Computer mouse use in two different hand positions: exposure, comfort, exertion and productivity

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Abstract

The aim of this study was to determine whether there are differences in exposure, comfort, exertion and productivity between a neutral and a pronated hand position when using a computer mouse.

Nineteen experienced VDU workers performed a standardised text editing task with each mouse hand position. The wrist positions and movements in the working arm were registered by an electrogoniometer and the muscle activity in the shoulder, two extensors in the forearm and the first dorsal interossei (FDI) was registered by electromyography. The subjects rated perceived exertion and comfort in work with each mouse hand position.

Work with the neutral hand position, compared to the pronated, gave a decreased muscle activity in the extensors of the forearm and in the FDI and a trend indicating a decrease in the frequency of deviation movements in the wrist. At the same time, the subjects showed a decreased productivity and they rated less comfort in work with the neutral hand position.

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1. Introduction

The most common nonkeyboard input device used during computer work today is the computer mouse. Musculoskeletal symptoms from the upper extremity are common among computer mouse users according to several studies. Sustained muscle loads in the forearm, as well as nonneutral postures, are associated with musculoskeletal disorders (Karlqvist et al., 1996; Jensen et al., 1998; Cooper and Straker, 1998). Experimental studies have shown differences in muscle activity and wrist movements during computer mouse use with different work techniques (Karlqvist et al., 1994; Wahlström et al., 2000). A study of 24 VDU-workers, where half were computer mouse users and half keyboards users only, showed that all of the computer mouse users worked with more extreme ulnar deviation of the wrist (Karlqvist et al., 1994). Keir et al. (1999) recommended a reduction of wrist extension during intensive mouse use after studying the carpal tunnel pressure during work with different computer mice in different mouse tasks. Pronation of the forearm is considered to be a potential risk factor for musculoskeletal disorders in the elbow and the forearm (Zipp et al., 1983).

Most of the computer mice used are traditionally designed, i.e. they are held with a more or less pronated forearm and are moved mainly with wrist movements. In recent years computer mice, which are gripped with a less pronated wrist, have been developed. Aarás and Ro (1997) have studied work with a vertical mouse (with the appearance of a joystick on wheel) compared to a traditional mouse. The vertical mouse, which was moved mainly by whole arm movements, gave the operator an almost neutral hand position and the thumb was used as the main button controller. The study showed that the muscle load on the forearm was significantly less when working with the vertical mouse compared to a traditional mouse.

The aim of this study was to determine whether there are differences in exposure, comfort, exertion and productivity between a neutral hand position (0° pronation/0° supination) and a pronated hand position when using a computer mouse.

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2. Subjects and methods

2.1. Experimental design

In a comparative, experimental study with repeated measure, two different types of mice were used: a traditionally designed mouse, Microsoft 2.1 A., which is designed to be held with a pronated hand position, and a newly designed prototype of a mouse, from now on called the neutral mouse, which is held with a neutral hand position and the ulnar side of the hand and wrist is resting on the mouse. The main button of the neutral mouse is placed under the pad of the index (or middle) finger when gripping the mouse and you use the button by pushing it horizontally towards the mouse (Fig. 1).

At their own VDU workstation, the subjects performed a standardised text editing task for 15 min with each hand position. The subjects were instructed to select highlighted characters (random location) with the mouse and then delete the characters by hitting the delete key on the keyboard with the mouse-using hand. They were instructed to work at the speed they normally used. They were also informed that the number of pages edited and the number of errors during this period were registered.

Wrist positions and movements in the right wrist were registered by an electrogoniometer and the muscular load in four muscles in the right forearm, hand and shoulder were registered by electromyography (EMG) during each standardised task.

The perceived exertion was rated directly before and after each standardised task and perceived comfort during work was rated after work with each hand position. When the standardised task was completed for the two hand positions, the subjects also gave their opinion of which mouse they preferred to use.

The order between the two mice was balanced with respect to sex and time of day (morning and afternoon).

2.2. Subjects

Nineteen employees, nine males and ten females, participated voluntarily in the study. The subjects were experienced VDU workers and used a computer mouse as input device in their ordinary work. All the subjects normally used their right hand to move the computer mouse. Their age varied between 24 and 64 years (Md 47 years). The subjects trained with the neutral mouse for half a working day before the study began. Before the training they were informed that the neutral mouse was designed to be moved with mainly whole arm movements.

