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Effect of Wrist Extension Angles and Low-Velocity Ulnar Deviation Movements on Forearm Muscle Activity

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Abstract: This study is conducted to examine the effect of wrist postures on the forearm muscle activity while performed low-velocity ulnar deviation movements. Eighteen healthy males participated in this study. The participants were asked to simulate several wrist angles representing the postures of computer input devices operations. The wrist angles were constructed from three levels of wrist extension angles (0^0, 25^0, and 50^0) and three levels of wrist ulnar deviation movement angles (10^0, 20^0, and 30^0). The angular velocity of the ulnar deviation movement was 10^0/s. In guiding the wrist movement on the desired angles, vertical and horizontal goniometers and metronome were utilized. The muscle activity was recorded using electromyography from two muscles in the forearm region: extensor digitorum and extensor carpi ulnaris. As the results, there was a significant effect of the wrist extension angles on the muscle activity of extensor digitorum as well as static muscle activity of extensor carpi ulnaris. Mean comparison of the muscle activity showed that each extension angles has statistically different level of muscle activity. The lowest muscle activity was found on 0^0 wrist extension angles, while the highest muscle activity was found on 50^0 wrist extension angles. On the other hand, significant differences in the muscle activity due to the effect of ulnar deviation movement angles only occurred for 30^0 ulnar deviation movement angles. The results of this study might be important as a consideration in the design process of computer-input devices.

Keywords: wrist, extension, ulnar deviation, movement, muscle activity.

1. Introduction

Changes in the way of social interactions make technology plays an important role in human lives. It is supported by the fact on the rapid increases of the computer-based device use. According to File (2013), 76.7% of 119,545 households in the United States owned and used at least one computer-based device in 2010. This number dramatically increased than the fact in 2000 which the number only reported in the range of 56.3% of 109,106 households.

Nevertheless, the rapid growth of computer-based device use was followed by the increases of reported work-related musculoskeletal disorders (WMSDs) in people who work with computers on their daily work. WMSDs caused by computer-based device usages occurred in several parts of the human body including neck, shoulders, and wrists (Cooper & Straker, 1998). Among those body parts, the human wrist was the body part that had the highest prevalence of non-fatal injuries which was contributed by musculoskeletal disorders such as tendinitis and carpal tunnel syndrome. In addition, tendinitis and carpal tunnel syndrome made the workers lost their workdays longer than other disorders such as back pain and skin wound (Wiatrowski, 2012).

Computer-based device use triggers WMSDs in the wrists due to the interaction of the hands to the computer input devices. There were 37,804 cases of work-related carpal tunnel syndrome in the United States during 1995, which 21% of them were caused by the use of computer input devices such as mouse and keyboard (Fagarasanu & Kumar, 2003). In contrast to human operated tasks for the industrial activity, computer input devices use requires less hand power. The use of computer input devices such as mouse and keyboard only required 7% of the wrist maximum voluntary contraction (Aaras & Ro, 1997). However, the computer input device use forced the operator to maintain non-neutral wrist postures repetitively for a long duration (Gustafsson & Hagberg, 2003; Simoneau, Marklin, & Berman, 2003).

The operations of the computer input devices required non-neutral wrist postures which were dominated by extension and ulnar deviation angles (Cook, Burgess-Limerick, & Papalia, 2004; Lintula, Nevala-Puranen, & Louhevaara, 2001). Computer mouse operations require the wrist positioned at 22^0 extension angles and 21^0 ulnar deviation angles (Asundi, Odell, Luce, & Dennerlein, 2012). Slightly different from the mouse operations, working using keyboard also required the wrist in the more non-neutral postures, 27^0 extension angles and 14^0 ulnar deviation angles (Lintula et al., 2001). In addition, working using notebook touchpad created wrist postures at 28^0 extension angles and 16^0 ulnar deviation angles (Asundi et al., 2012).

