Comparative Study of Two Computer Mouse Designs

Report by

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ABSTRACT

The effects of two computer mouse designs on wrist posture were tested. Twenty four seated subjects, men and women grouped at the 95th, 50th, and 5th percentiles, performed right handed mousing tasks involving cursor positioning, target acquisition and scrolling. Each subject wore an instrumented glove on their right hand to measure wrist flexion/ extension and radial/ulnar deviation. All conditions and tasks were counterbalanced. Results showed a difference in wrist extension and task performance between mouse designs, but no effects of mouse design on ulnar deviation. Significant interactions involving gender and stature were also found.

1.0 INTRODUCTION

Modern personal computer operating systems, such as Windows, Mac OS or Unix, present the user with a graphical user interface (GUI) that requires the use of an input device, along with a keyboard, to successful navigate and operate the system. A variety of manual input devices are available, such as the computer mouse, touchpad, trackpoint, trackball, and joystick. Modern personal computers typically offer a computer mouse in conjunction with a keyboard as the preferred input device configuration. Typical software programs for word processing, spreadsheet, database and graphics operations may require computer mouse use for up to two-thirds of the time (Johnson *et al.*, 1993).

Use of a computer mouse is not necessarily benign. Evidence is accumulating that suggests that computer mouse use is associated with a number of upper extremity musculoskeletal disorders. Analysis of worker’s compensation claim data from 1986 to 1993 revealed a dramatic increase in computer-related cumulative trauma disorders of the upper-extremity (CTDUE) associated with mouse use, from 0 in 1988 to over 325,000 by 1993 (Fogleman and Brogmus, 1995). Of all CTDUE claims analyzed, 51% involved wrist injury, and 46% of all mouse-related CTDUEs involved wrist injury. Sixty four percent of computer mouse injuries were strains and 13% were carpal tunnel syndrome (CTS). Computer mouse claims were more likely to involve the hand, lower arm, and upper arm (including the clavicle and scapula) than computer-related claims overall. In 1993 computer mouse-related claims were 6.1% of all computer-related claims, and computer-related claims represented 17.3% of all CTDUE claims.

Since 1993, software developments (Windows 95/98/NT) and growth of the Internet (including electronic mail) have increased the need for use of a pointing device, such as a mouse. Current navigation of World Wide Web pages is almost solely dependent upon a computer-pointing device.

Several studies have examined associations between computer mouse use and musculoskeletal discomfort. A Canadian study of word processor operators, draftspeople and CADD users (computer-aided design and drafting) showed an association between musculoskeletal discomfort and shoulder abduction, that occurred during operation of a graphics mouse and tablet (Atwood, 1989). Karqvist *et al.* (1994) compared upper body postures between using only a keyboard and using both a mouse and keyboard to edit text. Wrist ulnar deviation was significantly greater during mouse use (17.6°) compared with non-mouse use (1.8°). During mouse use subjects spent 34% of the time working in ulnar deviation between 15°-30° and 30% of the time working in ulnar deviation greater than 30°compared with only 2% and 0% respectively during non-mouse use.

Several other research studies have shown that extremes of flexion/extension and radial/ulnar deviated wrist postures beyond 20° raise intracarpal pressure which increases the risk of wrist and hand injuries (Keir *et al.*, 1998; Rempel *et al.*, 1994, Rempel and Gordon, 1998).

The location of the mouse during use in relation to the body's midline affects EMG muscle activity for the anterior and middle deltoid muscles (Cook and Kothiyal, 1998). EMG activity was higher with the mousing area farther from the midline (>26 cm) than closer (>16 cm). RULA scores for wrist postures were poor for all experimental mouse positions. Subjects reported that discomfort in their mousing hand was associated with poor wrist posture. The vertical location of the mousing surface and the provision of a wrist support also affects wrist posture. The least wrist extension occurs when the mousing surface is between 120%-140% of seated elbow height and when there is a wrist support present (Damann and Kroemer, 1995).

The present study investigates the effects of two different computer mouse designs on wrist posture, task performance, and subjective ratings of comfort and usability.

2.0 METHODS

2.1 Subjects

Twenty-four Cornell University students and staff (12 males and 12 females) volunteered to participate in the study. Three groups of four men and four women were selected by their stature to represent the 5th percentile (female 152.1 ± 0.3 cm; male 164.1 ± 0.4 cm), 50th percentile (female 162.4 ± 0.10 cm; male 174.8 ± 0.7 cm), and 95th percentile (female 171.9 ± 0.2 cm; male 185.7 ± 0.6 cm) ranges. The mean age of participants was 22.3 ± 0.8 years, and the age range was from 18 to 46 years. All subjects reported using their right-hand to operate a computer mouse.

