4.89	5.41	6.13	7.76
Minimum Wrist Ulnar deviation	4.66	4.23	3.73	3.41	3.34	2.93	3.89	4.41	5.13	6.91

Note: Si = Sitting; St = Standing

Typing Performance (Speed and Accuracy)

Typing speed data

Tilt angles (degrees)	-15^0		-10^0		-5^0		0^0		6^0	
Postures	Si	St	Si	St	Si	St	Si	St	Si	St
Minimum	32	34	31	33	33	31	31	32	33	32
Maximum	64	67	69	67	71	69	67	69	72	69
Average	45.8	46	45.23	45.56	46.46	45.7	46.21	47	46.96	46.3
Standard Deviation	8.07	8.78	8.85	8.68	9.31	9.37	2.48	9.9	9.08	8.9

Note: Si = Sitting; St = Standing

Typing accuracy data

Tilt angles (degrees)	-15^0		-10^0		-5^0		0^0		6^0	
Postures	Si	St	Si	St	Si	St	Si	St	Si	St
Minimum	84	81	84	82	84	83	85	84	87	79
Maximum	95	96	96	95	95	95	95	95	96	96
Average	89.5	88.16	89.7	89.36	89.43	89.4	89.6	89.93	90.03	89.23
Standard Deviation	2.8	4	2.74	3.21	2.4	2.81	2.49	2.39	2.36	3.08

Note: Si = Sitting; St = Standing

Distance for placement of Keyboard

Tilt angles (degrees)	-15^0		-10^0		-5^0		0^0		6^0	
Postures	Si	St	Si	St	Si	St	Si	St	Si	St
Minimum	88	88	88	86	86	80	88	68	92	88
Maximum	180	180	180	220	180	186	180	180	186	180
Average	131.6	132	134	139.76	137.6	137	137.13	138.8	129.9	128
Standard Deviation	25.16	25.98	26	30.71	26.18	28.4	24.66	28.78	23.77	25.67

Note: Si = Sitting; St = Standing

User Preference (On a 7-point Likert scale)

Tilt angles (degrees)	-15^0		-10^0		-5^0		0^0		6^0	
Postures	Si	St	Si	St	Si	St	Si	St	Si	St
Minimum	3	2	3	2	2	2	2	2	2	2
Maximum	6	6	6	6	6	5	5	5	4	5
Average	2.66	3.2	3.17	2.96	3.96	34	4.46	4.33	4.7	4.33
Standard Deviation	0.88	1	0.68	0.88	0.92	1	0.83	0.96	0.84	1.21

Note: Si = Sitting; St = Standing

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