

## **WRIST AND SHOULDER MUSCLE ACTIVITY CHANGES ACROSS COMPUTER TASKS**

Jack Dennerlein<sup>1</sup>, Maria-Helena DiMarino<sup>1</sup>, Ted Becker<sup>1</sup>, Peter Johnson<sup>2</sup>

<sup>1</sup>Harvard School of Public Health, Boston, MA

<sup>2</sup>Department of Environmental Health, University of Washington, Seattle WA

The computer workstation is a ubiquitous tool in the office work environment; however, its use varies across many different tasks from surfing the Internet to typing. The question, therefore, is how does exposure to different physical risk factors for musculoskeletal disorders vary across tasks? Fifteen adults (10 females, 5 males) completed tasks simulating work at a computer workstation. The tasks were typing text, completing an html-based form, editing a document, a graphics task, and finally navigating through a series of web pages. During these tasks the muscle activity of the wrist prime movers and three shoulder muscle groups were recorded using surface EMG. For the wrist, the extensors were the most active ranging on average from 8 to 25 percent of Maximum Voluntary Contraction amplitude, with the greatest activity occurring in the typing task. The wrist activity decreased when the work changed from a keyboard-based activity to predominantly mouse-based activity. For the shoulder, the greatest activity was in the Trapezius muscle. The shoulder muscles were most active when both the mouse and the keyboard were required by the task. In summary, wrist and shoulder muscle activities at a computer workstation depend upon the type of task at hand.

### **INTRODUCTION**

Computer work has long been associated with musculoskeletal disorders of the upper extremity (Faucett and Rempel, 1994 and Bergqvist et al., 1995). While the injury mechanisms of chronic musculoskeletal disorders are not fully understood, work-related physical risk factors (PRFs) include repetition, force, awkward posture, direct pressure, and vibration (Rempel et al., 1992; Armstrong et al., 1987; Silverstein et al., 1987). Work on computer workstations includes many of these risk factors. Interfacing with the computer through the keyboard and the pointing device (e.g. the mouse) involves prolonged exposure to force, repetition and non-neutral postures of the upper extremity.

Laboratory studies have examined mostly the effects of device design and workstation set up on exposure to these risk factors. For example, Gerard et al. (1999) examined the effects of key switch make force on the forces and muscle activity during touch-typing. Many studies of split keyboards have examined the resulting postural effects (e.g. Tittiranonda et al, 1999; Marklin et al, 1999). Harvey and Peper, (1997), have examined alternative pointing devices, such as track balls. Workstation set up affects postural loading and several studies have examined workstation factors. Karqvist et al, 1998 demonstrated that mouse to the right of the keyboard affects shoulder posture. Simoneau et al., (2001) demonstrated the effects of keyboard height and slope on the awkward postures of the wrist.

When interacting with the computer workstation, however, the physical interaction is often defined by the task of the user. For example, a CAD operator will rely on the mouse as the primary mode of input, while a secretary may spend hours a day simply typing into a word processing document. With the variety of windows-based packages used in today's computing environments, most operators will use

the mouse and keyboard in varying proportions based on the task. Some studies have examined portions of a task. For example, Keir et al, (1999) examined differences between dragging events and pointing events. Other studies, such as Onishi et al. (1992), have examined the prevalence of MSDs across different job titles.

Our goal is therefore to simulate various computer tasks that range from exclusive mouse use to exclusive keyboard activity and compare the muscle activity and posture of the upper extremity across these various tasks. Such a profile can be used to design administrative intervention programs and develop an exposure-based taxonomy derived from the proportion of mouse and keyboard activity. For the purposes of this laboratory study, our null hypothesis is that no differences in muscle activity exist across tasks.

### **METHODS**

Fifteen human subjects (5 males, 10 Females) ranging in age from 21 to 39 years (mean = 26.9 years, standard deviation = 4.9 years), all of whom touch-typed at 40 wpm or higher, participated in the study after providing consent. The HSPH Human Subject Committee approved all protocols and consent forms.

The electromyographic signals from seven muscles were recorded during the tasks using surface electrodes (DE-2.1 Single Differential Electrode, Delsys, Boston, MA v) placed on top of the muscle bellies in accordance with Perotto (1994). The wrist muscles monitored were the flexor carpi radialis (FCR), the flexor carpi ulnaris (FCU), the extensor carpi ulnaris (ECU), and the extensor carpi radialis (ECR). The three shoulder muscles monitored included the anterior deltoid (AD), the medial deltoid (MD), and the trapezius (Trap) muscles. The EMG signals were recorded onto a personal computer at 1000 samples per second. A root mean

square signal was calculated over a 0.2 second moving window and the data re-sampled at 200 samples per second.