2.2 Apparatus

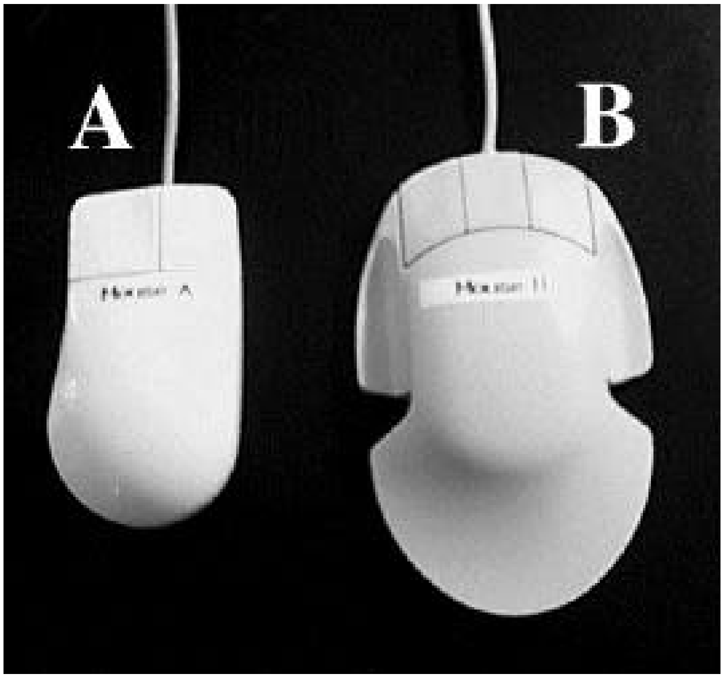
The study was conducted in the Human Factors Laboratory at Cornell University (Ithaca, NY). Two computer mouse designs, Mouse A (Microsoft Corporation mouse) and Mouse B (Humanscale, Whale mouse), were compared (Figure 1). Both mouses were designed to facilitate a neutral wrist posture. Mouse A had a curved design intended to reduce ulnar deviation. Mouse B was larger and flatter, and was also designed to discourage small, skating hand movements that repeatedly move the wrist into extremes of ulnar deviation. Mouse B also had a moveable sleeve that adjusted to different hand sizes and served as a built in wrist support. Mouse brand identity was concealed from subjects. The performance of both mouses was controlled by the same software (Allmouse Win'95 Controller, Whale Mouse Driver 5.0). Pointer speed (set at slowest) and trail length (set at shortest) were identical for both mouses and all trials. Mousing activities were performed on an articulating, level keyboard tray (25.5 cm width by 69 cm length) (Stella, Steelcase Corporation) mounted beneath a stationary desk (73 cm desktop height: Herman Miller). Subjects viewed a color computer monitor (38.1 cm diagonal: Gateway Corporation) that was placed 45 cm from the edge of the keyboard tray that was closest to the subject. The middle of the screen was 31.5 cm above the level desktop.

Wrist posture was measured dynamically at 10 Hz for two planes: flexion (-°) /extension (+°); radial (-°) /ulnar (+°) deviation, using an electrogoniometer instrumented glove (Wristmaster, Green Leaf Medical Systems). Three glove sizes were used and matched to the subject's hand size. A computerized survey was used to evaluate mouse comfort and usability.

FIGURE 1

The two mouses tested in the study.

(The proximal part of Mouse B is a movable sleeve that allows for a variety of hand sizes, here it is shown in the retracted position.)



2.3 Procedure

Prior to the testing, each subject's standing stature and handbreadth (distance between the distal ends of the metacarpal bones) were measured. Each subject used both mouses in a counterbalanced repeated measures design. Subjects were tested while seated. Each subject adjusted his or her chair and articulating keyboard tray to their preferred comfort level. They donned the instrumented glove and this was calibrated to manufacturer's specifications. Subjects were allowed to adjust Mouse B to best fit their hand size. At the start of each mouse trial, each mouse was centered on the built-in mouse pad on the right side of the articulating keyboard tray, approximately 22 cm from the body's midline. Use of the chairs' armrests while mousing was at the discretion of subjects, but subjects were consistent in their arm rest use for both mouse conditions.