Those subjects who were not used to working with the chosen model of traditional mouse were also allowed to practice half a working day with this mouse. The measurements then took place within a week from the day of practice.

2.3. Measuring methods

2.3.1. Registration of wrist positions and movements

A biaxial electrogoniometer and a data logger (Model X65 and DL1001, Biometrics; Gwent, UK) were used to register flexion/extension and radial/ulnar deviation of the right wrist. The goniometer was applied to the dorsal side of the wrist on the right hand according to the manual of the goniometer used.

The reference (zero) position of the wrist was recorded when the forearm fully pronated was held in a deviation and flexion/extension neutral position with the palm down on the desk (Greene and Heckman, 1994). The sampling rate was 20 Hz and the measuring data were transmitted after the measurement from the data logger to a PC, where they were analysed using a program written in Labview 4.0. The program calculated the 10th, 50th and 90th percentile of the wrist angle distribution, the mean velocity and the mean power frequency (MPF) for both flexion/extension and radial/ulnar deviation. A power spectrum was calculated using the Auto Power Spectrum virtual instrument (VI) in Labview. MPF was calculated on the portion of the power spectrum between 0 and 5 Hz as recommended by Hansson et al. (1996) with a low frequency cut-off of 0.033 Hz to eliminate the DC component of the spectrum (MPF calculated between 0.033 and 5 Hz). MPF is defined as the centre of gravity for the power spectrum and has been used as a measure of repetitiveness (Hansson et al., 1996).

2.3.2. Registration of muscular load

The muscle activity was registered in four muscles: the right extensor digitorum (ED), the right extensor carpi ulnaris (ECU), the right first dorsal interossei (FDI) and the pars descendent of the right trapezius muscle by
EMG (Muscle Tester ME3000P, Mega Electronics Ltd, Kuopio, Finland).

The electrodes for the ED, the ECU and the FDI were placed as recommended by Perotto (1994) measured from the lateral epicondyle, on 1/3 of the distance between the epicondyle and the styloid process of radius (ED) and styloid process of ulna (ECU), respectively. For the FDI the electrodes were placed over the muscle belly in the web between the thumb and the index finger. The electrodes for the trapezius were placed as recommended by Mathiassen et al. (1995) 20 mm lateral to the midpoint of the line between the seventh cervical vertebra and acromion.

Self-adhesive surface electrodes (M-00-N; Medicotest AS, Copenhagen, Denmark) were used and were placed in pairs with 20 mm centre distance on dry skin after the area had been dry shaved, cleaned with alcohol, abraded with sandpaper and cleaned with gauze saturated with water.

The raw data were recorded on-line using a portable PC and monitored in real time for quality control. The sampling rate was 1000 Hz. Full wave rectifying and filtering of the EMG signal derived the muscular activity, using a time constant of 100 ms. Standardised reference voluntary contractions (RVCs) were made by the subjects to obtain reference voluntary electrical activity (RVE) for the four muscles. For the ED, the ECU and the FDI, maximal voluntary electrical activity (MVE) was set with maximum static contraction against manual resistance for 5 s with supported forearm and hand with the palm against the desk. For the ED resistance were given on the back of the hand and the proximal parts of the fingers, for the ECU on the ulnar side of the hand and fingers and for the FDI the thumb were pressed against the lateral side of the proximal interphalangeal joint of the index finger. For the trapezius, RVE was set with both arms straight out with neutral shoulders in 90° abduction and palms turned downwards with a 1 kg dumbbell in each hand for 15 s.

The EMG-data were analysed in the ME3000P software version 1.5 and the 10th (static level), 50th (median level) and 90th (peak level) percentile of the muscle activity were calculated for each subject. The analysing program gave automatically the results in integers.

2.3.3. Perceived exertion and comfort

Immediately before and after work with both hand positions, perceived exertion in the neck, shoulders, arms, wrists and hands was rated using Borg’s CR-10 scale (Borg, 1990). The difference between the rated perceived exertion before and after work with each hand position was calculated for every rated body area. After work with each mouse, the subjects also rated the perceived whole body comfort using a bipolar scale, ranging from -4, very poor comfort, to +4, excellent comfort (Karlqvist et al., 1995).

2.3.4. Productivity

The number of pages edited within the specified time and the number of errors were calculated for each hand position.

