# GENDER DIFFERENCES IN EXPOSURE TO PHYSICAL RISK FACTORS DURING STANDARDIZED COMPUTER TASKS

Erik Won[1], Pete Johnson[2], Laura Punnett[3], Theodore Becker[1], Jack Dennerlein[1]

[1]Department of Environmental Health, Harvard School of Public Health, Boston, MA
[2]Department of Environmental and Occupational Health Sciences, University of Washington, Seattle, WA
[3]Department of Work Environment, University of Massachusetts Lowell, MA

OBJECTIVES: The aim of this study was to determine whether there were differences in exposure to physical risk factors between genders in a series of standardized laboratory-based tasks on computer workstations adjusted to wubject anthropometry. METHODS: Thirty computer users (15 men and 15 women) completed five different tasks. Surface electromyography measured muscular activity in the shoulders (anterior deltoid, medial deltoid, and trapezius) and wrists (extensor carpi radialis, extensor carpi ulnaris, flexor carpi radialis, and flexor carpi ulnaris). Electrogoniometers and electromagnetic sensors measured posture of the wrists and shoulders, respectively. A force-sensing platform placed under the keyboard measured typing force. Whole body and upper extremity anthropometric measurements were recorded manually. RESULTS: Normalized muscle activity (EMG), the forces applied to the keyboard relative to the maximum force of the fingertip (%MVC), and range of motion were consistently higher for women. Shoulder posture was less neutral for women. Pearson correlations revealed strong associations between anthropometric variables (height, shoulder width, and arm length) and physical risk factors (EMG, range of motion, force) that are different between genders. CONCLUSIONS: Women have greater exposure to physical risk factors during identical tasks on a computer workstation. Exposure to these risk factors was strongly correlated to anthropometric differences between genders. This demonstrates how biomechanics plays a role and may contribute to the higher prevalence of upper extremity musculoskeletal disorders found in females.

## INTRODUCTION

Computer work has long been associated with musculoskeletal disorders of the upper extremity (Punnett and Bergqvist, 1997). 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 (Bernard, 1997). Work on computer workstations includes many of these risk factors. Interfacing with the computer through the keyboard and mouse involves prolonged exposure to low-level static and dynamic forces, repetition and non-neutral postures of the upper extremity.

It appears that upper extremity disorders related to computer work may occur more frequently in women than men (Punnet and Bergqvist,1997). Punnett and Herbert's review (1999) of the epidemiologic literature showed that, both in the general population and in workplace settings, the putative excess risk of upper extremity disorders among women was not impressive when differences in occupation and job demands were taken into account. However, only a limited number of studies even permitted such analysis, and even fewer examined potential differences in exposure between men and women within job titles, across similar tasks, and taking into account anthropometric differences.

Wahlstrom et al. (2000) examined differences in musculoskeletal load between men and women using the computer mouse. They found that women used higher relative force (percentage of maximum voluntary contraction) when using the computer mouse. Karlqvist and Bernmark (1998) found more strenuous postures in narrowshouldered and shorter individuals in a lab study of computer mouse positions. Although they did not examine gender differences in anthropometrics, these characteristics would be more likely in women. These studies only examined a narrow set of tasks related to the mouse use.

Therefore, our goal was to examine differences between genders in PRF exposure during a standardized set of computer tasks. The tasks involved both computer keyboard and mouse usage in a controlled laboratory setting.

## METHODS

Thirty human subjects (15 male, 15 female) ranging in age from 21 to 39 years (mean = 26.9 years, standard deviation = 4.9 years), all of whom could touch-type at 40 wpm or higher, participated in the study after providing informed consent. The HSPH Human Subject Committee approved all protocols and consent forms. Upper extremity anthropometric measurements were taken using anatomical landmarks such as shoulder width (measured as distance across acromioclavicular joints), shoulder-elbow length (measured as acromioclavicular joint to olecranon process), and elbow-wrist (distance from olecranon process to ulnar styloid). Subjects were seated at computer workstations adjusted so that their thighs were horizontal to the ground with their feet flat and firmly supported by the floor, the home row of the keyboard was at elbow height and the top portion of the monitor screen was at or just below eye level. Once seated, the subjects completed five different tasks assigned in random order: typing (Type), text editing (Edit), completing a web based form (Form), graphics (Graphics), and Internet web page surfing (Web) (Dennerlein et al., 2002)

Surface electromyographic (EMG) signals were recorded from seven muscles: the flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), extensor carpi ulnaris(ECU), extensor carpi radialis (ECR) anterior deltoid (AD), medial deltoid (MD), and trapezius. The EMG signals were amplified (Bagnoli-8, Delysis Inc, Boston, MA) and recorded onto a personal computer at 1000 samples per second. An algorithm calculated the root mean square value over a 0.2 second moving window and the data were re-sampled at 200 samples per second.