A series of maximum voluntary isometric contractions (MVCs) were collected for each muscle. For the wrist, subjects placed their hand in a custom designed apparatus that constrained the hand and pushed in the primary direction of the muscle action. For the shoulder muscles, the experimenter restrained the subjects' limb during the contraction. The participants were instructed to contract as hard as possible for 5 seconds, using a 1-second ramp. At a minimum three MVC recordings were taken with 2 minute rest periods in between. Additional recordings were obtained, if needed, until the two highest measures differed by less than 10%. Again, the EMG was recorded onto a personal computer and the RMS value calculated over 0.2-second windows. The assigned MVC EMG value was the highest RMS EMG amplitude averaged over one-second epochs.

The wrist posture was measured using a goniometric biaxial glove wrist system (Greenleaf Medical Systems, Palo Alto California) worn in accordance with the manufacturer's instructions and calibrated using methods in Jonsson (2001). Data were recorded at 20 Hz. The shoulder postural data were collected using a three-axis orientation sensor (3DM Microstrain, Burlington, Vt.) placed on the lateral midpoint of the right humerus, defined as halfway between the lateral epicondyle and the AC process. The box was placed flush with the arm, while the forearm was in neutral position and flexed 90°. The 3DM measured abduction ( $\pm 70^\circ$ ) and flexion ( $\pm 180^\circ$ ) using inclinometers, and rotation ( $\pm 180$ ) using a magnetometer. The data were collected, through a serial port, into a personal computer at approximately 10Hz.

Subjects were seated at an adjustable computer workstation. An armless chair was adjusted such that, with the feet on the ground, the subjects' thighs were horizontal. The table height was adjusted such that the home row of the keyboard was at elbow height. The keyboard was placed near the edge of the workstation with the alphanumeric portion of the keyboard centered with the body's centerline. The monitor height was adjusted so the top of the view portion of the screen was at or just below eye level. For the typing tasks, subjects' wrists and forearms were not supported. For the mouse intensive tasks, the graphics and web surfing tasks, subjects were allowed to rest their wrists on the table. The neutral position was defined as seated, elbows flexed approximately 45°, and hands supported on the thighs.

(Graphics), and an Internet web page surfing (Web). For the typing task subjects typed Poe's The Raven into a word processor. The text-editing task required the participants to select a highlighted text in a word processing document, using a mouse, delete the text, and then enter the corrected text. For the web page based form, subjects filled in a series of text fields on a web page. The graphics task contained two portions. First participants sorted objects on a page by geometric shape. Second, participants resized objects to match the size of a second object in the field. Finally, in the web surfing task participants viewed a series of photographs with a short descriptive text on a set of local intranet web pages (removing delays in downloading). To navigate the web pages links for the next page were placed in random locations. Each task was designed for 3 - 5 minutes of data collection after a brief warm up and task familiarization.

For each task an amplitude probability distribution function (APDF) of the normalized EMG RMS signal and the postures were calculated. Repeated measures methods in JMP (SAS Institute Inc. Cary, NC, USA) tested for significant differences in the 10th, 50th, and 90th percentiles of the APDF across the tasks.

## RESULTS

Of the muscles monitored, the wrist extensor muscles had the highest level of activity (Table 1). The median value for wrist EMG during the various tasks ranged from 9 to 25 percent of the MVC. Shoulder activity was relatively low with median values ranging from 2 to 8 % MVC.

For the wrist, muscle activity was the highest during the typing task (Figures 2 – 3 and Table 1). No significant trends were observed for the 10th percentile across tasks for the wrist flexor muscles (Figure 1). For the extensors, however, differences were observed across the static component (10th percentile, Jonsson, 1988).

For the shoulder, muscle activity was the highest for tasks involving both the mouse and the keyboard. The trapezius muscle did not show any significant trends in static activity (10th percentile) across tasks; however the values for the graphics and web tasks were the lowest for the three points in the APDF (Figure 3).

The wrist postures did not vary much across the tasks; however, extension and ulnar deviation was the highest

**Table I: Median EMG Amplitude Values Across Tasks (\*\* p<0.01, \*\*\* p < 0.001)**

Task	Wrist Muscles				Shoulder		
	FCR***	FCU ***	ECU***	ECR***	Trap **	A Delt**	M. Delt*
Type	6.4%	8.3%	25.0%	23.2%	5.9%	3.9%	2.2%
Form	4.3%	3.7%	15.6%	15.3%	7.8%	4.4%	2.8%
Edit	5.3%	5.7%	15.5%	15.5%	7.0%	3.1%	3.4%
Graph	5.5%	6.6%	16.0%	14.8%	4.8%	2.5%	3.1%
Web	3.7%	2.8%	9.0%	8.9%	3.5%	1.6%	2.2%

Once seated, the subjects completed five different tasks assigned in random order: typing (Type), text editing (Edit), completing a web based form (Form), graphics

for the typing tasks (Figure 4, Table II). Upper arm posture did vary across tasks (Table II). The shoulder was the most neutral during the typing task. When the mouse was involved

**Table II: Median Postures across tasks**

(\*\* p<0.01, \*\*\* p < 0.001)

Task	Wrist		Shoulder		
	Ext. (°)**	Ulnar Dev. (°)	Flexio(°)***	Abduct (°)***	Rotate (°)***
Type	10	21	4	1	-2
Form	4	21	5	6	16
Edit	5	23	10	8	30
Graph	3	29	15	11	34
Web	5	24	14	7	28

in the task, the shoulder flexed, abducted, and externally rotated in order to reach out and interact with the mouse.

