Analysis of Electromyography on Computer Interaction Devices to the Risk of Carpal Tunnel Syndrome

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Abstract: Use of interaction devices on human-computer system may cause muscolusceletal disorders. This paper presents an Electromyography study to evaluate the hand muscle activities when it is interacted with the computer using mouse, keyboard and joystick. These muscles investigated are *flexor pollicis brevis*, *flexor digitorium superficiallis* and *abductor pollicis brevis*. Average of Root Mean Square (mRMS) signal was used as parameter. Experimental study was conducted where 8 females and 7 males were participated to complete virtual task for 15 minutes. Virtual manufacturing robots system was used as a case study. Non parametric statistical method was conducted to test the hypothesis. The result of this study shows that the highest risk of carpal tunnel syndrome was found in the joystick on *flexor pollicis brevis* muscle and *abductor pollicis brevis* muscle. Meanwhile on *flexor digitorium superficiallis* muscle contraction was found in the keyboard devices. Thus, use of mouse is better.

Key words: Electromyography, input devices, mRMS, CTS.

1. Background

In Indonesia, the percentage of Personal Computer (PC) users in 2010 to 2012 years are 7.45%, 6.89% and 6.46%. Inversely, use of laptops/netbooks have increased from year to year that are 6,44% in 2010, 8.80% in 2011 and 12.19% in 2012 [1].

Ref. [2] mentions that accessing a game by using laptop takes longer time than others, which is 8% of users play a game less than 1 hr/day and 8.7% play a game more than 16 hr/day with an average period of the players are 2-8 hr/day.

However, use of computer/laptop can lead to increase some health problems such as musculoskeletal disorders, eye fatigue and overuse injuries on the shoulder, arm, hand and wrist [3], [4]. Furthermore [5] & [6] expressed that computer devices such as keyboard, mouse and joystick also cause a risk in developing musculoskeletal symptoms especially at hand.

Carpal tunnel syndrome (CTS) was a symptom commonly that is reported in computer professionals. Where CTS is a syndrome that occurs because compression of median nerve in the carpal tunnel on wrist area when the nerve passes through a tunnel from the forearm to the hand [7]. It is caused by repetitive hand motion especially in persons whose work inquires repeated forceful finger and wrist while flexion and extension [5]. A survey on computer users indentified that 29.6% user experience hand paraesthesia syndrom and 10.5% user have CTS [8].

EMG is a tool to identify the quantitative signal amplitude of muscle activity and has been used in several studies related to activity of hand when using a computer [9]. The EMG signal describes hand muscle movements when using a computer, so that the risk of CTS can be detected [10].

The study presents an Electromyography investigation to evaluate the hand muscle activities when it was interacted with the computer using mouse, keyboard and joystick during complete virtual robot manufacturing system.

2. Research Method

2.1. Subject

Fifteen student (8 females and 7 males) from a university in Indonesia was participated in this study. Their age was in range between 19 to 23 years with the average age was 21.47 years old. And they have been familiar for playing a game is about 2 to 4 hours per day where 80% of participants using a mouse, keyboard and joystick. Samples were taken randomly and none of the participants suffer from musculoskeletal disorders.

2.2. Apparatus

The main tool in this study is Electromyography (EMG: ME3000P8) to investigate the muscle contraction. Raw signal from the EMG recorded by attaching electrodes on hand cleaned with an alcohol swab [11].

A set of personal computer is used to present the raw EMG signal using Megawind 700046 software version 2.4 (Mega Electronics, Ltd.). While, the experiments performed using a laptop 14" to display the virtual robot manufacturing system using computer interaction devices such as mouse, keyboard and joystick.

2.3. Empirical Study

2.3.1. Experimental design

Experiment was conducted in Ergonomics Laboratory. Each respondent in a sitting position as comfortable as possible on the seat that has been provided. Respondent was sit in front of a laptop with 60 cm of distance. Experiment requires 5 minutes for exercise, 15 minutes for experiments and 15 minute later to recovery. The total experiment period is 1.5 hours per respondent for three computer interaction devices.

2.3.2. Task

Respondents were instructed to play virtual robotic manufacturing system using any computer interaction device such as mouse, keyboard and joystick. Use of this device was selected randomly. Fig. 1 is a snap shot of virtual robots manufacturing system that has been adjusted [12].

Fig. 1. Virtual robotic maufacturing system.