In addition to the non-neutral postures, working using computer input devices also required the wrist perform low-velocity movements. Jensen et al. (1998) and Gustafsson & Hagberg (2003) found that during the operations of a computer

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mouse, human wrist moved on two types of movements: paused wrist movements and low angular velocity movements. The low-velocity movements were dominated by ulnar deviation movements which make the wrist move from neutral posture to ulnar deviated postures.

Recent studies show that working using keyboard and mouse whereas made the wrist positioned on non-neutral posture affect the forearm muscle activity. Gustafsson & Hagberg (2003) found that as the consequence of the extension and ulnar deviation angles in the wrist during operation of the conventional mouse, the muscle activity of extensor digitorum and extensor carpi ulnaris were significantly higher than those of vertical mouse. Slightly similar, Van Galen, Liesker, & de Haan (2007) also found that traditional keyboard remarkably increased the muscle activity of extensor digitorum, extensor carpi ulnaris, and extensor carpi radialis compared to the muscle activity on the modified separated vertical keyboard. However, as the development of many novel computer-based devices nowadays, the required wrist postures might also become more varied. One of the examples was the wrist postures of the computer tablet operations which could require up to 45^0 wrist extension angles (Young, Trudeau, Odell, Marinelli, & Dennerlein, 2012). Therefore, further studies on that might be needed.

Some researchers have attempted to use several approaches such as electromyography (EMG), biomechanical models, and fatigue curves per break to examine the potential presence of WMSDs. Among those approaches, myoelectric signals recorded in EMG were the most widely used approach. It occurred because the myoelectric signals representing the muscle activity can be used for measure resting, moderate working, and working activities. Accordingly, the ability of the EMG could be used to investigate the risk level of any movement in the human body (Kumar, 1999).

Because of the importance of understanding the effect of wrist postures representing the operation of computer input devices on the human body, this research was conducted to investigate the effect of wrist extension angles which is combined with low-velocity ulnar deviation movements on the forearm muscle activity. The findings of this research were expected to be utilized as consideration for improving the design of computer input devices. Thus, the users can be minimally exposed to the postural risk factors while using computer input devices.

2. Methods

2.1 Participants

Eighteen healthy and right-handed males voluntarily participated in this study. None of the participants had any injuries or disorders in the wrist and forearm in the last one year (self-reported). The average age (year), height (cm), weight (kg), and hand grip strength (kg) of the participants were 23.52 (1.60), 167.8 (5.0), 64.8 (7.3), and 38.4 (5.4).

2.2. Experimental Design

This research applied full factorial design with three levels of wrist extension angles (0^0, 25^0, and 50^0) and three levels of wrist ulnar deviation movement angles (10^0, 20^0, and 30^0) (Figure 1). The three wrist extension angles and three wrist ulnar deviation angles resulted in nine wrist postures that were investigated in this study. The selected postures represented the wrist postures for the operations of computer input devices (Jensen et al., 1998; Lintula et al., 2001; Marklin and Simoneau, 2001; Cook et al., 2004; Jonai et al., 2004; Young et al., 2012) (Cook et al., 2004; Jensen et al., 1998; Jonai, Villanueva, Takata, Sotoyama, & Saito, 2002; Lintula et al., 2001; Marklin & Simoneau, 2001; Young et al., 2012). We did not investigate wrist flexion postures because the operations of computer input devices such as mouse and keyboard rarely require this posture (Cook et al., 2004; Lintula et al., 2001). In addition, radial deviation position was not also taken into consideration because more than 93% wrist deviation on the operations of the computer input devices occurs in the ulnar deviation posture (Cook et al., 2004).

2.3. Procedure

The participants sat in a chair while was required to maintain right shoulder abduction at 25^0 and right elbow flexion at 90^0. In determining the maximum voluntary contraction (MVC), they were asked to push a resisted load using their right hand while sitting. Furthermore, they were asked to perform low-velocity wrist movement for nine investigated postures randomly. The low-velocity movement was selected at 10^0/s which represented the average speed of the wrist movements during the operation of a computer mouse. The movements were the repetitions of wrist movements from zero ulnar deviated posture (neutral posture) to the selected ulnar deviated posture that were guided using a metronome to create consistent motions. In ensuring that the participants performed correct postures during the data collection, vertical and horizontal goniometers were

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utilized. The illustration of the experimental setup can be seen in Figure 2. In between two wrist postures, the participants were given by at least 4-minutes breaks. They were suggested to place their hand on neutral postures during the break.

