

## Comparison of Muscle Activity and Input Performance of Operators Using a Computer Mouse and a Trackball

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### Abstract

This study compared the electromyographic activities and input performance of computer operators using a computer mouse and a trackball. Muscle activities were assessed at the upper trapezius (UT), middle deltoid (MD), extensor digitorum (ED), and first dorsal interosseous muscle (FDI). Twenty-six healthy subjects were recruited, and the test order was selected randomly for each subject. The task set was to click moving targets on a Windows program. The EMG amplitude was normalized using the percentage of reference voluntary contraction for UT and MD and the percentage of maximal voluntary contraction for ED and FDI. To analyze the differences in EMG activity, a paired t-test was used. UT muscle activities were significantly greater when the computer mouse was used ( $p < .05$ ). FDI muscle activities were significantly greater when the trackball was used ( $p < .05$ ). Using a trackball can reduce the load on the UT during computer work and help to prevent and manage work-related musculoskeletal disorders.

**Key Words:** Computer mouse; Trackball; Work-related musculoskeletal disorders.

### Introduction

Today, attention has focused on work-related musculoskeletal disorders (WMSDs), among various industrial accidents. Work-related musculoskeletal disorders are a group of painful disorders of muscles, tendons, and nerves. Carpal tunnel syndrome, tendonitis, thoracic outlet syndrome, and tension neck syndrome are examples. WMSDs arise from ordinary arm and hand movements such as bending, straightening, gripping, holding, twisting, clenching, and reaching. These common movements are not particularly harmful in the ordinary activities of daily life. What makes them hazardous in work situations is the continual repetition, often in a forceful manner, and most of all,

the speed of the movements and the lack of time for recovery between the movements. WMSDs are also associated with work patterns that include fixed or constrained body positions (Kee, 2003; Kim, 2004).

The Korean government has made efforts to reduce WMSDs in industry by revising the Industrial Safety and Health Act. Up to the present, the management of WMSDs had focused on heavy weight. However, nowadays, the focus has changed to repetition (Kim, 2004). Efforts to reduce WMSDs had focused on heavy industries such as motor plants or shipbuilding yards. The Korean government established a WMSDs task force in 2001, and established a reinforced task force in 2003. So the government had concentrated on preventing WMSDs in heavy industry area (Kee, 2003).

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The researches and efforts are concentrated on heavy industries, but insufficient on office workplace. Computers are ubiquitous in the office workplace as a basic system. Computer work in an office needs no strong muscle power but consists of many multi-repetitive movements (Magni et al, 1990; Park et al, 2006). Concentrated data-input tasks using a keyboard or computer mouse for more than 4 hours are specified as a musculoskeletal burden task in the Korean Industrial Safety and Health Act. Musculoskeletal symptoms are common among office workers.

Although it has been generally accepted that the risk of developing symptoms is due to static muscle work in office, very few studies and improvements have been tried (Juul-Kristensen and Jensen, 2005). Moreover, due to the long-term negligence of neck and upper limb musculoskeletal symptoms, office workers could contract severe WMSDs, so there is an urgent need for ergonomic research and development for office workplaces.

Two main computer operating systems are used in the office environment: the Microsoft Windows series and UNIX series. Microsoft Windows systems are not text-based, and are designed for graphic user interface (GUI). The UNIX series have X-Window systems. Therefore, the two main computer operating systems adopt GUI. There is repetitive mouse work under the GUI. Computer mouse operation started with GUI developed at the Palo Alto Research Center during the 1980s. There was no need to work with a mouse in text-based operating systems such as MS-DOS or old UNIX systems. But computerized work is mostly performed in GUI, and the frequency of using non-keyboard devices and mice is increasing more and more (Cook et al, 2000; Cooper and Straker, 1998).

Most of the previous studies about computer input devices were based on keyboard operation. There are many studies about the arrangement of keys and angles of slope, and many ergonomic designed keyboard products exist (Chen et al, 2009; Haynes, 2009;

Nag et al, 2009; Simoneau et al, 2003; Smutz et al, 1995). Despite the prevalence of mice, few studies could be found that addressed related musculoskeletal problems in the upper limb with the computer mouse (Park et al, 2006). And computer mice still haven't changed from the traditional design.

