Effects of computer mouse design and task on carpal tunnel pressure

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Computer mouse use has become an integral part of office work in the past decade. Intensive mouse use has been associated with increased risk of upper extremity musculoskeletal disorders, including carpal tunnel syndrome. Sustained, elevated fluid pressure in the carpal tunnel may play a role in the pathophysiology of carpal tunnel syndrome. Carpal tunnel pressure was measured in 14 healthy individuals while they performed tasks using three different computer mice. Participants performed a multidirectional dragging ('drag and drop') task starting with the hand resting (static posture) on the mouse. With one mouse, an additional pointing ('point-and-click') task was performed. All mice were associated with similar wrist extension postures \(p = 0.41\) and carpal tunnel pressures \(p = 0.48\). Pressures were significantly greater during dragging and pointing tasks than when resting the hand (static posture) on the mouse \(p = 0.003\). The mean pressures during the dragging tasks were 28.8–33.1 mmHg, ~12 mmHg greater than the static postures. Pressures during the dragging task were higher than the pointing task (33.1 versus 28.0 mmHg), although the difference was borderline non-significant \(p = 0.06\). In many participants the carpal tunnel pressures measured during mouse use were greater than pressures known to alter nerve function and structure, indicating that jobs with long periods of intensive mouse use may be at an increased risk of median mononeuropathy. A recommendation is made to minimize wrist extension, minimize prolonged dragging tasks and frequently perform other tasks with the mousing hand.

1. Introduction
The computer mouse has become an important input device that has created new problems in today’s workplace (Fogleman and Brogimus 1995). There have been anecdotal and research reports that intensive computer mouse users are at increased risk for carpal tunnel syndrome and other upper extremity musculoskeletal disorders (Franco et al. 1992, Franzblau et al. 1993, Karlqvist et al. 1994). However, unlike the keyboard, the number of studies that have examined the impact of mouse use on musculoskeletal health is limited. Fogleman and Brogimus (1995) reviewed workers’ compensation claims and

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found that although mouse-related claims were a small proportion of all claims, the problem was growing and deserved research attention.

People are now required to use the computer mouse as an input device for large proportions of their workday. Johnson et al. (1993) analysed 10 people performing word processing, spreadsheet/database, or graphics/drawing applications and found that mouse use constituted 31, 42 and 65% of each task respectively. As a general rule, it appears that computer users spend one- to two-thirds of their computer work using the mouse. Karlqvist et al. (1994) examined the postures associated with mouse use versus keyboard-only use. Although postural differences were noted, large variances and a brief testing period were deemed responsible for the lack of statistical significance. They concluded that ‘strenuous’ (i.e. greatly deviated from neutral) wrist and shoulder postures were maintained for a greater percentage of time while using the mouse than using the keyboard.

Sustained elevated carpal tunnel pressure has been proposed as a causative factor in carpal tunnel syndrome (Rempel 1995). Carpal tunnel pressure is elevated in patients with carpal tunnel syndrome as well as in healthy individuals when the wrist is deviated from neutral (Gelberman et al. 1981, Okutsu et al. 1989, Rojviroj et al. 1990, Werner et al. 1997). Nerve function and structure may be compromised if the extraneural pressure is sustained >30 mmHg (Hargens et al. 1979, Lundborg et al. 1983, Powell and Myers 1986, Dahlin et al. 1987).

The aim of this study was to determine whether differences in the design of a computer mouse influence wrist postures and carpal tunnel pressure. Furthermore, does mousing activity, in and of itself, increase carpal tunnel pressure? With each mouse, the postures and pressures were compared between holding the mouse (static posture) and using mouse during a ‘drag-and-drop’ task. With one mouse, an additional comparison was made between the ‘drag-and-drop’ task and a ‘point-and-click’ task.

2. Methods

2.1. Participants

Fourteen participants with no signs or symptoms of carpal tunnel syndrome participated in this study. There were nine men and five women with a mean (range) age of 31 (22–45) years. All participants used the right hand.

