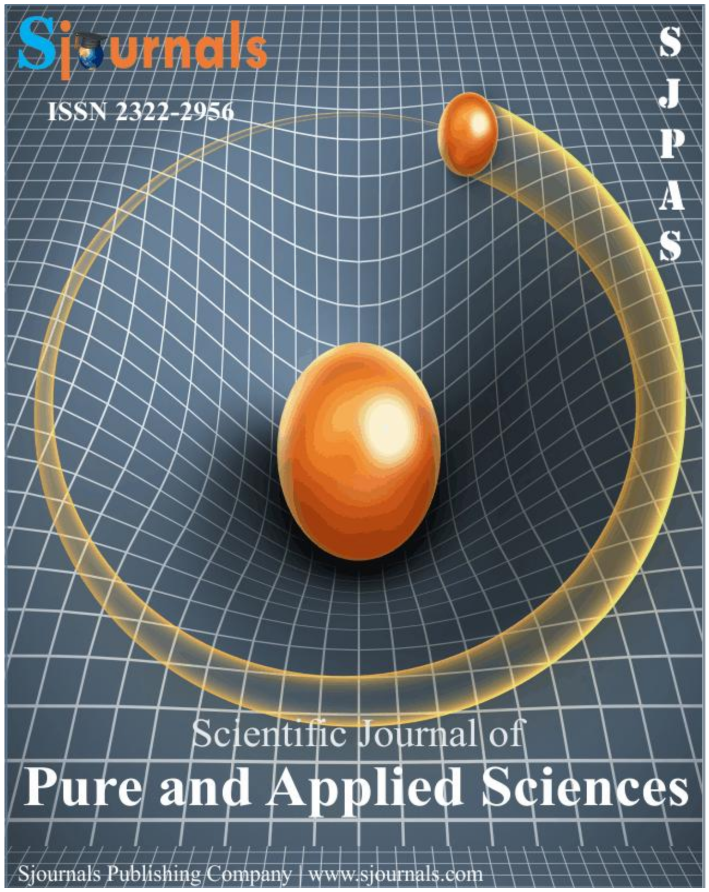
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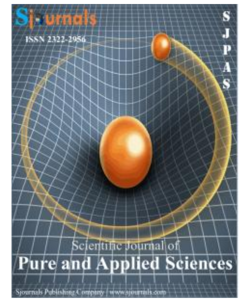

Original article

Comparison of physiological load among different sizes of computer mouse

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A B S T R A C T

The purpose of this study is to compare the difference in physiological load among three different sizes of computer mouse. The mouse is one of the most commonly used input devices for controlling computer system. However, due to the fact that there are many different sizes of mice available to consumers and the hand size of each consumer is quite different from each other, so this study is trying to determine the suitability of different mouse sizes with consideration of the parameter of hand size of each person. A series of operation experiments will be conducted to collect the data of EMG of hand muscles for evaluating physical load of computer mouse. Twelve adults were recruited according to the two genders and six size combinations of hand length and hand width distribution. The results showed that gender, computer operating activities and hand width may affect the EMG (% MVC) on four groups of muscle. It could apply to computer mouse design and other related hand tool design.

1. Introduction

In our daily life and work, the use of hand tools are very frequent for undertaking tasks, such as manipulating or operating various equipment and tools, such as computer mouse, smartphone, tablet computer, door knob, faucet, telephone, steering wheel, microphone, baseball bat, and power drill, etc. However, those hand size measurements measure the hand size with fingers in stretching position. Since they are not real hand-held size measurement, and cannot directly apply to the design of hand tools.

To the design of hand tools, the main consideration is that the design can help maximize hand tool performance with minimal loads on muscles, tendons, joints, and skin. In most parts of this design issues focus on optimizing hand tool contact points in order to maximize grip strength**,** minimize contact stress with an interest to sensitive areas of the palm and wrist, and provide appropriate tactile feedback (Rogers et al., 2008). The grip strength is much dependent on different hand postures, which also are the biomechanical advantage created by finger joint angles and the physiological advantage associated with the differences in muscle length (Buchholz and Armstrong, 1992). In addition, poor operating postures can lead to musculoskeletal system injuries and influence the grip strength as well. The holding posture and corresponding grip strength are affected by the handle shape and hand size, which also involves the contact surface area between handle and hand.