Typing forces were measured using a force-sensing platform placed under the keyboard (Becker et al., 2002). Typing force episodes were identified by first parsing the force data into epochs where the standard deviation of the force signal, calculated over a moving one-second window, is above a certain threshold. Summary statistics (mean force, 90$^{th}$ percentile, and duration) were calculated for these typing episodes.

A series of maximum voluntary isometric contractions (MVCs) were evaluated for each muscle studied by surface EMG, and for finger tip pinch force (typing). Isometric MVC's were measured by having subjects perform a maximum contraction of each muscle of interest while the experimenter completely resisted movement. Subjects were instructed to increase force over 1 second and then maintain the exertion for 5 seconds. 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%. These two measures were then averaged. As before, 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 at 20 Hz using a biaxial, glove-worn wrist electrogoniometric system (Greenleaf Medical Systems, Palo Alto California) worn in accordance with the manufacturer's instructions and calibrated as described in Jonsson (2001). An electro-magnetic motion analysis system (MiniBird, Ascension Technology, Burlington, VT) measured the position of the upper arm and lower using two sensors, one placed on the forearm and one on the upper arm, midway on the humerous. Data were recorded through the RS232 port at 10 samples per second.

For each subject and task, an amplitude probability distribution function (APDF) was calculated for typing force and for each posture. Summary statistics were then extracted for each subject: the median, the 10th and 90th percentile values, and the range of motion (ROM, 95th – 5th percentile). The duration of each typing episode, from the force platform data, was also calculated.

To test the hypothesis of gender difference in each measure, summary values for EMG, forces, and postures were compared between genders using regression with fixed effects for gender and random effects for the subjects with gender nested within the random effects.

## RESULTS

Females had higher median EMG values across all muscles and all tasks (see Figure 1). Median trapezius, flexor carpi radialis, and extensor carpi radialis muscles were statistically significant ($p<0.10$). This trend remained consistent through the 90th percentile measurements. Little to no difference was observed with the 10th percentile measurement.

**Table 1 Females used greater relative force (percentage of maximum voluntary contraction) during computer operations (* $p < 0.10$, ** $p < 0.05$).**

| | Abs Force (50%) | Abs force (90%)* | Rel Force (50%) ** | Rel Force (90%) * |
|---|---|---|---|---|
| FEMALES | 0.65 | 1.98 | 1.93 | 5.67 |
| MALES | 0.57 | 2.22 | 1.15 | 4.53 |

Females adopted postures that were less neutral than men in the shoulder but consistent postural differences were not observed in the wrist (see Figure 2).

The range of motion in shoulder external/internal rotation and wrist external/internal rotation was higher in females. Movement-velocity data were very similar across genders.

While the 90th percentile absolute forces (expressed in Newtons) applied to the keyboard were slightly higher in males, relative force (expressed as %MVC) was higher in the female subjects (see Table 1).

Height, shoulder width, and arm length (both shoulder to elbow length and elbow to wrist length) were significantly less in women. Pearson

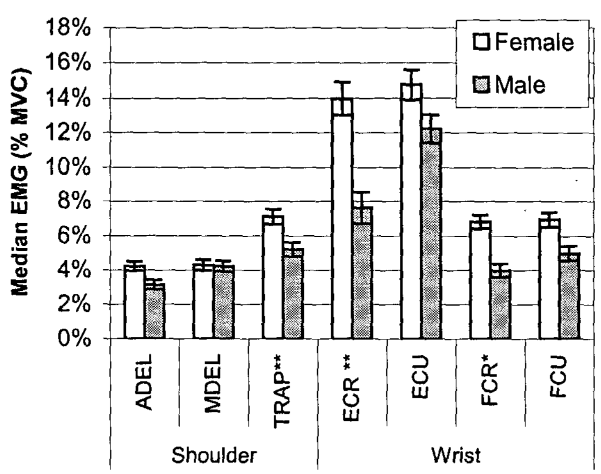


**Figure 1**: Median EMG values. Females had higher muscle activity in all shoulder and wrist muscles (* $p < 0.10$, ** $p < 0.05$).