2.3.3. Procedure

Identify the locations of flexor pollicis brevis muscle, flexor digitorium superficiallis muscle and abductor pollicis brevis muscle. Based on [13], location of these muscles were at medial aspect of the thenar eminence for the flexor pollicis brevis, at the middle of the forearm on the ventral side, approximately three quarters of the distance from the elbow to the wrist for flexor digitorium superficiallis, and at the center of the largest mound of the thenar eminence for abductor pollicis brevis.

Based on [13], placement of two active electrodes at flexor pollicis brevis muscle are on the medial aspect of the thenar eminence and parallel to thumb in 2 cm between both. Meanwhile, placement of two active electrodes at flexor digitorium superficialis are on forearm when it was identified by flexing the fingers. Then, placement of two active electrodes at abductor pollicis brevis are on the center of the argest mound of the thenar eminence and in the same direction of thumb.

Before starting the experiment, subjects were asked to sit and grip the device comfortably. Use a mouse, keyboard, joystick was reffered to [14] which the position of hands when holding and moving those devices should be gently and in the normal posture as well as not strained. The electrodes are removed from the skin when respondents have been completing the task.

2.4. Data Analysis

Data analysis was based on mean of RMS signal on muscle activity of flexor pollicis brevis, flexor pollicis digitorium superficiallis and abductor brevis. Fig. 2 describes mean of RMS signal indentified.

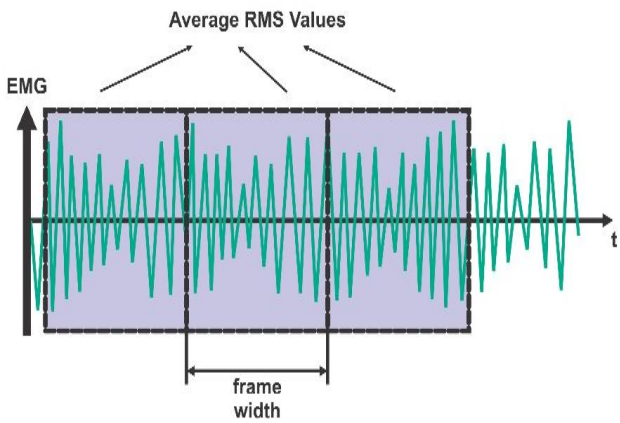


Fig. 2. Mean values of RMS [15].

Statistical analysis was performed using SPSS 18 to determine the significance of differences in each muscle activity when using the mouse, keyboard and joystick. Data signals is non parametric data that is processed using the Kruskal-Wallis test and Mann-Whitney test with significance $P<0.05$.

3. Result and Discussion

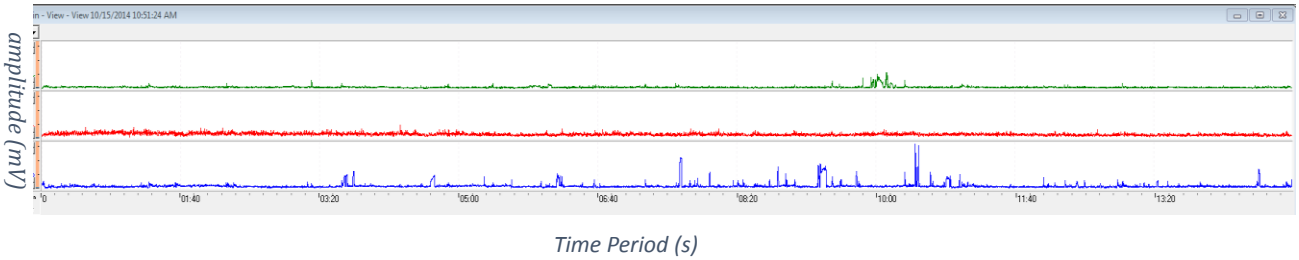
3.1. Analysis of EMG signal

In Fig. 3, Fig. 4, Fig. 5 show the average of RMS signals at flexor pollicis brevis muscle (green), flexor digitorium superficialis muscle (red) and abductor pollicis brevis muscle (blue). Fig. 3 shows the muscle contraction using mouse. And Fig. 4 presents the muscle contraction when user uses keyboard. While the Fig. 5 explains the muscle contraction when using joystick.

Fig. 6 shows the score of amplitude (in microvolt) for the overall type of muscle contraction when interacted with computer using mouse, keyboard or joystick.