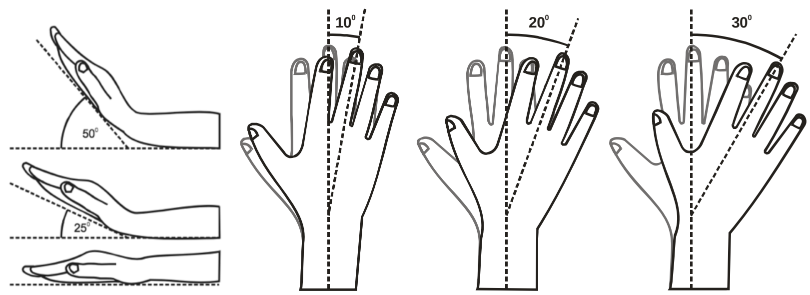

Figure 1. Wrist extension and ulnar deviation movement angles investigated in this study

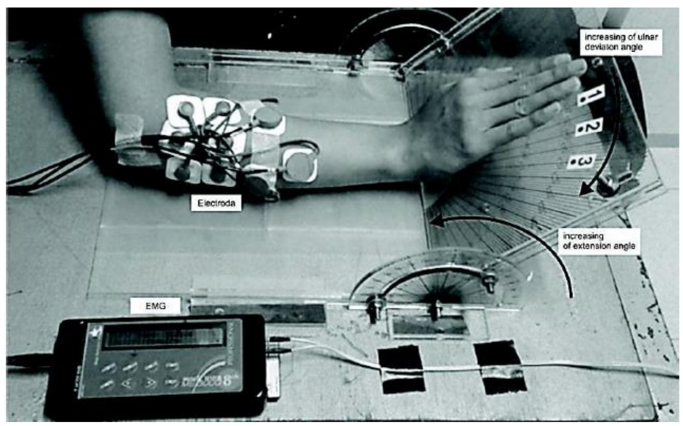

Figure 2. The experimental setup for this study

2.3. Surface EMG Signal Acquisition and Processing

Surface EMG signals were recorded from two forearm muscles: extensor digitorum (ED) and extensor carpi ulnaris (ECU) using Bipolar Ag–AgCl surface electrodes (Swaromed REF 1066 electrodes, NesslerMedizintechnik GmbH, Austria). The precise locations of EMG electrodes were adopted from Criswell (2010). Before attaching the electrodes, the forearm skin of the participants was carefully prepared by cleaning using tissue and alcohol. EMG signals were recorded using ME3000P8 (Mega Electronics Ltd., Finland). The sampling frequency of the EMG signals was 250 Hz. Before processed in the further computation, the signals were rectified and filtered. The signal processing was continued by filtering them using a low-pass filter (Butterworth, 2nd order, 20 Hz cut-off frequency).

2.4. Data Analysis

After being rectified and filtered, the signals were processed for computing the amplitude probability distribution function (APDF) 10%, 50%, and 90%. These APDFs can be utilized to describe the muscular load profile on a period of work (Jonsson, 1982). The APDF 50% expressed the median muscle activity, while the APDF 10% expressed the static muscle activity and the APDF 90% expressed the peak muscle activity. The APDFs was expressed using the percentage of maximum voluntary contraction (%MVC). % MVC was calculated from the EMG signal amplitudes which were normalized to the maximum voluntary contraction of the muscle. In determining the responses of the muscle activity due to the variation of the wrist postures, two-way analysis of variance tests were conducted. If significant differences were found, post-hoc tests would be performed.