In recent years, the uses of personal computers are more diverse, especially in the application of the electronic input devices, such as a mouse, keyboard, trackball or touch screen and so on. However, the usage frequency of mouse and keyboard are much higher than others. The research results show computer users almost spend two-thirds of their computer work using the mouse (Fogleman and Brogums, 1995). Until now the mouse is still an essential computer pointing device since it can speed up the operating speed of the compute. However, the mouse design, specification and use patterns, etc., will affect its operation performance (Lin and Tsai, 2015). Holding the poor posture for operating mouse for long periods of time, such as overstretching and overflexing of wrist can lead to fatigue problems and musculoskeletal injuries (Armstrong et al., 1995; Onyebeke et al., 2014). Past studies have also pointed out that after the continuous operation of the mouse for several hours; it will cause the entire arm discomfort and also lead to wrist and shoulder subjected to musculoskeletal injuries.Harvey and Peper (1997) also pointed out the increases of the events of upper-limb musculoskeletal pain is positively related with the widespread of using computer mouse. Therefore, the appropriate mouse design is very important to the user, wherein the size of the mouse plays a significantly important role. This research tries to explore the appropriate mouse size when operating the computer.

2. Materials and methods

For the purpose of performing evaluation of the effects of different mouse sizes on physiological load, this research conducts EMG measurements and calculations for three kinds of mice and also makes a comparison**.**

2.1. Samples

Each individual has different hand-shape indices of their hands. There also exists a difference between female and male (Kanchan and Krishan, 2011). Moreover, according to the database by Hsu and Yu (2010), the hand length of males is between 15.9 and 21.3 cm, with an average of 19.1 (±1.3) cm.The hand width of males is between 7.6 and 9.9 cm, with an average of 8.6 (±0.6)cm; while the hand length of females is between 14.4 and 19.6 cm, with an average of 17.1 (±1.1) cm. The hand width of males is between 6.2 and 9.6 cm, with an average of 7.8 (±0.6) cm. Therefore, the research sample for hand length group is divided into three sampling intervals, which arelong, middle, and short. The sampling for hand width group is divided into two sampling intervals, which are wide and narrow. The sampling for sex group is divided into male and female. Hence, this study involves three kinds of hand length, two kinds of hand width, and two kinds of sex that would make a total of twelve kinds of combinations. Table 1 shows sampling intervals for hand length and width both for male and female.

Table1
Sampling intervals for hand length and width both for male and female.

Hand length groups	Hand length(cm)		Hand width groups	Hand width(cm)	
	male	female		male	female
Long (L)	19.8~	17.7~	Wide (W)	8.6~	7.8~
Mid (M)	18.5~19.8	16.6~17.7	Narrow (N)	~8.6	~7.8
Short (S)	~18.5	~16.6			

2.2. Experimental design

This study is to compare physiological load on hand among three different sizes of computer mice by operating two kinds of computer activities including editing text and playing games. The main research structure is shown in Figure 1.

Three computer mouse designs, Mouse 1 (Large: 12×7.5×4 cm in length, width and height), Mouse 2 (Middle: 10×6×4 cm), and Mouse 3 (Small: 9×4×3 cm), are used to perform experiments. All of experiment-related equipment such as, computer, screen, keyboard, desk, table, and other environmental conditions are kept constant. Participants could adjust the tabletop to their most preferred work height, and adjust the screen location to their most preferred viewing angle. The participants are also asked to sit in an adjustable chair and position themselves in a comfortable position to use the mouse. Keep participants' upper arm to hang naturally downward and the upper arm are perpendicular to forearm. Participants should place their elbows on the top of the table. Viewing distance between the participant's eyes and the screen is kept around 50 to 55cm.