Subjects were provided written and oral instruction describing the mouse tasks and instructed to complete each task as quickly and as accurately as possible without any given time limit. Subjects were tested individually. Each subject performed the mousing task using each of two mouse designs consecutively in counterbalanced order. The mousing task was a simulation of a realistic office work task and it consisted of a web page with 59 radio buttons at various horizontal locations on the screen. To complete the task, subjects were required to point, acquire a target by selecting a radio buttons, and scroll vertically, all of these being commonplace mousing activities. A software driven survey was completed immediately after each mouse condition.

2.4 Data Analysis

Wrist posture data were collected throughout the mouse tasks. Two mouse performance measures were collected: task completion time and percent errors (incorrect radio button selections and misses were counted as errors.). The following analyses were performed. The survey collected subjective assessments of mouse design comfort and comparative ease of use, on five-point rating scales. Data were exported to Microsoft Excel (version '97) and statistical analysis was performed using SPSS (version 7.53). Means for both radial/ulnar and flexion/extension wrist angles were calculated for every participant and condition. The SPSS General Linear Model Repeated Measures (GLMRM) full factorial model was used to test for significant main and interaction effects of gender, stature, and mouse on mean wrist angles at $\alpha = .05$.

3.0 RESULTS

The number of wrist posture observations for each mouse task file used in the analysis ranged from 997 (1.67 minutes) to 1,710 (2.85 minutes), with a mean of 1,356 ±

27 observations. There was a significant gender difference in hand width ($F_{1,18}$=37.8, p = 0.000: women = 75.1 mm; men = 83.9 mm) but no significant effect of stature and no interaction of gender and stature. For hand length, there were significant main effects of gender ($F_{1,18}$=19.02, p = 0.000: women = 177.5 mm; men = 188.8 mm), and of stature ($F_{2,18}$=29.19, p = 0.000: 5th percentile = 172.5 mm; 50th percentile = 180.6 mm; 95th percentile = 196.3 mm), but no significant interactions. There was a significant correlation between hand width and hand length (r = 0.61, n = 24, p = 0.002).

3.1 Wrist Extension

There was a significant main effect of mouse design on mean flexion/extension wrist angles ($F_{1,18}$=27.7, p = 0.000). Figure 2 shows that the mean flexion/extension wrist angles for Mouse A (26.5°± 2.1°) were significantly higher than those for Mouse B (18.3°± 2.4°). Figure 3 illustrates the difference in wrist posture between the two mouse designs.

FIGURE 2

Effects of Mouse Design on Wrist Extension

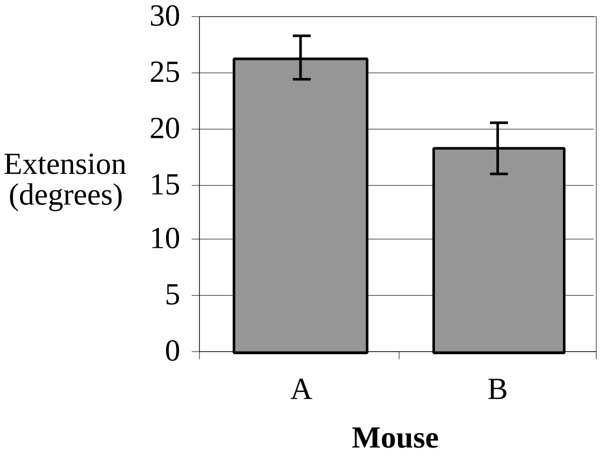
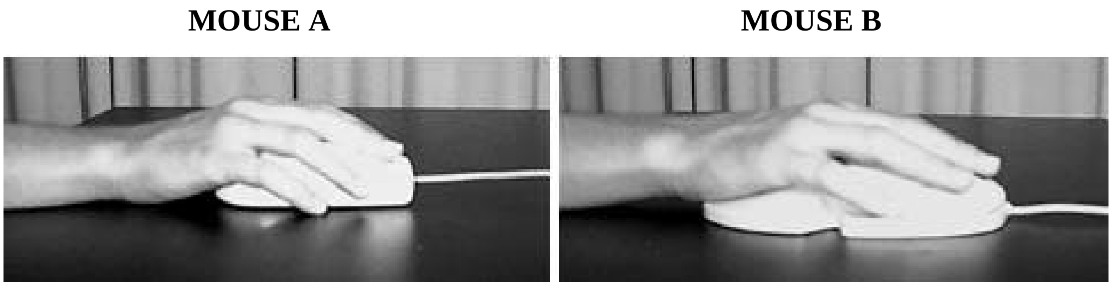


FIGURE 3

Side views of Mouse A and Mouse B placed upon a desk to illustrate the presence of the integral wrist support for Mouse B and to show the differences in wrist extension.