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3. Results and Discussion

3.1. Muscle Activity of Extensor Digitorum

The muscle activity presented as APDF 10%, 50%, and 90% of the extensor digitorum can be seen in Figure 3. Meanwhile, the results of the analysis of variance test are shown in Table 1. As seen in Table 1, no significant effect of the interaction between wrist extension angles and wrist ulnar deviation movement angles on the muscle activity was observed. Furthermore, there was a significant effect of the wrist extension angles on the APDF 10%, 50%, and 90% of extensor digitorum (p<.001). Post hoc comparisons using LSD test indicated that the means of all muscle activity were significantly different at p<.05 for all wrist extension angle pairs. The lowest muscle activity was found on 0^0 wrist extension angles, while the highest muscle activity was found on 50^0 wrist extension angles. On the other hand, the main effect of the ulnar deviation movement angles yielded at p>.05, indicating that the effect of ulnar deviation movement angles was not significant.

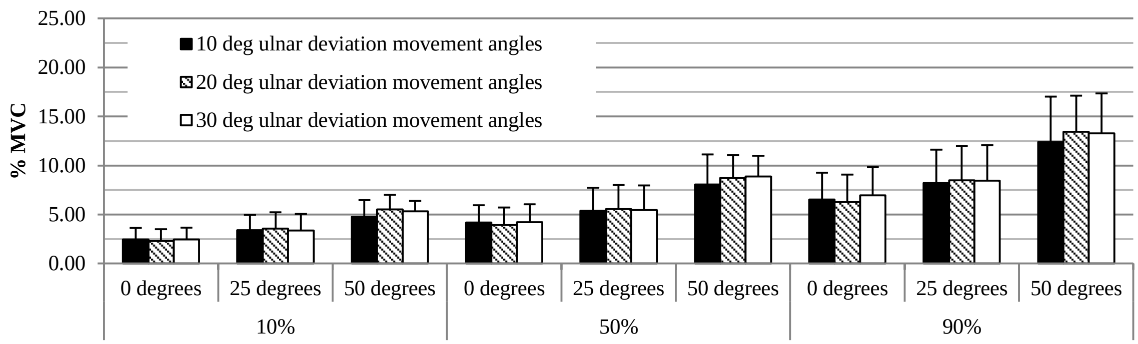

Figure 3. Mean and standard deviation of APDF 10%, 50%, and 90% for extensor digitorum muscle

Table 1. P-values of two-way ANOVA for APDF 10%, 50%, and 90% of extensor digitorum muscle

Source of Variation	APDF 10%	APDF 50%	APDF 90%
Extension Angles	<0.001**	<0.001**	<0.001**
Ulnar Deviation Movement Angles	0.662	<0.769	0.752
Interaction	0.741	0.909	0.950

*) significant at p<.05 **) significant at p<.001

3.2. Muscle Activity of Extensor Carpi Ulnaris

The muscle activity presented as APDF 10%, 50%, and 90% of the extensor carpi ulnaris can be seen in Figure 4, while the results of the two-way analysis of variance tests are presented in Table 2. The analysis of variance tests on the muscle activity of extensor carpi ulnaris showed that variation of wrist extension angles only created significant differences in the static muscle activity (APDF 10%). No significant effect was observed on APDF 50% and 90% for the three wrist extension angles. Post hoc comparisons using LSD test indicated that the means of APDF 10% were significantly different at p<.05 for the pair of 0^0 and 25^0 wrist extension angles as well as the pair of 25^0 and 50^0 wrist extension angles. Furthermore, the main effect of the wrist ulnar deviation movement angles was found to be significant at p<.05 on the APDF 50% and APDF 90%. The post hoc test results for the two APDF levels found that only the pair of 10^0 and 30^0 wrist ulnar deviation movement angles which had significantly different means at p<.05. No significant mean differences were observed for other pairs of the wrist ulnar deviation movement angles.