In our research, reference is made to the investigation by the research (Chen et al., 2009; Lee and Lee, 2010). Our experiment was divided into two categories: word processing and computer games. Word processing includes editing text by selecting the exercise in MOS certification (Microsoft Office Specialist) in the Word 2010; and computer games adopt Windows 7 Minesweeper game (Figure 2). These two computer activities are mouse-based operations; the participants are required to repeatedly perform the move, click, drag and other activities. It is noted that before the normal experiment the participants must practice these two activities at home in order to get familiar with them. Furthermore, in order to conduct the experiment normally, participants are told that the scores of word processing and computer games are not directly related to the experimental results.

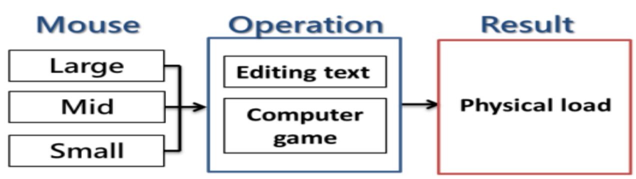

Fig. 1. Experiment structure.

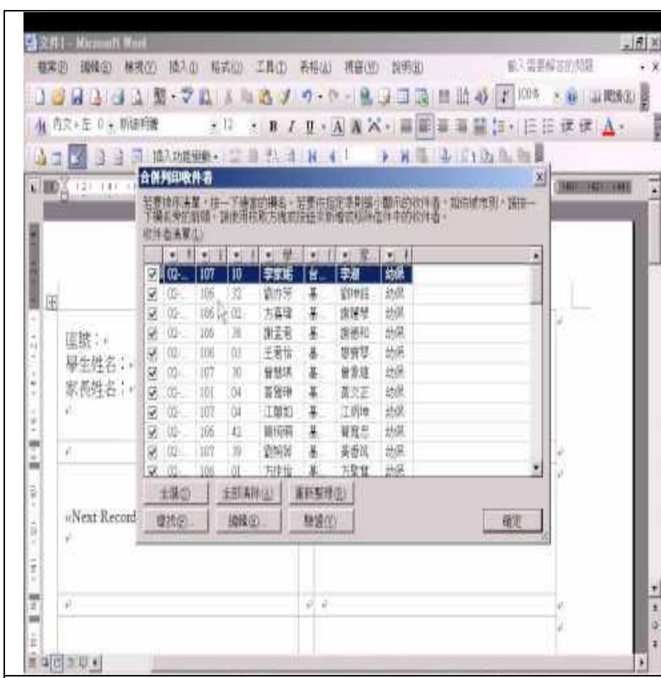	
Editing text	Computer game

Fig. 2. Two kinds of computer activities.

2.3. The measurement of hand EMG

Four muscle groups, including Extensor Carpi Radialis, Extensor carpi ulnaris, Brachioradialis and Flexor DigitorumSuperficialis are selected to be measured in this study. The positions where all four muscles located are in the shallow layer of the hand muscles, and relatively easy to measure, which is shown in Table 2.

This research adopts Noraxon (Arizona, US) MyoTrace 400 EMG system, which includes four channels with bandwidth 20-500Hz. During the experiment, surface electrodes are attached to the above four muscle groups of participants so as to observe the electric potential change while their muscle activity is measured and collected with the EMG machine. The collected EMG signal is then preprocessed by Myo Research XP Clinical Application Software for further editing and compiling. Using this analysis system, when participants conduct different computer activities and even using different mice, a comparison of EMG signal changes could be made for further investigating the trend of the electrical activity of the muscles**.**

Table 2
Function of hand muscles.

Muscle	Function
Extensor Carpi Radialis	Moving the hand towards the thumb
Extensor carpi ulnaris	Moving the hand towards the thumb
Brachioradialis	Flexing the forearm at the elbow
Flexor Digitorum Superficialis	Fully extending the fingers as well as flexing the metacarpophalangeal joints

After measuring EMG signal for each hand muscle activity during each mouse operation, the root mean square (RMS) value of each EMG signal was calculated. Then we convert it to become EMG (% MVC) for subsequent analysis. The conversion formula for EMG (% MVC) is as follows:

$$EMG(\%MVC) = \left[\frac{EMG - EMG_{rest}}{EMG_{\max} - EMG_{rest}}\right] \times 100\%$$

During which EMG_{rest} is the EMG level when hand muscle at rest, EMG_{max} is the maximum value EMG signal obtained from the muscle while the hand subjected to extending and flexing. Therefore, before our experiment we must first measure the EMG value both at Maximum Voluntary Contraction Maximum Voluntary Contraction (MVC) and rest condition for the muscle groups of Extensor Carpi Radialis, Extensor digitorum, Extensor Carpi ulnaris, and Flexor DigitorumSuperficialis. It is noted that the time for operating mouse for each task is ten minutes. Also noted that a proper time should be given to rest between each task in order to recover from fatigue.