MOUSE A **MOUSE B**

There was a significant main effect of gender on mean flexion/extension wrist angles ($F_{1,18}$=7.40, p = 0.014). Mean wrist extension for men (27.7°±1.8°) was significantly higher than for women (17.1°±2.4°). There was no significant effect of stature on wrist extension (see Figure 4) and no interactions were significant.

There were significant correlations between hand width and wrist extension for both Mouse A (r = 0.60, n = 24, p = 0.002) and Mouse B (r = 0.52, n = 24, p = 0.010). There was a significant correlation between hand length and mean wrist extension only for Mouse A (r = 0.45, n = 24, p = 0.029).

3.2 Ulnar Deviation

There was no significant main effect of mouse design on mean ulnar deviation. Mean ulnar deviation for Mouse A was 13.4°±2.2°, and for Mouse B it was 13.1°± 2.4°. There was no significant gender difference for mean ulnar deviation (men = 14.9°± 2.1°; women = 11.7°± 2.5°). There was no significant effect of stature on wrist extension and no interactions were significant. Figure 5 shows mean ulnar deviation for each gender, stature, and mouse combination. There were no significant correlations between ulnar deviation and either hand width or hand length.

FIGURE 4

Mean Wrist Extension by Gender, Stature and Mouse.

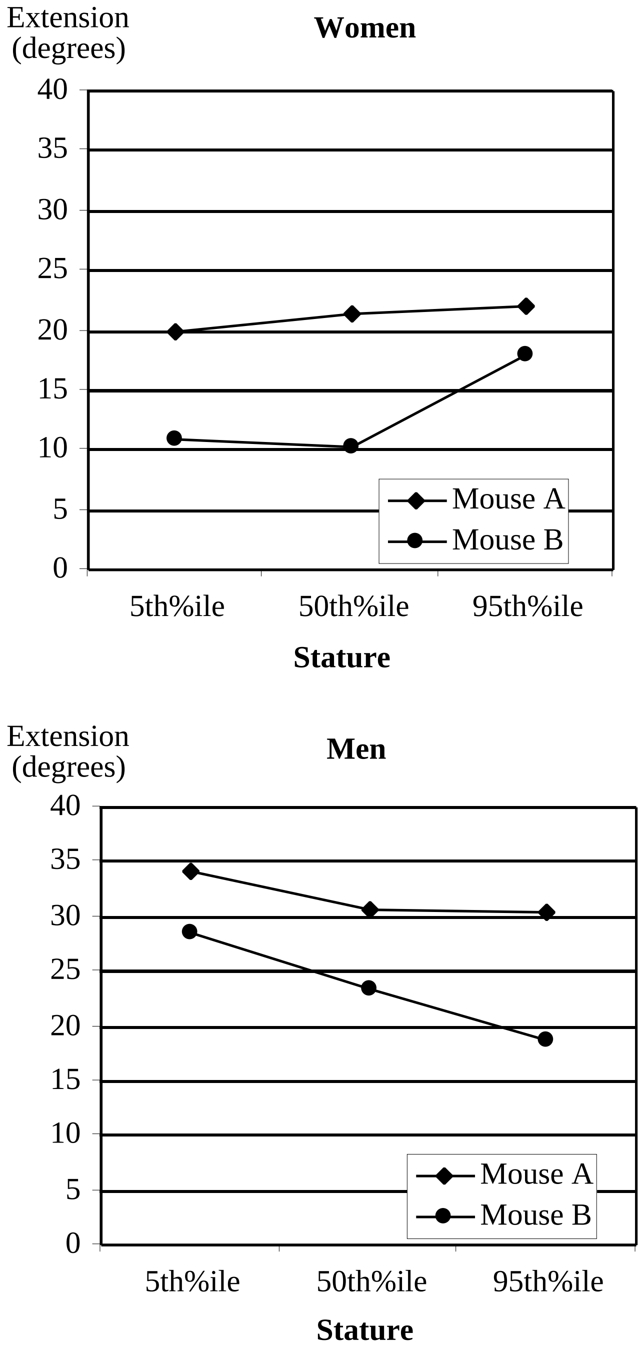
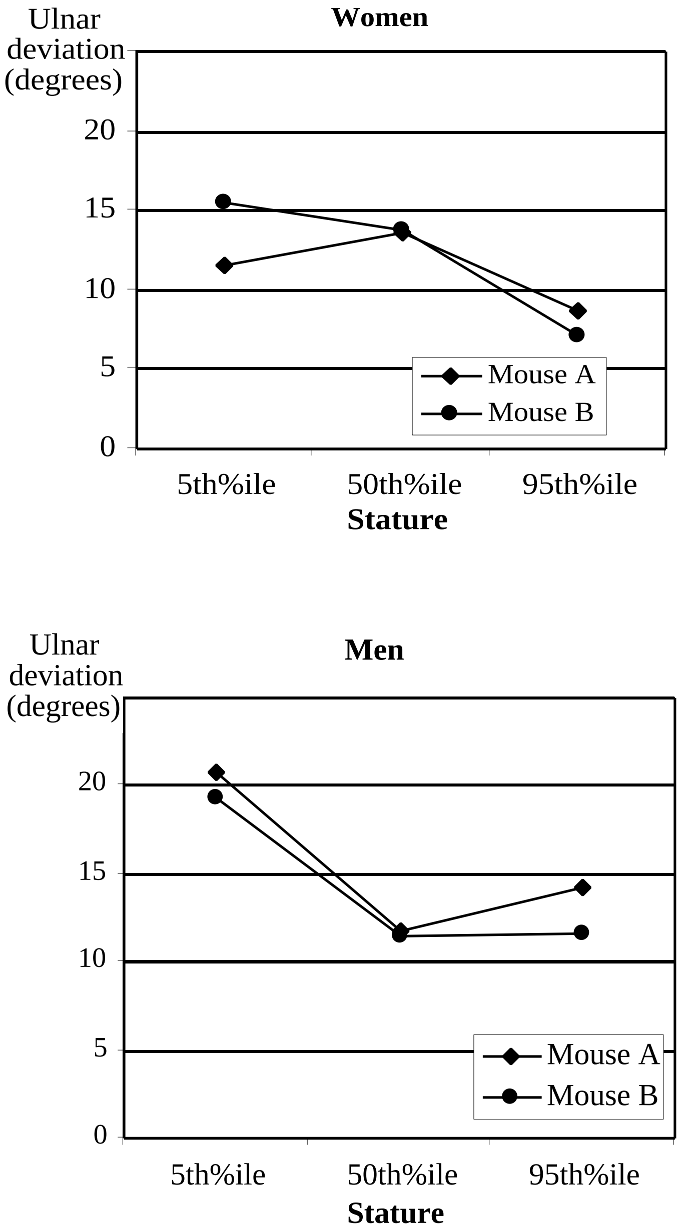


