Malaysian Journal of Ergonomics
*Volume 1, December 2011 (71-82)*

# The Horizontal Position of Computer Keyboard and the Upper Extremities Muscular Load among University Students

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**Abstract**

The effects of the horizontal position of the keyboard on electromyography (EMG) activities of the shoulder and forearm muscles are determined among 100 healthy subjects. The subjects performed a typing task at four difference keyboard placements. [NEAR = the keyboard was placed at 0cm from the edge of the table, MID = the keyboard was placed at 8cm from the edge of the table, FAR = the keyboard was placed at 15cm from the edge of the table, Far with Pad (FWP) = the keyboard was placed at 15cm from the edge of the table with addition of a foam pad]. Surface EMG recordings were done on the upper trapezius (UT) and extensor carpi ulnaris (ECU), both on left and right side. Discomfort level was rated by the subjects by using 100mm visual analogue discomfort scale (VADS). Information of the individual preference for the four keyboard placements was obtained from a set of questionnaire. The result showed significant difference between four horizontal placements of keyboard in the percentage of Maximum Voluntary Contraction (%MVC) of both UT and ECU. However, the %MVC of UT was the lowest values at the NEAR position, whereas the %MVC of ECU was the lowest at FWP position. There was no significant correlation between the forearm length and the muscle contractions. However, the result showed there was significant lower value of the VADS at FWP position compared to NEAR position. There was highest number of subjects who preferred FWP positions due to lowest discomfort level while typing at that position. In conclusion, horizontal position of computer keyboard has an important role in affecting the upper extremity muscle activities.

*Keywords:* Keyboard, Upper trapezius, Extensor carpi ulnaris, Surface electromyography, Muscle activity.

## 1. Introduction

Cumulative trauma disorder had become an increasing trend among computer users in the workplace. Computer usage, which is more commonly referred to as Visual Display Terminal (VDT) had risen dramatically due to its capability to sustain global databases and process large quantities of data (Gerard, 1994). However, the incidence of musculoskeletal injuries in the Cumulative Trauma Disorders (CTD) has also risen with the increasing usage of VDT. (Hedge, 1995; Herington, 1995; Sauter, 1991). Number of cases of CTDs, which is also known as Work-Related Musculoskeletal Disorders (WMSD), Work-Related Upper Extremity Disorders (WRUEDs), repetitive Strain or Stress Injuries (RSI) and Repetitive Motion Injuries (RMI), are rapidly increasing. (Brogmus, 1996; Silverstein, 1986).

The permanent operation of computer keyboards has become a primary risk factor for acquiring RSI which is also known as work-related upper extremity disorders (Wahlstrom, 2005). Due to the extensive use of computer, even moderately small risks related with their usage would have important public health implications. Description of those risks is very important, eventually, for the prevention of their undesirable health effects (Gerr *et al.*, 2004).

Upper extremity symptoms are very frequently reported and have become one of the main causes of work disability. These disorders are a great economic burden on modern society especially for women, who are more affected than men (Bernard, 1997). Work-related upper limb symptoms are not medically diagnose, but recorded as pain perception. Lacking of recovery after local muscular fatigue can be very critical in the beginning of muscular pain in work-related upper limb symptoms (Zairina, 2009).

Previous studies often found that there were increased risks of getting musculoskeletal disorders (MSD) among keyboard users when compared to non-users. Therefore, consideration soon focused on specific aspects of keyboard work that might be accountable for the increase risk of MSD (Gerr *et al.*, 2006).

Work on the computer workstations includes many risk factors such as repetition, force, awkward posture of the upper extremity of the users. There were numerous studies that examined the effects of the device design and workstation arrangement may cause the exposure to these risk factors (Sauter, 1991; Hedg *et al.*, 1995; McLean, 2001;Dennerlein *et al.*, 2002; Kotani *et al.*, 2007).

There are growing incidence of employee sick leave, medical claims and litigation from musculoskeletal disorders (McLean, 2001; Morken *et al.*, 2002). Thus, ergonomists and organizations have to identify and eliminate all the risk factors to prevent the occurrence of MSDs and to reduce these costs.

## 2. Subjects and Methods

### *2.1 Subjects*

A total of 100 respondents (50 females and 50 males) ranging in age from 18 to 30 years (mean 21.4 years, SD 1.3 years) were recruited through simple random sampling among university students. All subjects reported that they had no current or past history of upper extremity musculoskeletal disorders. The demographic characteristics are shown in Table 1.