The common GUI input devices used in computer work today are the traditionally designed computer mouse, tablet, and joystick. In recent years, input devices such as the trackball, which are gripped with a less pronated wrist and reduce the muscle load on the upper limb, have been developed (Gustafsson and Hagberg, 2003). Compared to the traditionally designed computer mouse, the trackball doesn't need gross movement of the upper limb, so the trackball can reduce the muscle load on shoulder and wrist joints. The reduced muscle activities of the upper limb could reduce the WMSDs due to accumulated injuries. Usability and correctness are important factors to consider when selecting input device (Karlqvist et al, 1999). The purpose of this study is to compare the electromyographic activities and input performances of computer operators using the computer mouse and trackball.

## Methods

### Subjects

Thirteen healthy men and thirteen healthy women who lived in Seoul participated in this study. Written consent was obtained from each subject prior to data collection. Subjects were excluded if they had a pre-existing neck and upper limb disorder, a congenital deformity, and any neurological or systemic illness that may have impaired performance. The mean age of all subjects was  $26.7 \pm 3.7$  years; the mean age of the men was  $27.8 \pm 3.7$  years, and the mean age of the women was  $25.5 \pm 3.5$  years. All subjects were right-handed.

### Experimental Set-up

We used surface electromyography (EMG), QEMG-4<sup>1)</sup> to measure muscle activities and surface electrodes<sup>2)</sup> to collect EMG signals. A surface electrode is disposable, Ag/AgCl electrode covered with conducting gel and has an adhesive area. The EMG signals were collected via 2-poles electrode shield cables with a ground electrode, active electrode, and reference electrode. Surface EMG signals digitalized in the EMG system were converted with TeleScan 2.8 software on a personal computer. The sampling rate of surface EMG signals was 1024 Hz. The notch filter was used to eliminate noises made by electric signals. Surface EMG signals created when using the computer mouse and trackball were converted to the root mean square (RMS) and analyzed.

The computer mouse used for this study was general-size and -shaped computer mouse<sup>3)</sup>, and the trackball was a general-size trackball<sup>4)</sup> (Figure 1). A controllable chair, footrest, and angle-adjustable computer monitor were used for differences in anthropometric data among the subjects. Subjects watched the monitor 10~15° downward, with their upper arms dropped comfortably, elbows flexed at approximately 90°, and sat deeply in the chair for proper back support their right shoulders were slightly abducted (Figure 2).

### Procedures

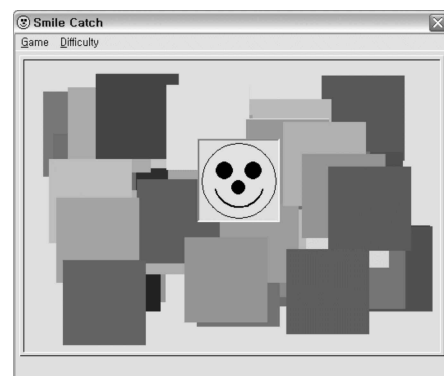
We referenced previous studies (Gustafsson and Hagberg, 2003; Karlqvist et al, 1999), and selected the right four upper limb muscles, upper trapezius, middle deltoid, extensor digitorum, and first dorsal interosseous to measure the muscle activities used during computer mouse and trackball operations. We attached electrodes to the skin on the muscles referenced by Cram et al (1988). Manual muscle testing (MMT) was performed to select the center of the muscle belly, and the positions were marked. Then we polished the skin



**Figure 1.** The computer mouse and the trackball.



**Figure 2.** Electrode positions and experimental position.



**Figure 3.** Smile Catch program.

1) QEMG-4, LXM3204, Laxtha, Daejeon, Korea.

2) Red Dot, 3M Korea. Seoul, Korea.

3) Wheel Mouse Optical 1.1A USB and PS/2 Compatible, Microsoft, Beijing, China.

4) Trackman Wheel, Logitech Electronics Company, Suzhou, China.

with sand paper several times to remove the horny layer and cleaned the area with disinfected alcohol on a cotton swab. The surface electrode, reference electrode and active electrode were placed in pairs within 3 cm center distance, upon the carefully prepared skin overlying the target muscles. The ground electrode was placed on the left wrist.