**DISCUSSION**

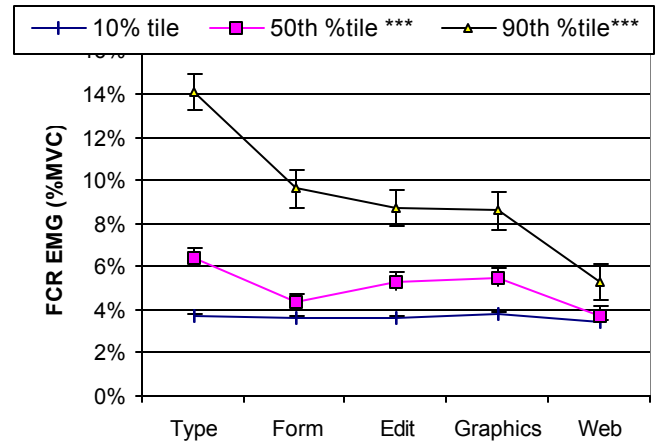
The data presented rejects our null hypothesis -- muscle activity and postures do vary across tasks. Wrist muscle activity decreases with decrease in keyboard activity, while shoulder activity is highest for the tasks involving both the keyboard and the mouse. Wrist posture appears to be the most extreme with typing and becomes more neutral with the decrease in keyboard activity. Shoulder posture is the most neutral for keyboard tasks and becomes less neutral as the mouse is utilized more frequently in the task.

Dynamic activities associated with the tasks are evident in these data. For example, typing involves repetitive motion of the fingers. The wrist muscles provide joint stability to counteract the finger forces. These data show a high dynamic activity (the 50<sup>th</sup> and 90<sup>th</sup> percentile) of the wrist muscles for the typing tasks as seen in Figure 1 supporting this hypothesis. For the shoulder, the dynamic activity is highest for the tasks involving both the keyboard and the computer mouse. In these tasks, the right arm has to move the hand between the keyboard and the computer keyboard frequently. This postural range of motion is observed in the shoulder flexion in Figure 4, where the motions were the largest for the form and edit-tasks.

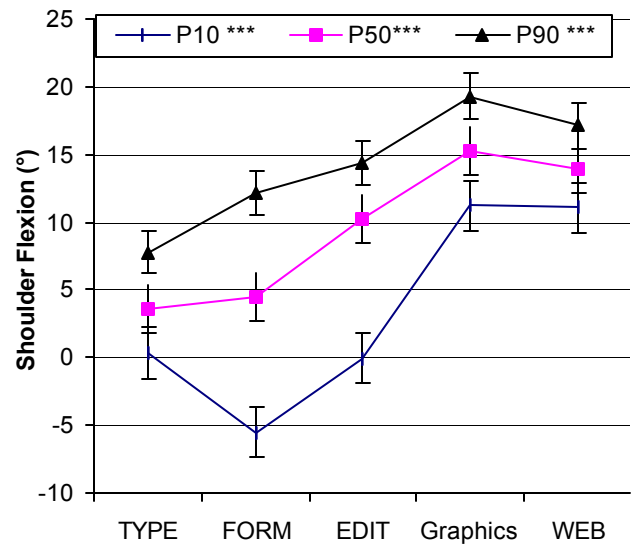
The static components (10<sup>th</sup> percentile) of the muscle activity of the wrist flexor muscles varied little across tasks compared to the extensors. The extensor activity corresponds with the extreme wrist postures. As the wrist extension increases so does the extensor activity. This behavior was not as obvious for the shoulder postures and muscle activities.

In the mouse intensive tasks, muscle activity in the graphics task was higher than in the web task. This result could be explained by the fact that the graphics task involved many drag events while the web task consisted of primarily point-and-click tasks. Other research has indicated that drag tasks involve higher levels of exposure to risk factors (Keir et al, 1999; Johnson et al., 1993). Furthermore, the graphics task required some amount of precision motor control for the resizing of objects, whereas the web surfing task did not.