2.2. Participant medical examination

Each participant was interviewed and examined by a physician for the signs and symptoms of carpal tunnel syndrome; evaluation of muscle strength (thumb opposition, interossei, grip) and thenar atrophy. Sensation to touch in the hand and fingers was tested, as were Phalen’s and Tinel’s signs. Each participant had an electrodiagnostic study of the median nerve by thenar muscle recording, measuring antidromic sensory conduction between the wrist and index finger and recording the orthodromic short-segment between the palm and the wrist. The findings of the history, physical examinations and nerve conduction studies were normal for all participants. Participants were recruited from postings of notices at the university. This study was approved by the Committee on Human Research, University of California at San Francisco.
2.3. Materials and task

Each participant used three computer mice (figure 1): 'mouse A', a prototype of the Contour Mouse (Multipoint Technology, Lowell, MA, USA); 'mouse B', the Apple II ADB Mouse (Apple Computer, Inc., Cupertino, CA, USA); and 'mouse C', the Microsoft Serial Mouse (Microsoft Corp., Redmond, WA, USA). A dragging task ('drag-and-drop') was performed with each mouse and an additional pointing task ('point-and-click') was performed with mouse C. Following the template in figure 2, the dragging task started at the top circle (labelled '1'), and followed the progression as indicated by the arrows. After clicking and holding the mouse button depressed on circle 1, the next target (circle 2) in sequence became dark and the current target was dragged to the darkened target where it was 'dropped' by releasing the mouse button. The cycle then began again with the darkening of circle 3. The pointing task (only mouse C) followed the same sequence except that the participant simply clicked the mouse button over each successive target. Prior to the initiation of each task, the participant assumed a static (functional) posture with the hand holding the mouse, then on cue began the dragging or pointing task.

The participant was seated and the workstation was adjusted so that the mouse was approximately at elbow height and its use did not require shoulder flexion. The top of the monitor was just below eye level. Participants could make fine adjustments for comfort if desired. Prior to starting the study, participants practised until they were familiar with all mice and tasks.

Figure 1. The three mice evaluated. Left to right: mouse A, B, C.
2.4. Experimental set-up
Carpal tunnel pressure was measured by means of a saline-filled, multiperforated 20-gauge (0.8 mm) catheter (Burron Medical, Inc., Bethlehem, PA, USA) inserted percutaneously into the carpal tunnel of the right hand and connected to a pressure transducer (Rempel et al. 1994). The pressure transducer was maintained at the same elevation as the carpal tunnel. To minimize the possibility of occlusion, a slight positive flow of physiologic saline at 0.5 ml h\(^{-1}\) was maintained using a low-flow continuous flush device (model 42002-02; Sorenson Intraflow II).

Figure 2. Mousing task template. Dragging: after clicking and holding the mouse button depressed on circle 1 (top), the next target in sequence (circle 2) turns dark. The captured target is dragged (indicated by arrows) to the now darkened target and ‘dropped’ by releasing the mouse button. The cycle then begins again with the darkening of circle 3, and continues until all targets are eliminated. Pointing: this task (mouse C only) follows the same sequence except that the participant simply clicks the mouse button after pointing to each successive darkened target.
A biaxial electrogoniometer (Penny and Giles, Gwent, UK) was affixed to the dorsum of the participant’s hand and wrist. The goniometer provided radioulnar and flexion–extension angles. Calibration of the device included deviation to known angles as well as defining a zero or neutral wrist position for each participant (Greene and Heckman 1994). In addition, a resting posture was determined for each participant. This posture was defined as the repeatable hand posture in which the lowest carpal tunnel pressure was observed; usually at a neutral wrist posture with the forearm pronated to 45° (Weiss et al. 1995). The pressure transducer and goniometer calibration protocols have been described previously (Weiss et al. 1995).

Outputs from the pressure transducer and the goniometer were digitally sampled at 40 Hz and stored on a computer.

2.5. Statistical analyses
Mean wrist postures and carpal tunnel pressure were calculated for each participant–mouse type-task over the duration of each task. The data were analysed using a repeated measures ANOVA while specific post hoc analyses used the Tukey–Kramer HSD test ($\alpha = 0.05$). For the first analysis the main effects were mouse type and task (static versus dragging); for the second analysis only data from mouse C were used and the main effects tested were dragging versus pointing and static versus active.

3. Results
Mean resting (lowest) carpal tunnel pressure prior to placing the hand on the mouse was 5.3 ± 1.0 mmHg (mean ± SEM). The mean pressures rose to 18.7 ± 3.8, 16.8 ± 4.4 and 18.4 ± 3.4 mmHg for mice A to C respectively, after the hand was placed on the mouse (i.e. static posture). The mean pressures rose further during the dragging tasks to 28.8 ± 6.0, 31.1 ± 6.1 and 33.1 ± 6.7 mmHg for mice A to C respectively (table 1); the differences between mice were not significant ($p > 0.48$). An example of the continuous pressure and wrist posture during a dragging task is presented for one participant in figure 3. The pressure and wrist angles fluctuated slightly as the task was performed. The mean pressures for each participant and task are presented in the plot in figure 4. It can be seen that there was a marked difference in pressure response across the study participants. The mean pressure obtained during the dragging task (table 1) was ~12 mmHg greater than that measured while assuming a static position on the mouse, a significant difference ($p = 0.003$).