2.4. Data analysis

The independent variables in this study are: sex, hand length, hand width, operating task, gender, and mouse type. The dependent variable is hand EMG (% MVC). Descriptive statistics analyses are first made, then the mean value and standard deviation of hand EMG, can be calculated for different mouse types, operating tasks, and genders. Besides the statistical data, they can be reported in the form of a plot, which shows and compares the difference and trend of EMG under various mouse types and operating tasks. Analysis of variance (ANOVA) was used to test the effects of gender, operating task, and mouse type, on hand EMG. If there was a significant influence, Duncan's multiple range test were conducted for post hoc comparisons for finding out the source of difference so as to fully understand how good mouse design will affect its physiological loads on participants muscle.

3. Results and discussion

3.1. Hand EMG (% MVC)

Figure3, 4, 5, and 6 show, respectively, the EMG (% MVC) on four muscle groups of Extensor Carpi Radialis, Extensor Carpi ulnaris, Brachioradialis, and Flexor DigitorumSuperficialis, with two different genders, two different computer operating activities, and three kinds of mouse type. From Figure 3, it is obviously that the factor of gender and computer operating activities significantly affect the EMG (% MVC) for the muscle of Extensor Carpi

Radialis. The effect due to male gender is greater than female, and the effect due to playing game is greater than editing text. The mouse types would not influence on the EMG (% MVC) for the muscle of Extensor Carpi Radialis. In Extensor Carpi ulnaris aspect, computer operations significantly affect the EMG (% MVC), the effect due to playing gam is also greater than editing text game.The mouse types and genders would not influence on the EMG (% MVC) as shown in Figure 4.

For the aspects of Brachioradialisand Flexor Digitorum Superficialis, the factor of gender significantly affects the EMG (% MVC) for both muscles. The effect due to male gender is greater than female, and both computer operating activities and mouse type have no effect on the EMG (% MVC) for both muscle (shown in Figure 5 and Figure 6).

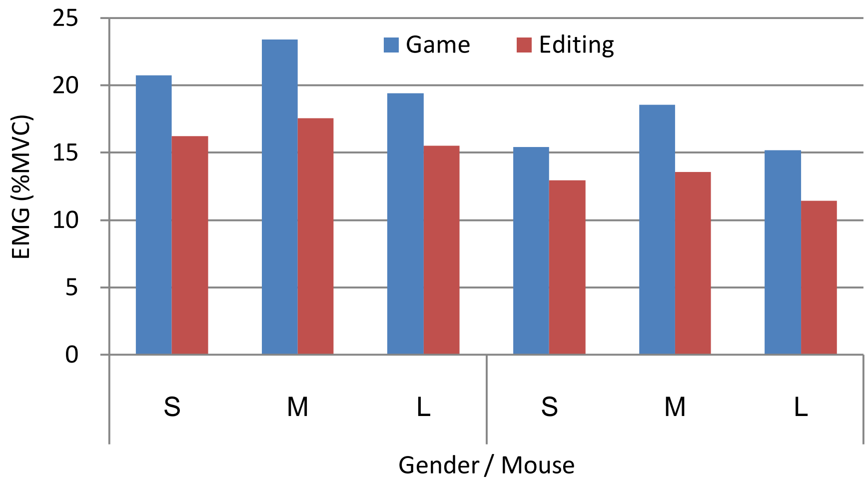

Fig. 3. EMG (% MVC) for the muscle of Extensor Carpi Radialis under different genders, mouse types, and computer operating activities.