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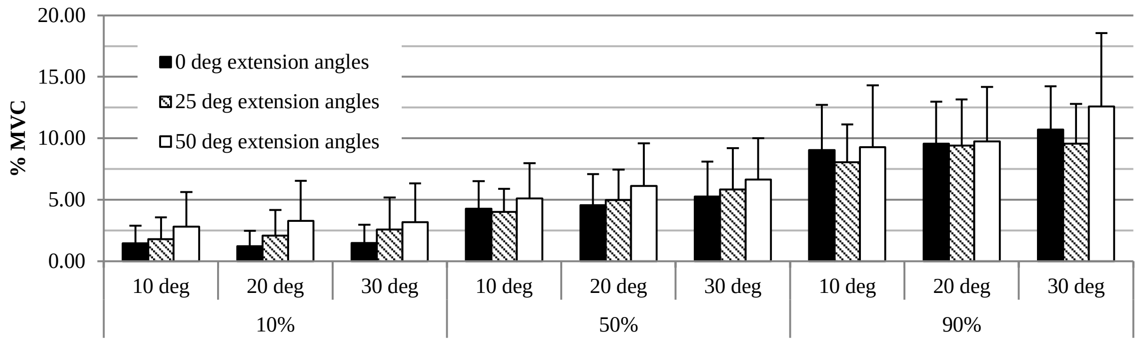

Figure 4. Mean and standard deviation of APDF 10%, 50%, and 90% for extensor carpi ulnaris muscle

Table 2. P-values of two-way ANOVA for APDF 10%, 50%, and 90% of extensor carpi ulnaris muscle

Source of variation	APDF 10%	APDF 50%	APDF 90%
Extension Angles	<0.001**	0.057	0.181
Ulnar Deviation Movement Angles	0.355	0.035*	0.033*
Interaction	0.703	0.970	0.729

*) significant at p<.05 **) significant at p<.001

3.2. Discussion

The results of this study found that wrist extension angles had a significant effect on all level muscle activity of extensor digitorum as well as static muscle activity of extensor carpi ulnaris. The mean comparison of the muscle activity showed that each wrist extension angles has statistically different level of muscle activity. The significant effect of wrist extension angles on muscle activity was also found on Gustafsson & Hagberg (2003), Fagarasanu, Kumar, & Narayan (2004), and Oikawa, Tsubota, Chikenji, Chin, & Aoki (2011). Gustafsson & Hagberg (2003) found that working with a conventional mouse creates a greater muscle activity of extensor digitorum and extensor carpi ulnaris than those of an ergonomic mouse. The conventional mouse requires higher wrist extension angles than the ergonomic mouse. Similar findings also found by Fagarasanu et al. (2004) which compared 45^0 wrist extension angle postures to neutral wrist postures. As the results, significantly higher muscle activity was recorded for almost all forearm muscle compared to the neutral posture. In addition, Oikawa et al. (2011) also found that playing a louder sound in a piano that requires more wrist extension angles would increase the muscle activity compared to the less loud sound which requires a more neutral posture.

Furthermore, this study found that not all ulnar deviation movement angles would create the significant effect on muscle activity of extensor carpi ulnaris. No significant effect of 10^0 and 20^0 ulnar deviation angles on median and peak muscle activity was observed. Meanwhile, the significant effect was only observed for 30^0 ulnar deviation angles on median and peak muscle activity. This finding was in line with the results of Fagarasanu et al. (2004) which found that 30^0 wrist ulnar deviation postures would produce a significantly higher muscle activity compared to the neutral posture.

4. Conclusion

This study examined the effect of several wrist angles on forearm muscle activity while working on low-velocity wrist movements which represented wrist posture while operating computer input devices. As the results, the significant effect of wrist extension angles on all level muscle activity of extensor digitorum as well as static muscle activity of extensor carpi ulnaris was observed for all wrist extension angles. The 0^0 wrist extension angles created the lowest muscle activity, while the highest muscle activity was observed for 50^0 wrist extension angles. Furthermore, the significant effect on the muscle activity of extensor carpi ulnaris regarding the effect of ulnar deviation postures was found for 30^0 wrist ulnar deviation movement angles. According to the findings of this study, computer input devices should be designed that they require almost neutral

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wrist extension postures as well as less than 30^0 wrist ulnar deviation postures in order to minimize muscular load in the forearm.

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