A comparison between the pointing and dragging tasks with mouse C demonstrated that the task of dragging increased carpal tunnel pressure more than during a pointing task (33.1 versus 28.0 mmHg), which was borderline nonsignificant ($p = 0.06$). Again, the pressure difference between active pointing with the mouse and static posture on the mouse was statistically significant ($p = 0.005$).

No significant differences in wrist flexion angle were found between any of the mice tested; between the static postures or while using the mouse. All of the mice tested promoted an extended wrist angle between 25 and 30° during the tasks and 23 to 28° in the static postures (table 1). While there were no statistical differences in wrist flexion–extension angle between the mice or with respect to active or static posture, there was a significant difference in the radioulnar angle between the mice ($p = 0.0004$). Mouse A led to a slightly more neutral posture in the active position and a more radial posture in the static position (table 1) than did the other two mice.
Table 1. Mean wrist posture (±SE) and carpal tunnel pressure for each mouse during static positioning and during the mousing tasks (n = 14).

<table>
<thead>
<tr>
<th>Mouse device</th>
<th>Task</th>
<th>Flexion–extension$^1$ (°)</th>
<th>Radioulnar deviation$^2$ (°)</th>
<th>Carpal tunnel pressure (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Static</td>
<td>Active</td>
<td>Static</td>
</tr>
<tr>
<td>A</td>
<td>dragging</td>
<td>25.5 ± 2.5</td>
<td>25.2 ± 2.6</td>
<td>− 3.2 ± 1.5</td>
</tr>
<tr>
<td>B</td>
<td>dragging</td>
<td>23.1 ± 1.8</td>
<td>26.7 ± 2.3</td>
<td>1.7 ± 1.8</td>
</tr>
<tr>
<td>C</td>
<td>dragging</td>
<td>28.2 ± 2.3</td>
<td>29.4 ± 2.4</td>
<td>0.8 ± 1.5</td>
</tr>
<tr>
<td>C</td>
<td>pointing</td>
<td>28.2 ± 1.8</td>
<td>28.7 ± 2.0</td>
<td>− 0.3 ± 1.4</td>
</tr>
</tbody>
</table>

$^1$Positive values indicate wrist extension.

$^2$Positive values are wrist ulnar deviation; negative values are radial deviation.
None of the radial and ulnar deviations exceeded $5.2^\circ$ from neutral. There were no significant differences between genders in wrist postures or carpal tunnel pressure. The time required (mean $\pm$ SD) to complete the dragging task was $71.2 \pm 21.5$, $76.0 \pm 25.6$ and $66.0 \pm 23.9$ s for mouse A to C respectively. The pointing task required less time to complete ($56.2 \pm 6.7$ s).

4. Discussion

Under the conditions used in this study, we have found that the three computer mouse designs tested were associated with similar carpal tunnel pressures and wrist postures. We have also determined that carpal tunnel pressure is greater during computer mouse use than when the hand is statically positioned over the mouse. There is a trend ($p = 0.06$) for a repeated dragging task to increase carpal tunnel pressure to a greater extent than a similar pointing task.

Our results indicate that although the shape of the three mice tested altered radioulnar deviation, there was no differential effect on carpal tunnel pressure. Pressure responds very little to small changes in radioulnar deviation angle near the neutral wrist posture (Rempel et al. 1997a). It is unlikely that these conclusions would change even if the number of participants was increased.

Carpal tunnel pressures measured while performing mousing tasks were found to attain a level of concern (figure 4). Active use of the mouse elevated the pressure in
the carpal tunnel to $\sim 30$ mmHg. Prolonged pressure of this magnitude has been associated with altered nerve function and structure in human and animal nerve studies (Hargens et al. 1979, Lundborg et al. 1983, Powell and Myers 1986, Dahlin et al. 1987) as well as eliciting symptoms of carpal tunnel syndrome when induced in the carpal tunnel (Lundborg et al. 1982). These changes in tissue physiology may be the first step in a cascade of events that lead to carpal tunnel syndrome (Dahlin et al. 1987, Rempel 1995). This indicates that individuals who use a mouse for long durations (e.g. CAD operators) may be at a higher risk for developing carpal tunnel syndrome or aggravating existing symptoms. This is consistent with the finding of increased risk of carpal tunnel syndrome among graphic artists who used mice extensively (Franzblau et al. 1993). In a limited number of graphic artists, Franzblau et al. found an increased rating of pain in the hand and forearm over that reported by the non-graphic artist office workers.