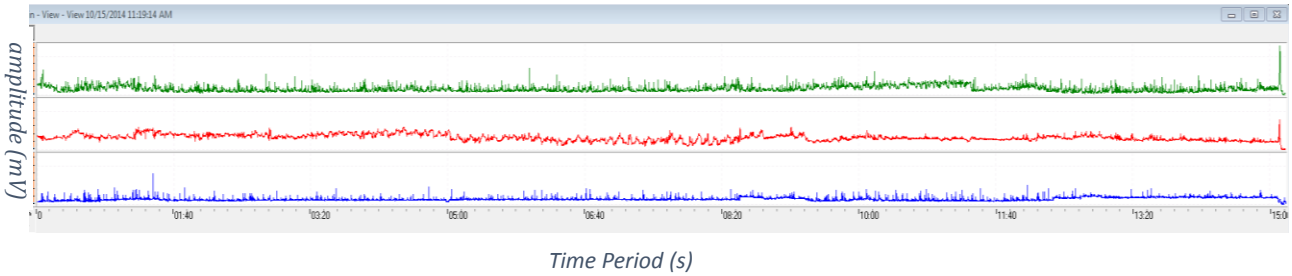
Amplitude score for muscle contraction of flexor pollicis brevis when using mouse is 53.4 mV, using

keyboard is 72 mV and using joystick is 274.5 mV. And for muscle contraction of flexor digitorium superficialis, the mouse score is 34.8 mV, keyboard score is 53.13 mV and joystick score is 48.93 mV. While for muscle contraction of abductor pollicis brevis when using mouse is 60 mV, using keyboard is 53.13 mV and using joystick is 130.47 mV.



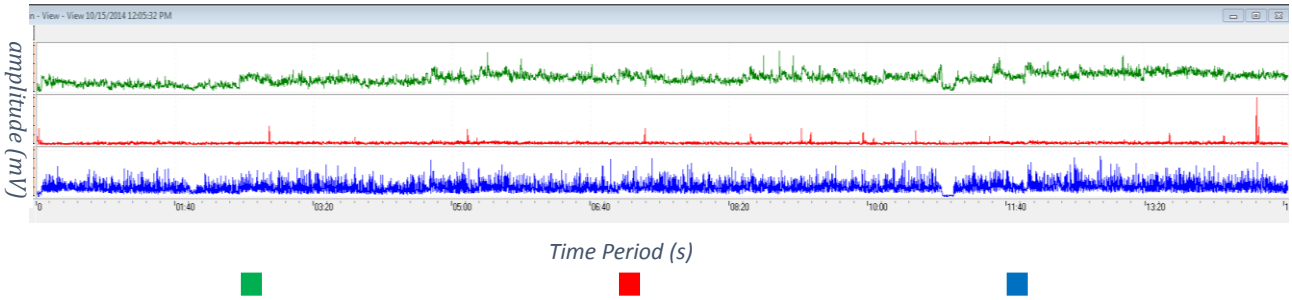
m. Flexor Pollicis Brevis m.Flexor digitorium superficiallis m. Abductor Pollicis Brevis

Fig. 3. mRMS of mouse signal.



m. Flexor Pollicis Brevis m.Flexor digitorium superficiallis m. Abductor Pollicis Brevis

Fig. 4. mRMS of keyboard signal.



m. Flexor Pollicis Brevis m.Flexor digitorium superficiallis m. Abductor Pollicis Brevis

Fig. 5. mRMS of joystick signal.

The lowest amplitude score in each muscle is shown when using a mouse to run. It means that the mouse device may produce low muscle contraction such that a risk of carpal tunnel syndrome does not be occured immediately [16], [17]. It is because when subject running virtual robot manufacturing system using mouse, participants only focus on the movement of the wrist with abduction and adduction direction without moving the fingers. So the activity of the fingers are rarely used.

While between use of keyboard and joystick, use of keyboard produce lower amplitude score than the joystick in flexor pollicis brevis muscle and abductor pollicis brevis muscle, but in flexor digitorium superficialis the joystick generate almost similliar score to the keyboard. This condition presents that use of joystick to play the game has higher risk than keyboard. It because of the keys which used on the keyboard is just right and left arrow so that the movement of forefinger and middle finger moves dominant. And

when using joystick the movement used both hands to grip the stick, but only the right hand are used to move, especially the thumb. The thumb on the right hand move actively when running virtual robotic manufacturing system with rotating direction while the other fingers didn't move, maximum movement of the thumb make the flexor pollicis brevis muscle has a strongest contraction.