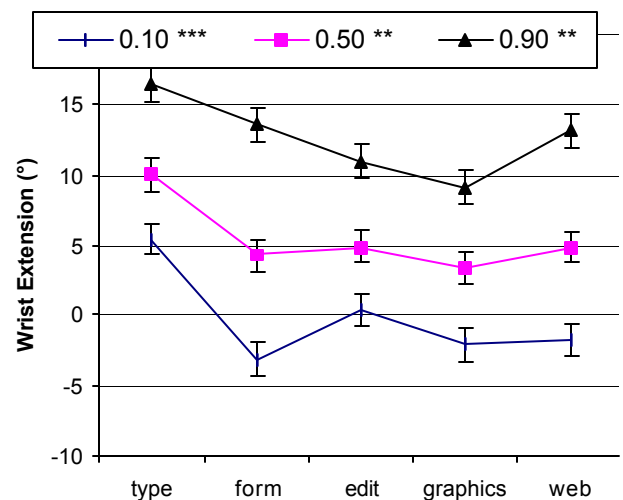
The limitations of this study are primarily the short duration of exposure and that the task simulations did not expose the subjects to the psychological pressures and demands associated with real world tasks in a paying job. In addition, a limited number of muscles and postures were monitored during these tasks. For example, we measured the EMG of the trapezius; however, we did not monitor shoulder elevation of the joint articulation associated with the trapezius.



**Figure 1.** EMG of a wrist flexors (FCR). The static component of the EMG (10%tile) was relatively constant across tasks compared to the dynamic component (90%tile). (\*\* n<0.01, \*\*\* n < 0.001)



**Figure 4:** Shoulder flexion. The shoulder is most neutral during the typing task. When the mouse is involved the shoulder flexes, abducts and externally rotates out. (\*\* p<0.01, \*\*\* p < 0.001)



**Figure 5:** Wrist Extension. Typing has the most extension recorded for all of the subjects. (\*\* n<0.01, \*\*\* n < 0.001)

We also did not control for arm support during the tasks utilizing the mouse. What these experiments do provide, though, is a basis for the description of exposure across specific computer tasks

## Acknowledgements

CDC/NIOSH Grant 1R010H03997-01  
The Office Ergonomics Research Committee, Yarmouth,  
Massachusetts

## References

- Armstrong TJ and Silverstein BA. (1987) Upper-Extremity Pain in the Workplace- Role of Usage in Causality, In Clinical Concepts in Regional Musculoskeletal Illness (ed. by Norton M. Hadler.) Orlando : Grune & Stratton.
- Bergqvist U, Wolgast E, Nilsson B, Voss M (1995) Musculoskeletal disorders among visual display terminal workers: individual, ergonomic and work organizational factors. *Ergonomics*, 38(4): 763-776
- Faucett, J., Rempel, D. (1994) VDT-Related Musculoskeletal Symptoms: Interactions Between Work Posture And Psychosocial Work Factors. *American J. Industrial Medicine*, 26(5):597-612.
- Gerard MJ, Armstrong TJ, Franzblau A, Martin BJ, Rempel DM. The effects of keyswitch stiffness on typing force, finger electromyography, and subjective discomfort. *Am Ind Hyg Assoc J*. 1999 Nov-Dec;60(6):762-9.
- Harvey R, Peper E. Surface electromyography and mouse use position. *Ergonomics*. 1997;40(8):781-9.
- Jonsson B, The static load component in muscle work. *Eur J Appl Physiol Occup Physiol*. 1988 57:310-515
- Keir PJ, Bach JM, Rempel D. Effects of computer mouse design and task on carpal tunnel pressure. *Ergonomics*. 1999 Oct;42(10):1350-60.
- Marklin RW, Simoneau GG, Monroe JF. Wrist and forearm posture from typing on split and vertically inclined computer keyboards. *Hum Factors*. 1999 Dec;41(4):559-69.
- Onishi N, Sakai K, Kogi K. Arm and shoulder load in various keyboard operating jobs of women. *J. Human Ergol*. 22: 98-97, 1982.
- Rempel DM, Harrison RJ, Barnhart S. Work-related cumulative trauma disorders of the upper extremity. *JAMA* 1992 Feb 12;267(6):838-42.
- Serina ER, Tal R, Rempel D. Wrist and forearm postures and motions during typing. *Ergonomics*. 1999 Jul;42(7):938-51.
- Silverstein BA, Fine LJ, Armstrong TJ. (1987) Occupational factors and carpal tunnel syndrome. *American Journal of Industrial Medicine*, 11: 343-358.
- Simoneau GG, Marklin RW. Effect of computer keyboard slope and height on wrist extension angle. *Hum Factors*. 2001 Summer;43(2):287-98.
- Tittiranonda P, Rempel D, Armstrong T, Burastero S. Workplace use of an adjustable keyboard: adjustment preferences and effect on wrist posture. *Am Ind Hyg Assoc J*. 1999 May-Jun;60(3):340-8.