### *2.2 Experimental workstation*

There were four types of keyboard placements that being evaluated in this study.

- NEAR = The keyboard was placed at 0cm from the edge of the table
- MID = The keyboard was placed at 8cm from the edge of the table
- FAR = The keyboard was placed at 15cm from the edge of the table
- FWP = The keyboard was placed at 15cm from the edge of the table with addition of a foam pad (Far with Pad).

The workstation (Figure 1) included a height-adjustable work surface, where the keyboard, mouse and flat-panel monitor were resided. Prior to the start of the experiment, the subjects were required to adjust the chair until the feet were flat on the floor with the thighs were parallel to the ground. Then, the back support was adjusted to desired position. The chair setting remained unchanged throughout the task. The height of the table was adjusted for each subject so that the J-key of the keyboard was at the same height as the elbow; with the arms and shoulders in relax condition. During all the experimental condition, the alphanumeric part of the keyboard was located centrally to the respondents' body.

Figure 1: Subject with Workstation.

### *2.3 Task*

Prior to the measurement of muscle activities, the anthropometry data of subjects (forearm length, height and weight) was measured by using measuring tape (forearm length), Seca Body Meter Model 206 (height) and Detecto Scale (Weight).

The subjects were required to complete typing task across four types of conditions with different horizontal positions of the keyboard as shown in Figure 1. There were three different horizontal keyboard distance from the front edge of the table, where the keyboard was placed at 0cm from the edge of the table (NEAR), the keyboard was placed at 8cm from the edge of the table (MID), the keyboard was placed at 15cm from the edge of the table (FAR), the keyboard was placed at 15cm from the edge of the table with addition of a foam pad (Far With Pad).

The subjects were required to perform the typing task for 10 minutes at each keyboard placement. The typing task required the subjects to type according to the text which given by researcher continuously into word processing program. The texts were shown in a separate dialogue window on the computer screen. The sequence of the four experimental conditions and the typing task for each condition was randomized.

a) NEAR Condition

b) MID Condition

c) FAR condition

d) FAR with Pad condition

Figure 2: Horizontal Position of Computer Keyboard.

### *2.4 Electromyography*

Surface electrodes (DE-2.1 Single Differential Electrode) were attached on the skin of the subjects. Prior to attachment, the skin surfaces of the two muscles sites (UT and ECU) were prepared by cleaning the area with alcohol swabs, and for some subjects the area was shaved. The location of the recording electrodes were as followed: 1) along the line of axis between the 7$^{th}$ cervical vertebra (C7) and acromion, 2cm laterally from the midpoint (Jensen, 1996); and 2) 1/3 of the distance between the midpoint between the lateral epicondyle of the humerus and the olecranon process and the styloid process of the ulna (Barr *et al.*, 2001).

A portable EMG machine (Delsys Myomonitor Portable EMG System; Delsys, Boston, MA, USA) was used to record the muscle activities. Sampling of the muscle activity was done at a frequency of 1024 Hz. Recording was done continuously 10 minutes for all subjects doing typing task at 4 different keyboard placements.

To ease the individual comparison, the muscle activity was normalized as percentage of the maximum voluntary contraction (MVC). Five seconds of MVC were collected for each muscle and the MVC were obtained three times to get the highest reading. The maximum force that achieved in any of the three attempts was considered to be an MVC. Since the MVC is specific for each type of muscle that had been tested, therefore; MVC for upper trapezius (UT) and extensor carpi ulnaris (ECU) muscles were performed separately.

### *2.5 Questionnaire*

Self administrated questionnaire was used for this study. It was mainly divided into two main parts. The first part was filled by the subjects before started the typing tasks. Visual Analogue Discomfort Scale (VADS) is a tool to access the discomfort level of the respondents (Straker, 1999). It is a 100 mm horizontal line, scale from 0-100 to determine the comfort level. At the end of each experimental condition, the subjects were required to rate their discomfort level on the VADS. Finally at the end of the entire typing task, the subjects were required to determine which keyboard placement is most preferable by them.

### *2.6 Data and statistical analysis*

All the research data was analyzed by using Excel and "Statistical Package for Social Sciences" (SPSS) version 15 software.