2.4. Statistics

The results of the group are presented as medians for each of the two hand positions as well as medians for the differences of all the subjects with 95% confidence intervals (CI) for median values (Altman, 1991). As the data were not normally distributed, the differences in the results between the use of the two hand positions were compared by using the Wilcoxon signed rank test for repeated measurement. The differences between the sexes, order of the two hand positions and time of day were compared with the Wilcoxon rank sum test for group comparison. The tests of significance were two-tailed with a significance level of 0.05 (Altman, 1991).

The p-values were read from table B9 Wilcoxon one sample (or matched pairs) test and table B10 The Mann-Whitney test (Wilcoxon two sample test) in Altman (1991).

Median values and other data calculations were made in the statistical program Jmp (version 3.2.6, SAS Institute Inc., NC, USA).

3. Results

3.1. Wrist movements

The results are based on 15 subjects since five measurements were excluded because of technical problems.

A great variation in the registered wrist angles between the subjects was found. The median value, however, showed less ulnar deviation and also an effect indicating a decrease in extension in work with the neutral mouse hand position compared to the pronated one. A trend indicating a decrease in the frequency of the deviation movements was also found (Table 1).

3.2. Muscular activity

All subjects showed a decreased or unchanged muscular activity in the forearm (EDC, ECU) during work with the neutral hand position compared with the pronated one.

The muscular activity in the FDI showed similar results except for one subject, who showed increased muscular activity.

The muscular activity in the right trapezius decreased for some of the subjects and increased for others. However, the median difference was 0% RVE in the 10th, 50th and 90th percentile (Table 2).
3.3. Perceived exertion and comfort

The perceived exertion was rated higher in right shoulder (CI −0.5; 2, \( p < 0.1 \)) and wrist (CI −1; 2, \( p < 0.05 \)) in work with the pronated hand position compared to the neutral. In the other rated body areas no statistically significant differences in perceived exertion between the two hand positions (\( p > 0.2 \)) were found. The median for the difference in rated perceived exertion between the two hand positions were zero for all de rated body areas.

The neutral hand position was considered to give better whole body comfort than the pronated by three subjects, while one subject rated the two as equal and 15 subjects rated work with the neutral hand position less comfortable (Md −1 scale step, CI −2; −1, \( p < 0.05 \)).
3.4. Productivity

Twenty-four per cent decreased productivity were shown in work with the neutral hand position. All subjects edited fewer pages (Md = 2.5 pages, CI = 3.25; –1.5, p < 0.05) when working with the neutral hand position compared with the pronated. Only minor differences in number of errors between the two hand positions were found, with a median of one more error in work with the neutral hand position compared with the pronated (CI 0; 1).

3.5. Preference

All subjects preferred to work with the traditional mouse, which was held with the pronated hand position, compared with the neutral mouse used in the study, which was held with the neutral hand position. Half of the subjects considered the neutral mouse to have less precision and to be more difficult to move than the traditional mouse used.

No statistically significant differences between males and females, order of the two hand positions or time of the day were found between the two hand positions in any of the measurements.

4. Discussion

4.1. Wrist positions and movements

Forearm pronation/supination has been shown to affect wrist goniometer measurement accuracy (Buchholtz and Wellman, 1997; Hansson et al., 1996; Johnson et al., 2002; Jonsson and Johnson, 2001) and Johnson et al. (2002) have evaluated and compared the crosstalk and off-set error when using two different electrogoniometer system including the system used in the present study. The goniometers were calibrated with the subject’s wrist in 90° pronation as in the present study. Their study showed that the measured values differ from the true values. The true value can be calculated by adding the error shown in their study to the measured value. According to this, if we perform the calculation of the effect for one typical subject, represented by the group median values, for a representative wrist position (the 50th percentile of flexion/extension and deviation) the effect of the forearm supination/pronation in the present study would be in pronated hand position (90° pronation) +1° in flexion/extension and +4° in deviation. (Hence, the true value for the 50th percentile should be 24° extension and 9° deviation.) (see Table 1) In neutral hand position (0° supination/0° pronation) the effect would be –9° inflexion/extension and +5° in deviation. (Hence, the true value for the 50th percentile should be 9° extension and 1° deviation.) (see Table 1) If we consider this effect of forearm supination/pronation the difference in wrist extension will be larger and the wrist position in the deviation plane will be more neutral compared to the measured values presented in the present study in work with the neutral hand position compared to the pronated hand position.