FIGURE 5

Mean Wrist Ulnar Deviation by Gender, Stature and Mouse.



3.3 Risk zone analysis

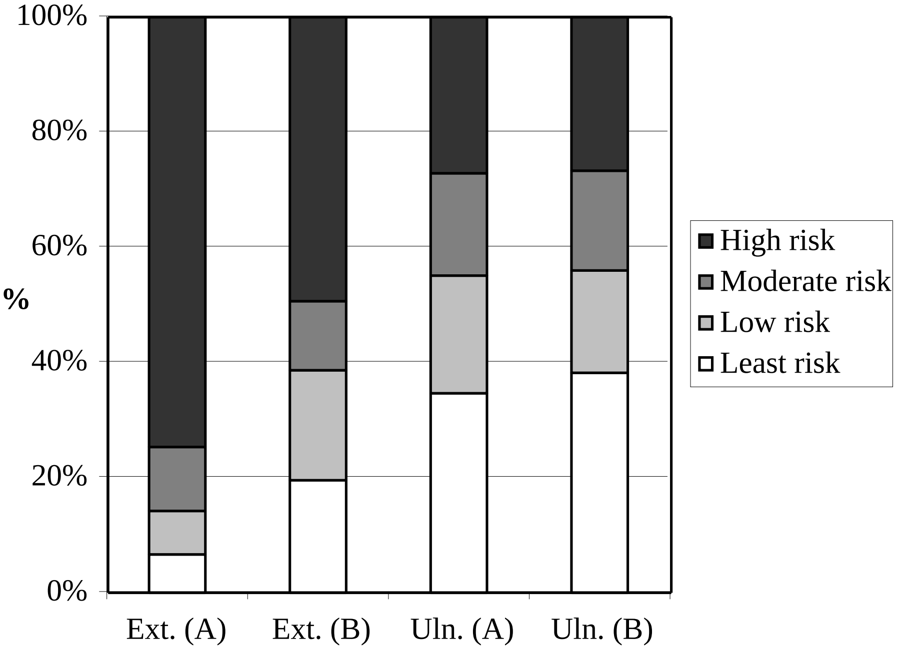
For each subject, the percentage of mousing movements in four potential risk zones for wrist flexion/extension and radial/ulnar deviation separately, were categorized as follows:

- Least Risk Zone: -10.5º to 10.5º
- Low Risk Zone: -15.5º to –10.6º or 10.6º to 15.5º
- Moderate Risk Zone: -15.6º to –20.5º or 15.6º to 20.5º
- Highest Risk Zone: <-20.6º or >20.6º

Figure 6 shows the percentage of movements in each of the four zones for wrist extension and ulnar deviation for each mouse.

FIGURE 6

Risk zone analysis for Wrist Posture for each Mouse

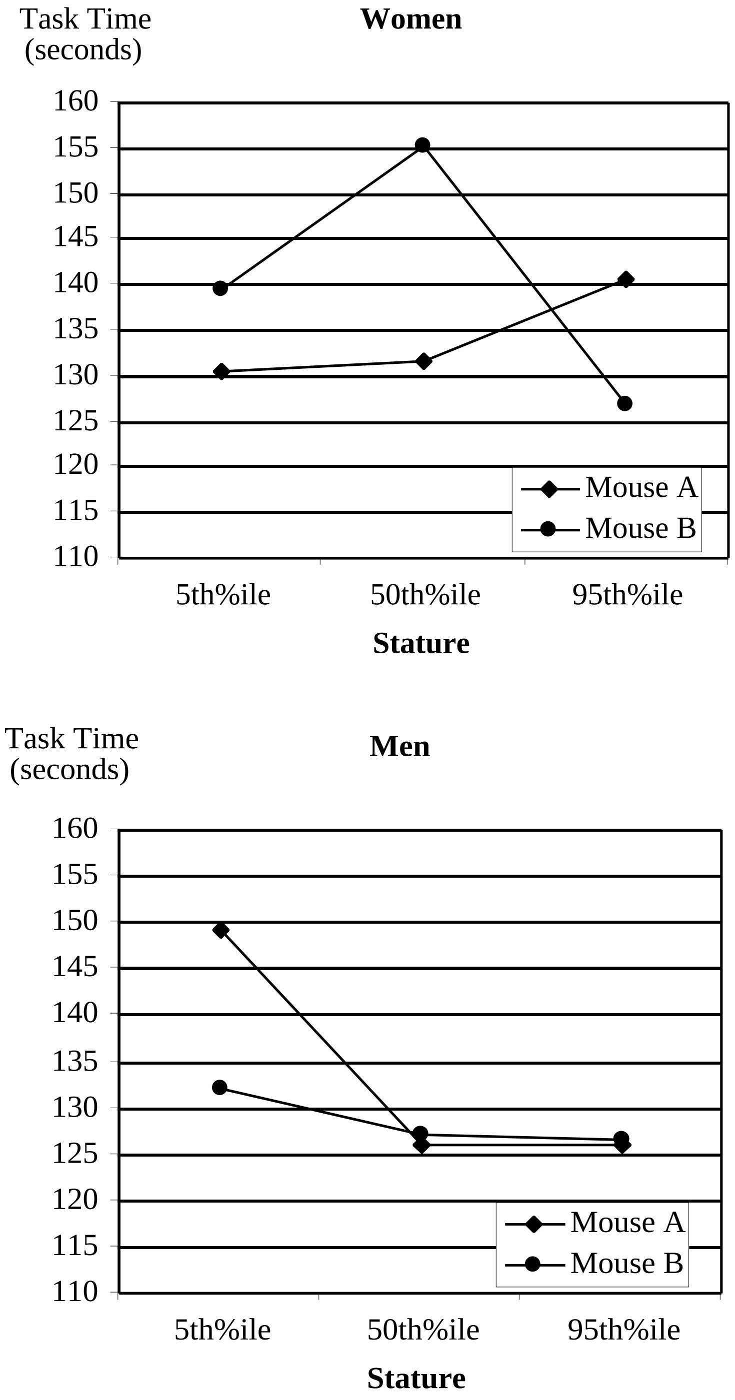


3.4 Task Performance

The average time to complete the task for Mouse A was 122.3 ± 3.2 seconds, and for Mouse B this was 145.7 ± 3.2 seconds. There were no significant main effects, but there was a significant interaction of gender ($F_{1,15}$ = 7.28, p = 0.017) and a significant interaction of gender x stature x mouse ($F_{2,15}$ = 3.69, p = 0.050). This interaction is shown in Figure 7.