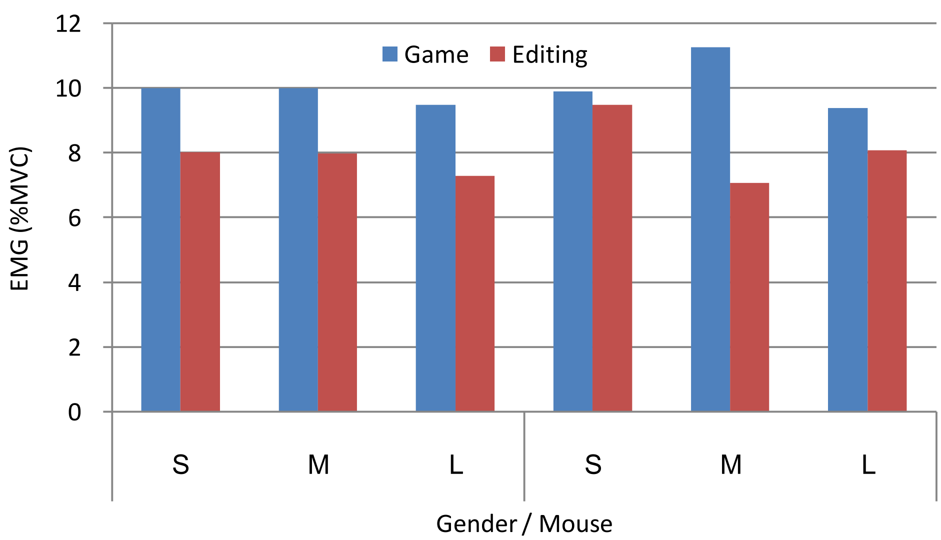

Fig. 4. EMG (% MVC) for the muscle of Extensor Carpi Ulnarisis under different genders, mouse types, and computer operating activities.

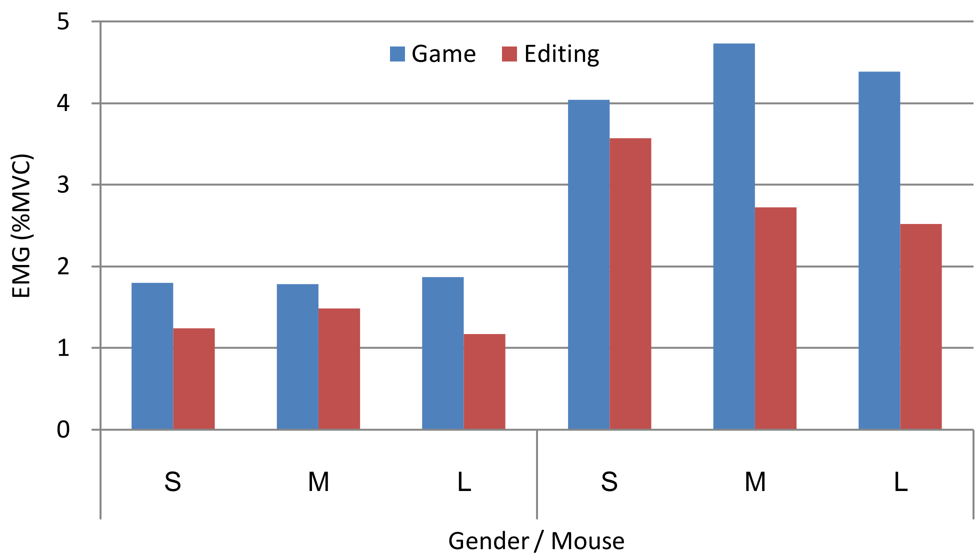

Fig. 5. EMG (% MVC) for the muscle of Brachioradialis under different genders, mouse types, and computer operating activities.