The descriptive test was done to display the socio-demographic data of the subjects. The statistic of the muscle activities consisted of the root mean square of the amplitude probability distribution function (APDF) values at 10$^{th}$ percentile, 50$^{th}$ percentile and 90$^{th}$ percentile of the signal amplitude that provided a description of the range of the parameter values across the experimental condition. Subjective discomfort ratings for each muscle were analyzed as continuous scales between 0 and 100 mm, with 0 having no discomfort and 100 mm having the greatest discomfort. Differences for the EMG value and the subjective discomfort ratings between the four conditions (NEAR, MID, FAR, FWP) were analyzed individually by using a Friedman repeated measures ANOVA.

## 3. Results

### *3.1 Individual preference*

Majority of the subjects (41%) were preferred Far with Pad (FWP) placement of computer keyboard. Whereas there were 39% of the subjects were preferred MID keyboard placement, 13% of respondents preferred FAR keyboard placement whereas only 7% of the respondents preferred NEAR keyboard placement.

### *3.2 Relationship of forearm length and muscle contraction*

All the result for four different horizontal position of computer keyboard did not shown significant correlation between forearm length and the muscle contraction (ECU and UT). The result was shown in Table 3.

Table 1: Spearman Rank Correlation Coefficient to Identify the Correlation between Forearm Length and Muscle Contraction

| Muscle Contraction | Forearm Length Correlation Coefficient (ρ) | Forearm Length Correlation Coefficient (ρ) |
|---|---|---|
| **NEAR** | | |
| %MVC (ECU) | -0.02 | 0.89 |
| %MVC (UT) | 0.04 | 0.67 |
| **MID** | | |
| %MVC (ECU) | -0.02 | 0.82 |
| %MVC (UT) | 0.04 | 0.69 |
| **FAR** | | |
| %MVC (ECU) | -0.02 | 0.86 |
| %MVC (UT) | 0.06 | 0.58 |
| **FWP** | | |
| %MVC (ECU) | -0.02 | 0.86 |
| %MVC (UT) | 0.04 | 0.71 |

N = 100
*Significant at p value < 0.05
*ECU = Extensor carpi ulnaris
*UT = Upper trapezius

### *3.3 Upper trapezius muscle activities and four different keyboard placements*

The normalized EMG activities of the upper trapezius muscle were compared across the keyboard placements. The Friedman repeated measures ANOVA on the was done to compare the muscle activity for the four different horizontal positions of the computer keyboard as shown in Table 2. It showed that there were significant differences in the muscle activity across the four different placements of computer keyboard. The muscle activities of UT are the lowest at NEAR position except for right UT at 50th percentile of muscle activity.

For left UT, the contrast between NEAR-MID (10th percentile and 90th percentile) and NEAR-FAR (10th percentile, 50th percentile and 90th percentile) were found to be significant. For right UT, the contrast between NEAR-MID (90th percentile) was found to be significant. However the contrast that between others placement, were not significant across four different placement of keyboard.

Table 2: Comparison of the Upper Trapezius Muscle Activity for 4 Different Placement of Computer Keyboard by Using Friedman Repeated Measures Analysis of Variance on Ranks

| Muscle Activity (MVC %) | Mean (Mean Rank) | | | | $X^2$ (df) | P |
|---|---|---|---|---|---|---|
| | NEAR | MID | FAR | FWP | | |
| **10th percentile** | | | | | | |
| Left | 3.96(2.01) | 4.39(2.74) | 4.12(2.71) | 4.25(2.54) | 20.60 (3) | <0.001* |
| Right | 2.79(2.12) | 2.80(2.77) | 2.87(2.65) | 2.85(2.46) | 14.84(3) | 0.002* |
| **50th percentile** | | | | | | |
| Left | 4.14(2.02) | 4.40(2.76) | 4.15(2.64) | 4.36(2.59) | 19.43(3) | <0.001* |
| Right | 2.88(2.14) | 2.87(2.82) | 2.92(2.60) | 2.92(2.45) | 14.66(3) | 0.002* |
| **90th percentile** | | | | | | |
| Left | 4.17(1.98) | 4.46(2.90) | 4.17(2.57) | 4.44(2.55) | 26.27(3) | <0.001* |
| Right | 2.93(2.23) | 2.96(2.83) | 2.98(2.49) | 2.96(2.45) | 11.06(3) | 0.011* |

N = 100
*Significant at p value < 0.05
*MID=middle
*FWP=far with pad

### *3.4 Extensor carpi ulnaris muscle activities and four different keyboard placements*

The normalized EMG activities of the ECU muscle were compared across the keyboard placements. The Friedman repeated measures ANOVA was done to compare the muscle activity for the four different horizontal positions of the computer keyboard as showed in Table 3. Table showed that the ECU muscle activity is the lowest when the pad was added to the FAR keyboard position.