The decrease in ulnar deviation in work with the neutral mouse hand position observed in this study could be expected since the ulnar side of the hand and wrist are resting on the mouse during the mouse operations.

The trend indicating a decrease in wrist extension and frequency of deviation movements in work with the neutral hand position can also be explained by the design of the neutral mouse, which mostly made the subjects use arm movements instead of wrist movements.

4.2. Muscular activity

Since the used analysing program automatically gave results only in integers there is an uncertainty in the size of the calculated differences of ±1% MVE/RVE. This might effect the results, especially where the differences are small, since only 19 subjects were studied.

The muscular activity in the extensor muscles of the forearm decreased during work with the neutral hand position, compared with the pronated one. This result is in agreement with a study by Aarás and Ro (1997) and can probably be explained by the fact that the neutral hand position is a more relaxing position for the muscles with the wrist in a rest position similar to the position when standing with the arm hanging relaxed beside the body. In work with the neutral hand position the hand and wrist was also resting on the neutral mouse. Another explanation could be that the neutral mouse like Aarás’ vertical mouse was mainly moved by whole arm movements. The decrease in the FDI during work with the neutral hand position cannot entirely be explained by the hand position but is probably also due to the fact that less force was needed to click the button of the neutral mouse compared to the traditional.

4.3. Perceived exertion and comfort

There was a great variation in perceived exertion among the subjects during work with the two hand positions. This can probably be explained by differences in work technique between the subjects and the fact that some of them had difficulties moving the neutral mouse smoothly on the desk surface.

The differences in perceived exertion between the two hand positions for each subject were small, except for the right shoulder and hand. This and the perceived lower comfort can probably also be explained by the
fact that some of the subjects had difficulties moving the neutral mouse smoothly. In work with the neutral hand position, most of the subjects used a technique where they moved the input device with arm movements, in contrast to the pronated hand position, where they moved the input device with hand or finger movements. Arm movements involve larger muscles made for rough motorial movements. Hand and finger movements involve smaller muscles, which are made for fine motorial movements.

4.4. Productivity and preference

The lower productivity expressed by the number of pages edited during work with the neutral hand position is supported by a recently presented study by Straker et al. (2000). It showed a decrease of performance by 11% even after 2 weeks of practice with a mouse that was held with a neutral hand position. In the present study, almost all the subjects considered work with the neutral hand position more restful and convenient for the hand and the wrist but all the subjects still preferred to work with the traditional mouse. This can probably at least partly be explained by their familiarity with this mouse design.

4.5. Possible effects on musculoskeletal disorders

High muscular load in the forearm muscles, like high repetitiveness in wrist movements and extreme postures in the wrist, is associated with musculoskeletal disorders (Marras and Schoenmarklin, 1993; Ranney et al., 1995; Bernard, 1997; Viikari-Juntura and Silverstein, 1999). According to this it is likely that a neutral hand position in work with a computer mouse can decrease the risk of musculoskeletal disorders in intensive computer mouse use. This is also in agreement with the study of Aarás et al. (1999), which showed that work with a vertical mouse used with a neutral position of the forearm, wrist and hand significantly reduced the pain in the neck, shoulder, forearm and hand for VDU workers who experienced pain in these areas.

4.6. Limitations of the study

Since the standardised task only consisted of text editing, the results of this study can only be assumed to be valid for this kind of computer work.

It is possible that the time of practice with the prototype mouse was too short for some of the subjects. A longer time of practice would perhaps have given other results, above all regarding productivity, perceived comfort and preference. The study by Straker et al. (2000) referred to above showed, however, the same results even after two weeks of practice.

It is possible that 15 min of work with each mouse was too short. A longer time of measurement would perhaps have given other results, especially regarding perceived exertion.

5. Conclusions

This study shows that the hand position in work with a computer mouse is of importance for the muscle activity in the forearm and for the wrist positions and movements. However, the study also shows that work with the neutral mouse hand position in this experimental setting resulted in lower productivity and less perceived comfort.

According to the positive findings of Aarás et al. (1999, 2001) with reduced pain among VDU workers when using a more neutral forearm and hand position in work with the computer mouse it would be of interest to study the health effect of using a neutral hand position when working with the computer mouse in healthy populations.

References