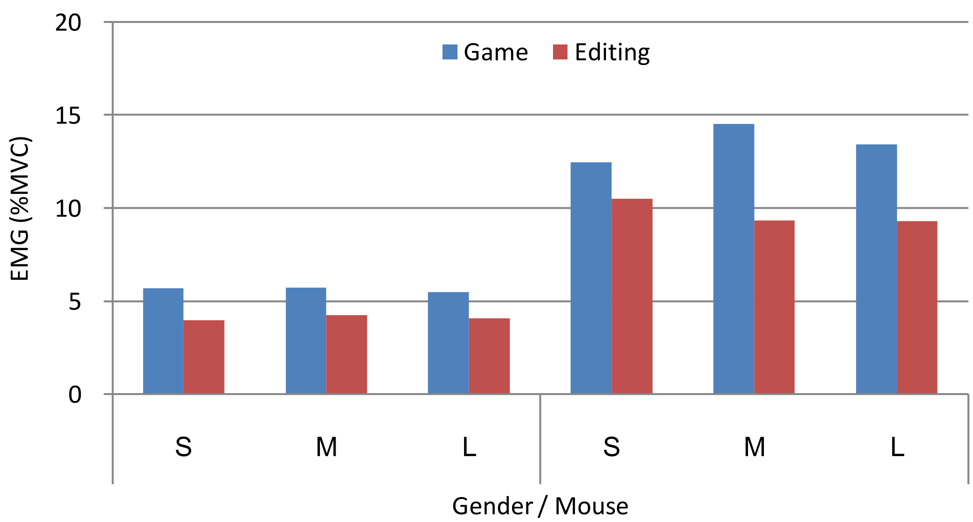

Fig. 6. EMG (% MVC) for the muscle of Flexor DigitorumSuperficialis under different genders, mouse types, and computer operating activities.

Analysis of variance was used to test the effects of gender, mouse type, and computer operating activity, on the EMG (% MVC) for four groups of muscle, which were shown on Table 3 for comparison. The analysis results are quite similar with the above discussions. It is noted that the hand length did not significantly affect the EMG (%MVC) of the four groups of muscle. Also participants' EMG (% MVC) on their muscles will obviously change with their hand width. The shorter the hand width, the more loads will apply on their muscles.

Table 3
Comparison of EMG (% MVC) measurements for four groups of muscle.

	Extensor Carpi Radialis		**Extensor Carpi ulnaris**		**Brachioradialis**		**Flexor DigitorumSuperficialis**	
	F-value	**P-value**	**F-value**	**P-value**	**F-value**	**P-value**	**F-value**	**P-value**
Gender	4.50	0.038	0.12	0.730	10.19	0.002	16.70	0.000
Duncan's Test	Male > Female		—		Male < Female		Male < Female	
Hand length	2.68	0.076	0.08	0.921	0.97	0.385	1.62	0.206
Hand width	6.56	0.013	4.82	0.031	8.80	0.004	24.43	0.000
Duncan's Test	N > W		N > W		N > W		N > W	
Mouse type	0.66	0.522	0.16	0.854	0.03	0.970	0.02	0.985
Computer activity	4.36	0.040	3.14	0.081	1.99	0.163	2.16	0.146
Duncan's Test	Playing game>editing text		—		—		—	

This study utilized the EMG measurement and subjective perception of comfort to investigate the influence of three different sizes of mouse and two different of computer operating activities. Through our experimental and statistical analysis, some conclusions would be drawn as below.

Gender, computer operating activities and hand width may affect the EMG (% MVC) on four groups of muscle. Participants receive more physiological load when playing games than operating editing texts. Also the participants with shorter hand width, their muscles will receive more physiological load. This results correspond to Cheng (2012) who mentioned that the correlation between mouse width and wrist's ulnar and radial deviation was negative. The wider mouse results in smaller wrist deviation, and the narrower mouse results in larger wrist deviation, which means the hand receives more loads.

Based on the above conclusions, mouse with less height is ideal for users with small hands, and mouse with greater height is ideal for users with big hands. The users should choose different sizes of mouse depending on their actual palm sizes. Playing games and editing text will easily cause muscle fatigue after a prolonged use of mouse. Consequently, the occurrence of pain and injuries are caused by the accumulation of muscle fatigue attributed to prolonged use of mouse. Also, it is noted that physiological load due by playing game is much higher than editing text. It is simply because playing game will take a long time operation of mouse and intensive use of hand muscles. It is suggested that all mouse users should have adequate rest periods after carrying out a computer activity for a long period of time.

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