FIGURE 7

Mean Task Time (seconds) by Gender, Stature, and Mouse.



3.5 Survey Results

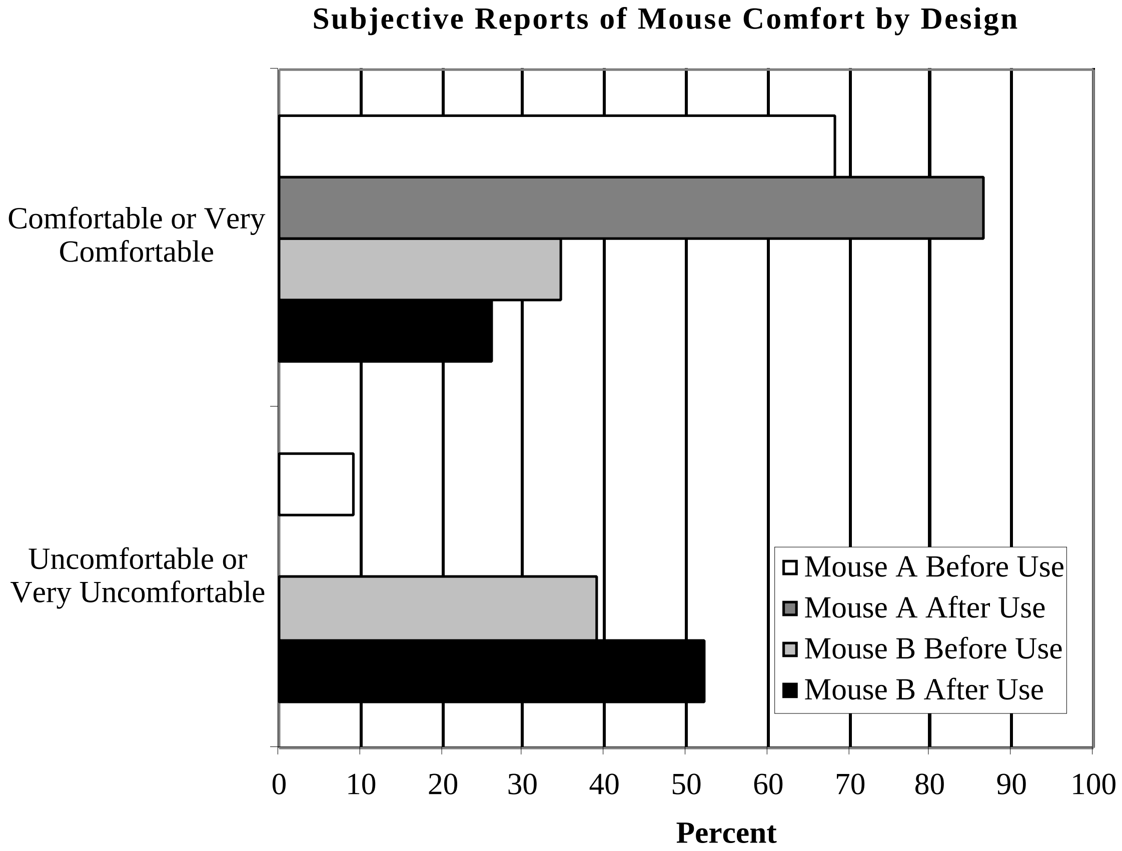
Subjects rated the anticipated comfort of each mouse based upon its appearance before use and then again after use. The mean comfort rating for Mouse A after use (1.1 ± 0.1) was significantly higher than before use (0.7 ± 0.2: $F_{1,16} = 6.409$, p.022). The mean comfort rating of Mouse A (0.7 ± 0.2) was significantly higher than Mouse B (0.0 ± .2) before use ($F_{1,16} = 6.894$, p = 0.018). The percentage of subjects reporting Mouse A to be "comfortable" or "very comfortable" increased from an initial 68.2% to 86.4% after use (n=22). Only 9.1% reported Mouse A to be"uncomfortable" or "very uncomfortable" before use and 0% reported this after use. The number of subjects reporting Mouse B to be "comfortable" or "very comfortable" before use decreased from 34.7% to 26.1% after use (n=23). The percentage of subjects reporting Mouse B to be "uncomfortable" or "very uncomfortable" before use increased from 39.1% to 52.2% after use. There were no significant differences in mean comfort ratings.