For left ECU, the contrast between NEAR-MID (10th percentile, 50th percentile and 90th percentile) and MID-FAR (10th percentile, 50th percentile and 90th percentile) were found to be significant; whereas for right ECU, all the contrast were not significant across four different placement of keyboard.

Table 3: Comparison of the Extensor Carpi Ulnaris Muscle Activity for 4 Different Placement of Computer Keyboard by Using Friedman Repeated Measures Analysis of Variance on Ranks

| Muscle Activity (MVC %) | Mean (Mean Rank) | | | | $X^2$ (df) | P |
|---|---|---|---|---|---|---|
| | NEAR | MID | FAR | FWP | | |
| **10thpercentile** | | | | | | |
| Left | 73.05(2.08) | 73.37(3.09) | 73.22(2.45) | 72.72(2.38) | 32.48(3) | <0.001* |
| Right | 69.40(2.18) | 68.95(2.75) | 69.02(2.74) | 67.57(2.33) | 15.08(3) | 0.002* |
| **50thpercentile** | | | | | | |
| Left | 73.12(2.11) | 73.43(3.12) | 73.30(2.43) | 72.92(2.35) | 34(3) | <0.001* |
| Right | 70.63(2.18) | 69.29(2.82) | 69.16(2.61) | 67.81(2.39) | 13.74(3) | 0.003* |
| **90thpercentile** | | | | | | |
| Left | 73.17(2.17) | 73.49(3.09) | 73.77(2.39) | 73.14(2.35) | 29.5(3) | <0.001* |
| Right | 70.80(2.19) | 69.57(2.79) | 69.40(2.59) | 68.03(2.43) | 11.59(3) | 0.009* |

N = 100
*Significant at p value <0.05
*MID=middle
*FWP=far with pad

### *3.5 Subjective Self-reported discomfortness at four different keyboard placements*

Friedman Repeated Measures ANOVA was used to compare the self-reported discomfortness of the respondents for the 4 horizontal placements of computer keyboard. The result shown that there was significant difference of Visual Analogue Discomfort Scale (VADS) between four different position of computer keyboard, $X^2(3, N=100) = 47.97$, $p<0.001$.

Table 4: Distribution of the Discomfortness of the Four Different Horizontal Positions of Computer Keyboard

| VADS | Mean (Mean Rank) | | | | $X^2$(df) | P |
|---|---|---|---|---|---|---|
| | NEAR | MID | FAR | FWP | | |
| | 4.97(3.20) | 3.50(2.37) | 3.71(2.42) | 3.02(2.02) | 47.97(3) | <0.001* |

N = 100
*Significant at p value <0.05

## 4. Discussion

### *4.1 Individual preference*

The individual preference was corresponding with the result of the visual analogue discomfort scale. Majority of the respondents (41%) was preferred FWP position while this position scored the lowest discomfort value by using VADS.

According to the respondents, FAR position caused increased of their wrist extension, this was due to their dificculty to float their posture during FAR position, therefore, they tend to rest their forearm on the table surface proximal of the keyboard in order to support their arms. However, the hard surface of the table and increasing of the wrist extension caused discomfortness during typing. By adding a foam pad that raised the surface proximal to the keyboard during FWP position, the extension of the wrist was reduced (Kotani *et al*., 2007).

The respondents reported that the foam pad may reduced the contact stress between the forearm and the hard surface of the table and the extension of the wrsit was reduced, hence, they preffered FWP position when using computer keyboard. Besides, there were 93% of the respondents did not preffered NEAR position when using keyboard. These respondents claimed that NEAR position may increased the flexion of their elbow and the extension of the shoulder.