The differences seen in pressure with active use of the mouse correspond to our previous studies that found elevated carpal tunnel pressure with increased fingertip force (Rempel et al. 1997b, Keir et al. 1998). Magnitudes of fingertip force applied to the button during mousing tasks are $\sim 1.5 - 2.0$ N when averaged over time while forces applied to the sides of the mouse may be as high as 4 N (Johnson et al. 1994). The effects of these forces on carpal tunnel pressure have not been tested previously. However, fingertip loads of 5 or 6 N lead to carpal tunnel pressures of 15–40 mmHg (depending on wrist and forearm posture), which are significantly greater than pressures without fingertip loading (Rempel et al. 1997b, Keir et al. 1998).

The near significant ($p = 0.06$) finding that the dragging task created higher pressures than the pointing task deserves discussion. With a larger participant pool
this difference would likely have been statistically significant. There are two factors that differ between dragging and pointing with the mouse. First, the button is depressed for a greater percentage of the task cycle during dragging. Second, pinch forces on the side of the mouse are about three times greater during dragging tasks than pointing tasks (Johnson et al. 1994). This means there is greater fingertip loading of longer duration during a dragging task than during pointing. The increase in pressure with dragging is consistent with a previous study that evaluated carpal tunnel pressure during pinching (Keir et al. 1998).

Mousing, in general, promotes a fully pronated forearm. Forearm rotation has been shown to affect carpal tunnel pressure (Rempel et al. 1998, Werner et al. 1997). However, from the data in both papers, it appears that there is relatively little effect of pronation in the range tested. The data from Rempel et al. (1998) indicate minimal effect of forearm posture, from neutral to full pronation, on carpal tunnel pressure. Werner et al. (1997) used large gradations for wrist angle (20° flexion to 20° extension, 20–60° extension) and also found minimal differences between ‘pronated’ and ‘semi-pronated’ forearm positions (8.3 versus 9.5 and 15.6 versus 12.8 mmHg). Although these data indicate that the effect on carpal tunnel pressure is small, a forearm not fully pronated may lead to slightly lower pressures when the wrist is extended to 20–30°, the posture observed during mouse use in this study.

Two factors may account for the elevated carpal tunnel pressure during computer mouse use: (1) wrist extension and (2) the fingertip force applied to depress the button and to grip the sides of the mouse. A recent study in our laboratory of 37 healthy individuals found that a wrist extension angle of ≥30° created a carpal tunnel pressure that was significantly greater than that associated with the neutral wrist position (Rempel et al. 1997a). From a design perspective, some options are to promote training and workstation, software and tool designs that reduce wrist extension, reduce the duration of elevated forces applied during computer mouse use (e.g. minimize dragging tasks) and limit the duration of continuous mouse use. We propose that, if used, computer mouse workstation forearm supports be designed to reduce wrist extension angle and that employees be educated about methods to reduce wrist extension, especially if mouse use is intensive and of long duration.

There are several limitations to this study. First, the exposure period was brief (< 90 s per task). However, preliminary data from participants performing keyboard work for 20 min indicate that mean carpal tunnel pressure is stable for that duration. Second, the workstation was not a conventional workstation. Third, the task is artificial although it was designed to mimic typical pointing tasks. Fourth, the sample size was relatively small; a larger sample size would have reduced the chance of a type II error (failing to reject a false null hypothesis). Fifth, the carpal tunnel pressure measured in this study represents the interstitial fluid pressure and does not include the direct contact pressures that may also restrict the vascular supply to the median nerve. Sixth, the study was limited to healthy individuals. The changes in carpal tunnel pressure during wrist motion in patients with carpal tunnel syndrome are similar in direction to, but larger than, pressures in healthy individuals (Weiss et al. 1995). Generalization of these data to clinical or symptomatic individuals should be reserved until further research with those populations has been conducted. Although the mice tested were somewhat different, their designs were not extreme, that is, they were all variations of the ‘classic’ mouse design.
5. Conclusions

No important differences in wrist posture or carpal tunnel pressure were observed between the three computer mice tested. There was, however, a significant increase in carpal tunnel pressure when using the mouse as opposed to resting the hand on the mouse (i.e. static posture). It is possible that using a mouse for long duration may expose some individuals to carpal tunnel pressure levels that may initiate pathophysiologic events that lead to carpal tunnel syndrome. We suggest that efforts be made by employees, employers and manufacturers to reduce the wrist extension associated with mouse use, reduce sustained button down activities (e.g. dragging) and interrupt prolonged mouse usage with other tasks for the mousing hand. Further studies investigating the incidence and prevalence of carpal tunnel syndrome and other musculoskeletal disorders among intensive mouse users are suggested.

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References