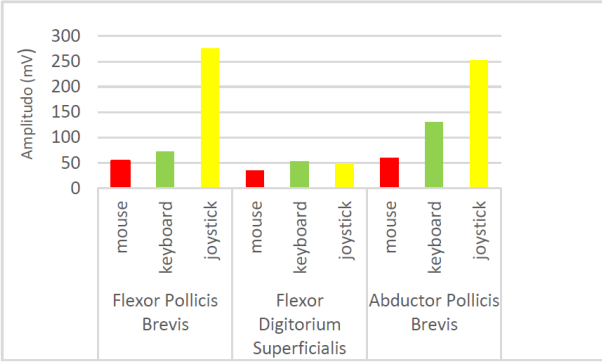


Fig. 6. Amplitude score for muscle contraction (mV).

3.2. Statistical Analysis

Table 1 shows the result of Kruskall-Walis test that describes the difference of muscle contraction (amplitude score) among three different muscles and different computer interaction devices.

Table 1. The Result of Kruskall-Walis Test

Muscle	Mouse	Keyboard	Joystick
Mean Flexor Pollicis Brevis (mV)	53.4	72	275.4
Sig.	$P(0.00)<0.05$		
Mean Flexor Digitorium Superficialis (mV)	34.87	53.13	48.93
Sig.	$P(0.184)>0.05$		
Mean Abductor Pollicis Brevis (mV)	60	130.47	252.67
Sig.	$P(0.02)<0.05$		

There were significants difference in the muscle contraction of flexor pollicis brevis muscle and abductor pollicis brevis muscle when using mouse, keyboard and joystick devices at 5% significant level. But in the flexor digitorium superficiallis muscle contraction was not different significantly for the three computer interaction devices. It is because flexor pollicis brevis muscle and abductor pollicis brevis muscle located in the palm of the hand so the movement of the fingers to contract directly with the muscle.

Table 2. The Result of Mann-Whitney Test

Muscle	Computer Interaction Devices	Sig		
		Mouse	Keyboard	Joystick
Flexor Pollicis Brevis	Mouse		$P(0.141)>0.05$	$P(0.000)<0.05$
	Keyboard	$P(0.141)>0.05$		$P(0.001)<0.05$
	Joystick	$P(0.000)<0.05$	$P(0.001)<0.05$	
Abductor Pollicis Brevis	Mouse		$P(0.007)<0.05$	$P(0.002)<0.05$
	Keyboard	$P(0.007)<0.05$		$P(0.152)>0.05$
	Joystick	$P(0.002)<0.05$	$P(0.152)>0.05$	

While Table 2 shows the result of Mann-Whitney test. It describes difference among three different computer interaction devices for two kind of muscles; flexor pollicis brevis muscle and abductor pollicis brevis muscle.

There were significant difference in the muscle contraction of the flexor pollicis brevis muscle between

use of a keyboard and a joystick device and also use of a mouse and a joystick device at 5% significant level. But between use of a mouse and a keyboard device doesn't has a significant difference. This is because the focus of the movement is almost similar between use of a keyboard and a mouse in which the load of muscle movement spread to the third study muscles, so the flexor pollicis brevis muscle contraction on both devices has no significant difference.

Meanwhile, there was significant differences in the abductor pollicis brevis muscle between use of a mouse and a keyboard device and also use of a mouse and a joystick device at 5% significant level. But, between use of a keyboard and a joystick devices has no significant difference. Thus the use of a mouse is better in interacting with the computer.

4. Conclusion

Based on the analysis, it can be concluded as follows:

1) The lowest muscle contraction in flexor pollicis brevis muscle, flexor digitorium superficialis muscle and abductor pollicis brevis muscle occur in the mouse device and the highest muscle contraction tend to occur in the joystick device. It means that the highest risk of carpal tunnel syndrome occur in the joystick device, and the lowest risk occur in the mouse device.
2) There are significant differences in the muscle contraction of flexor pollicis brevis between the use of a keyboard and a joystick also between the use of a mouse and a joystick. And significant differences also occur in the abductor pollicis brevis between use of a mouse and a keyboard device and also use of a mouse and a joystick device. While in the muscle of flexor digitorium superficiallis has no significant difference.
3) The use of mouse is better in interacting with the computer.

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