Ratings of comfort after use were compared between mouses (Figure 8). Overall, 73.9% of the subjects reported that Mouse A was either "more" or "much more" comfortable than Mouse B, and only 17.4% of the subjects reported the opposite, that Mouse B was more comfortable than Mouse A. Significantly more subjects reported that Mouse A (n = 17) was "more" or "much more" comfortable than Mouse B (n = 4) (χ^2=17.304, df=2, p = .000). Mean comfort ratings for Mouse A (1.1 ± 0.1) were significantly higher than Mouse B (-0.4 ± 0.2) after use ($F_{1,16} = 20.81$, p = 0.000).

Ratings of usability were also made and 59.1% of the subjects rated fine hand movements with Mouse A as "easy" or "very easy", whereas only 17.3% felt the same about Mouse B. For Mouse B 60.9% of the subjects rated fine hand movements as "difficult" or "very difficult" while only 9.1% felt the same for Mouse A. Mean ratings of the ability to perform detailed movements for Mouse A (0.7 ± 0.2) were significantly higher than for Mouse B (-0.7 ± 0.2: $F_{1,16} = 16.100$, p = 0.001).

FIGURE 8

Effects of Mouse Design and Mouse Use on Comfort Ratings



In addition, 87.0% of the subjects reported Mouse A to be "easier" or "much easier" to use than Mouse B. Only 8.7% of the subjects reported the same for Mouse B of Mouse A. Significantly more subjects reported Mouse A (n = 20) to be "easier" or "much easier" to use than Mouse B (n=2) (χ^2=29.826, df = 2, p = 0.000).

4.0 DISCUSSION

The results from this study show that mouse design has a significant effect on user's wrist extension posture when the mouse is used external to the right of the keyboard and at the same level as the keyboard. Wrist extension was lower for Mouse B than Mouse A by an average of over 8°. Wrist extension for Mouse B (18.3°) compares favorably with the lowest angles reported by previous researchers (Damann and Kroemer, 1995). The Mouse B design significantly reduced wrist extension and moved average wrist extension from being outside of a neutral zone of movement of < 20° to being inside of this. Analysis of wrist movements by risk zones showed that more than 50% of all hand movements with Mouse B fell inside a neutral zone compared with 25% of movements with Mouse A. The effects of the Mouse B design on wrist posture were consistent for men and women and for 5th percentile through 95th percentile stature users. The average wrist extension for both mouse designs was correlated with hand width, but hand length was only significantly correlated with hand posture for Mouse A. This suggests that the longer Mouse B design was effective in removing effects of hand length on wrist extension, and the design of Mouse B encouraged users to perform more of their mouse work with the hand in a vertically neutral posture.

Users' gender had a significant effect on wrist extension, and this was around 10° less for women than for men. Stature did not affect wrist extension. Although no interactions were significant, Figure 3 suggests that Mouse B may encourage more neutral postures in average and smaller stature women than larger stature women, but average and larger stature men rather than smaller stature men.

There was no significant difference in average ulnar deviation between the two mouses, and there were no significant no interactions of gender and/or stature and mouse design.

Task performance was affected by the mouse design. On average it took about 19% longer to perform the tasks with Mouse B than with Mouse A. There were significant interactions of gender and stature with task time. The Mouse B design is an unfamiliar design and subjects received little practice with this mouse. In view of the relatively short task times and the unfamiliarity of the Mouse B design, any time difference in performance may be eliminated by longer-term use.

Interestingly, Mouse B has been designed to discourage "skating" or "flicking" mouse movements, because these may increase the risk of a wrist injury. Subjects noted this in their ratings of usability and comments about the mouse design where 60.9% of the subjects said that fine hand movements were diffcult compared with only 9.1% reporting this for Mouse A.

Overall, findings from this study suggest that the use of Mouse B may assist in reducing the wrist extension postural risks associated with mouse use. The results in this study were achieved with the mouse located on a keyboard tray at the same level as the keyboard and external of this at around seated elbow height. Previous research suggests that this may not be an optimum location (Damann and Kroemer, 1995). Consequently, even better results can be anticipated if Mouse B is used on a mouse tray that is located 20% above seated elbow height and closer to the mid-line of the body. This arrangement and longer term mouse use should be tested in future studies.

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