Each subject performed two tasks using the computer mouse and trackball, and four muscle activities were measured. The orders of task were assigned randomly. Subjects ran the "Smile Catch" program designed for this study on Windows for five minutes. The "Smile Catch" is a mouse click program (Figure 3). A user of the program clicked the moving targets that appeared at random locations every .75 seconds in the window, and the program counted the correctly clicking numbers for five minutes to measure the input device performance. Each subject took a rest for five minutes between the two tasks. Most of the subjects were not familiar with the trackball, so they were trained to use the trackball for ten minutes before the experiments.

To normalize the measured muscle activities, the reference voluntary contraction (RVC) was used for the upper trapezius and middle deltoid. To measure the RVC of the upper trapezius and middle deltoid, each subject held one kg dumbbell in his or her right hand, with the shoulder abducted to 90°, and the forearm pronated. Each subject maintained this position for five seconds and then repeated this movement three times. We used the mean values of each middle three seconds for 100%RVC. To normalize the measured muscle activities, the maximal voluntary isometric contraction (MVIC) was used for the extensor digitorum and first dorsal interosseous. The examiner pressed the subject's right hand on a table so the hand would not move, and the subject then raised his or her fingers, and then repeated this movement three times. We used the mean values of each middle three seconds for 100%MVIC (Karlqvist et al, 1999). Each subject used the "Smile Catch" program for five minutes. We measured the muscle activities

for a total of three minutes excluding the first minute due to unfamiliarity with the input devices and the last minute due to fatigue, converted using RMS, normalized by %RVC for the upper trapezius and middle deltoid, and normalized by %MVIC for the extensor digitorum and first dorsal interosseous.

### Statistical Analysis

Paired t-tests were used to test for significant differences between muscle activities and performance using the computer mouse and trackball. The level of significance was set at  $p=.05$ . The commercial program SPSS 12.0 for Windows was used for statistical analysis.

## Results

The average of the upper trapezius muscle activity %RVC using a computer mouse was 25.08%RVC the standard deviation was 9.71. The average of the upper trapezius muscle activity %RVC using a trackball was 21.44%RVC the standard deviation was 8.99. Comparison between the two input devices showed significant higher activity in the upper trapezius with computer mouse operation ( $p<.05$ ). The average of middle deltoid muscle activity %RVC using a computer mouse was 23.62%RVC the standard deviation was 11.27. The average of middle deltoid muscle activity %RVC using a trackball was 20.20%RVC the standard deviation was 7.17. Comparison between the two input devices showed no significant difference in muscle activity of the middle deltoid ( $p>.05$ ). The average of extensor digitorum muscle activity %MVIC using a computer mouse was 46.30%MVIC the standard deviation was 14.11. The average of extensor digitorum muscle activity %MVIC using a trackball was 41.91%MVIC the standard deviation was 18.52. Comparison between the two input devices showed no significant difference in muscle activity of the extensor digitorum ( $p>.05$ ). The average of first dorsal inteross-

eous muscle activity %MVIC using a computer mouse was 39.86%MVIC the standard deviation was 18.84. The average of dorsal interosseous muscle activity %MVIC using a trackball was 43.31%MVIC the standard deviation was 14.29. Comparison between the two input devices showed significant higher activity in the first dorsal interosseous with trackball operation ( $p<.05$ ) (Table 1).

A target that moves every .75 second and moves 400 times every five minutes. Using the computer mouse, the average of correctly clicking numbers was 372.80, and the standard deviation was 21.08. Using the trackball, the average of correctly clicking numbers was 213.15, and the standard deviation was 49.29 with trackball. Comparison between the two input devices showed a significant higher performance with computer mouse operation ( $p<.05$ ) (Table 2).

## Discussion

Over the past few decades, computer technologies have developed greatly, and now, the computer is necessary in the industry field. Especially, every task in the office is being done on the computer. Because of the high use of the computer, health problems are increasing rapidly. The increasing rate of office workers' computer work has lead to musculoskeletal problems related to use of the computer. But the WMSDs of office workers haven't been focused like labor workers'.

Computer-related musculoskeletal disorders contain long duration of task, lots of repetition, stiffened posture of the wrist, arm, and neck, fixed posture, and psychological and social factors (Haynes, 2009).