### *4.2 Relationship between forearm length and muscle contraction*

This study showed that there was no significant correlation ($p>0.05$) between forearm length and the muscle contraction (ECU and UT). Result of this study was supported by Serina *et al*. (1999) who stated that there was no significant effect between the anthropometry and the wrist and forearm posture during typing. The wrist and forearm posture were not predictable based on respondents' size, shoulder width, hand length, or wrist dimension at an adjusted workstation. Rose (1991) suggested that the degree of wrsit ulnar deviation was influenced by the anthropometry of the respondents. They stated that the elbows of a smaller-sized individual would be closer to the centre of the body due to narrower shouldet widths which lead to less ulnar deviation. On the other hand, larger sized individual would have their elbows further apart, which increased their wrist ulnar deviation.

### *4.3 Upper trapezius muscle activities and four different keyboard placements*

The goal of this study was to determine the effect of the horizontal position of the computer keyboard on the muscular load on the two types of upper extremity muscles (UT and ECU). In this study, the significant difference in the muscle activities for the UT across four different keyboard placements is a warning sign to the keyboard users that the changing of the horizontal keyboard placement away from the user's body will increase the stretching of the UT muscle and hence increase the muscle activities. Other than that, the upper arm posture moved away from the neutral position as the keyboard distance increased (Kotani *et al.*, 2007). However, there was another study which related to the effect of horizontal position of the computer keyboard to the muscle activity of the keyboard users had also found that there was no significant effect in the muscle activities across the different placement of keyboard (Kotani *et al.,* 2007).

### *4.4 Extensor carpi ulnaris muscle activities and four different keyboard placements*

In this study, results show significant differences in the ECU muscle activities across the four different horizontal placement of computer keyboard. As the keyboard was moved away from the edge of the table, keyboarding task requires less ulnar deviation and hence forearm muscle activity. This was supported by finding from Kotani *et al.* (2007), who stated that ulnar deviation of the wrist decreased toward neutral posture when the keyboard was positioned further away from the edge of the table. Thus, reduced in ulnar deviation appears to be protective for keyboard-related musculoskeletal disorders (Gerr *et al.,* 2006).

Yet, with the increased in the distance from edge of the table, wrist extension will be dramatically increase and this has been associated with higher prevalence of hand and forearm disorders (Gerr *et al.*, 2006). The reason for the dramatic increase of the wirst extension is due to the subjects will tend to placed their forearms on the table surface proximal of the keyboard in order to support their arms. By adding a foam pad that raised the surface proximal to the keyboard can reduced both wirst extension and forearm muscle activity. Nonetheless, study by Cook *et al.* (2004) did not observe any changes in wrist extension after addition of pad which prevent the distal end of the forearm from resting or planting on the table.

### *4.5 Subjective self-reported discomfortness at four different keyboard placements*

In this study, there was significant higher of the VADS score at the NEAR position compare then FWP position.

Throughout the study observation, adduction of the shoulder at NEAR condition was highest. This occurred because the respondents have to move their elbow laterally in order to clear the torso. NEAR condition allowed the respondent's posture to be as close as possible to the posture based on the so-called "90-90-90" rule. This condition create the least neutral posture in the writs and shoulder by increase the ulnar deviation of the wrist, increase the shoulder abduction angles, and hence increase the subjective discomfort levels (VADS). These data which obtained from Cook et al. (2004) was compatible with the result from this study where NEAR position caused highest level of discomfort among the respodents while performing typing tasks.

Wrist extension increased as the keyboard moved away from the respondents. However, the addition of a foam pad which raised the surface proximal to the keyboard reduced the muscle activity and wrsit extension. This result from this study review that ulnar deviation of the wrist decreased toward neutral posture when the keyboard was positioned further away from the edge of the table. (Kotani *et al.*, 2007). The reduction of the ulnar deviation appears to be protective effect for keyboard-related musculoskeletal disorders (Gerr *et al.*, 2006).

## 5. Conclusion

In conclusion, the result shown that there is significant different of the muscle activity for both the upper trapezius and extensor carpi ulnaris muscle. The upper Trapezius muscle activity is the lowest at NEAR position whereas the extensor carpi ulnaris muscle activity is the lowest at FWP position.

However, in term of discomfortness and individual preference, the FWP position was most preferred by most of the respondents since the FWP position scored the lowest VADS and more preferred by the respondents. Whereas NEAR position was the position which may cause the highest discomfortness among the respondents and less than 10% of the respondents which preferred this placement of keyboard. This could be explaining by the increased of the shoulder flexion and ulnar deviation while typing at the NEAR position.

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