According to previous research, if office workers are interested and want improvement, their musculoskeletal disorders can be treated, and productivity can be improved (Magni et al, 1990). Improvements in environments where office workers use computers office workers included adjusting the height, position, and angle of the monitor, adjusting the height of the chair, armrest, and desk, and using a document holder. Previous researchers have found that these treatments showed high effectiveness (Fernström and Åborg, 1999; Hamrick, 2004). Also, altering an input device can decrease the muscle tension of the upper limbs, and lower the rate of musculoskeletal problems (Aaras et al, 2002). This research measured upper extremity muscle tones from different input devices using surface EMG. The muscle tone of the upper trapezius, middle deltoid, extensor digitorum, and first dorsal interosseous, which are known to frequently used when using a computer input device, have been checked.

According to the results of this research, the muscle tone of the upper trapezius is high when a computer mouse is used. On the other hand, the muscle tone of the first dorsal interosseous is high when a trackball is used. The extent of motion of the upper limb varies according to the input device used. When

**Table 1.** Comparisons of muscle activities between the two input devices

(N=26)

Muscles	Computer mouse	Trackball	p
Upper trapezius	25.08±9.71 <sup>a</sup>	21.44±8.99	<.001
Middle deltoid	23.62±11.27 <sup>a</sup>	21.20±7.17	.113
Extensor digitorum	46.30±14.11 <sup>b</sup>	41.91±18.52	.074
First dorsal interosseous	39.86±18.84 <sup>b</sup>	43.31±14.29	.045

<sup>a</sup>Mean±SD %RVC, <sup>b</sup>Mean±SD %MVIC.

**Table 2.** Comparisons of performance between the two input devices

Unit: times

	Computer mouse	Trackball	p
Performance (Mean±SD)	372.80±21.08	213.15±49.30	<.001

a computer mouse is used, large joints, including the glenohumeral joint, move in a wide range to shift the cursor on the mouse on the desk and move the mouse (Jensen et al, 1999). On the other hand, when a trackball is used, the large joints are not used, but the finger has to move to operate trackball, so the movement of the first dorsal interosseous is preferable. Consequently, if the input device is changed to a trackball for GUI, the muscle tone of the upper trapezius will decrease, and it will help prevent and treat WMSDs around neck and shoulder.

However, when a trackball is used, the muscle tone of the first dorsal interosseous increases; thus, trackball operation could cause WMSDs around the hand. So using a trackball has to be considered carefully for treating WMSDs around the hand. A previous researcher (Karlqvist et al, 1999; Smith et al, 1999) noted that the size and height of the trackball itself increases wrist angle and finger movement. So, when using a trackball, the wrist should be supported by using an external prop up such as a wrist pad.

In a performance study of computer mouse and trackball operations, the computer mouse was rated a lot higher than the trackball, because the mouse is a device frequently used by the subjects and was familiar to them. But the differences of familiarity of input devices can cause restrictions for performance study. Adjustment time was given before the test, but it was not enough to learn a new device and have familiarity with it. This learning effect can affect a performance study. A study allowed the subjects to become familiar with new input devices by using a long period of time before test, but the outcomes varied by subjects. A study of the performance differences between the computer mouse and other devices found no difference in performance (Karlqvist et al, 1999). But another study reported that the computer mouse was rated higher (Gustafsson and Hagberg, 2003). Consequently, performance studies of different input devices need further consideration about things that can affect the result.

Another limitation of this study is that the tasks

given to the subjects were too simple they only moved the mouse and promptly clicked, compared with the complex computer work task of an actual office. Another study used only simple text editing task prompts as well. Future studies should be concerned about the level of training on various input devices and performance tasks that are close to actual computer work when testing input devices' influence on muscle tone and performance when doing computer work.

## Conclusion

This study compared the electromyographic activities and input performance of computer operators using a computer mouse and a trackball. The muscle tone of the upper trapezius is high when a computer mouse is used. On the other hand, the muscle tone of the first dorsal interosseous is high when a trackball is used. Therefore, using a trackball can reduce the load on the UT during computer work and help to prevent and manage work-related musculoskeletal disorders.

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