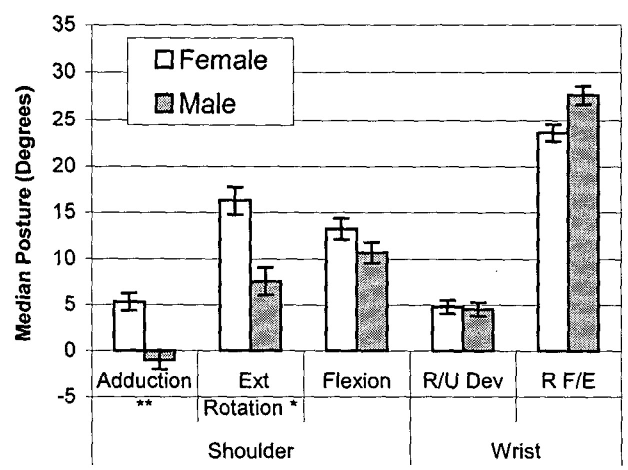


**Figure 2**: Median posture values. Female postures tended to be further from neutral than male postures (* $p < 0.10$, ** $p < 0.05$).

| **Table2: Correlations between anthropometry and Exposure variables** | r | P-value |
|---|---|---|
| Shoulder width and Trap EMG | -0.583 | 0.001 |
| Height and FCR EMG | -0.419 | 0.024 |
| Shoulder width and Sh Adduction Posture | -0.541 | 0.003 |
| Height and Shoulder Ext Rotation Posture | -0.461 | 0.011 |
| Shoulder width and ECR ROM | -0.416 | 0.031 |
| Arm length and Shoulder Ext Rotation ROM | -0.575 | 0.001 |
| Arm length and Keyboard force | -0.461 | 0.012 |
| Height and Keyboard force | -0.398 | 0.029 |

correlations demonstrated a strong association between anthropometric dimensions and PRF's (see table 2).

## DISCUSSION

Our data suggests that there are physiologic and biomechanical differences in exposure to PRF's between men and women even when the tasks are standardized and the workstations have been vertically adjusted to each subject. EMG and keyboard force data are consistent with the findings reported by Wahlstrom and Svensson (2000). We were able to extend these findings by examining several parameters, such as posture, range of motion, and muscle activity, across computer tasks and mouse positions.

The finding of gender differences across these parameters (relative force, muscle activity, and range of motion) may be partially explained by anthropometrics. Several significant differences in anthropometric parameters were found between men and women: most notably, women had narrower shoulders and shorter arm length than men. Karlqvist et al (1998) found that subjects with narrower shoulder width tended to work in more extreme postures and had greater muscle activity. We have found a similar association.

In conclusion, we observed gender differences in exposure to PRF's (shoulder and wrist muscle EMG, postures, range of motion, and typing forces) across several different tasks emulating real computer work. Strong correlations were found between anthropometric differences and exposure to PRF's. This demonstrates how biomechanics plays a role in contributing to the higher prevalence of upper extremity musculoskeletal disorders found in females.

## REFERENCES

Becker T, Johnson P, Dennerlein JT. (2002) The Development of a Keyboard Force Platform. *Proc. of World Congress of Biomechanics*, Calgary, Canada.

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

Bernard BP, editor. (1997) Musculoskeletal disorders and workplace factors: A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. Cincinatti, OH: DHHS (NIOSH) 97-141

Dennerlein JT, et al. (2002) Wrist and Shoulder Muscle Activities Changes Across Computer Tasks. Proc of the Human Factors and Ergonomics Society Conference, Baltimore, MD.

Gerr F, Michele M, et al. A Prospective Study of Computer Users: I. Study Design and Incidence of Musculoskeletal Symptoms and Disorders. American Journal of Industrial Medicine, 2002, 41:221-235.

Jonsson, P. and P. W. Johnson (2001). Comparison of measurement accuracy between two types of wrist goniometer systems. *Appl Ergon* 32(6): 599-607

Karlqvist LK, Bernmark E, et al. (1998) Computer mouse position as a determinant of posture, muscular load and perceived exertion. Scan J Work Environ Health, 2002, 24(1): 62-73

Punnett L, Bergqvist U. (1997)Visual Display Unit Work and Upper Extremity Musculoskeletal Disorders: A Review of Epidemiologic Findings. Solna SWEDEN: National Institute of Working Life, Arbete och Hälsa, 16:1-161.

Punnett L, Herbert R.(1999) Workrelated Musculoskeletal Disorders: Is There a Gender Differential, and If So, What Does it Mean? In: Women and Health, eds. Goldman MB, Hatch M. San Diego CA: Academic Press.

Rempel DM, Harrison RJ, Barnhart S. Work-related cumulative trauma disorders of the upper extremity. JAMA 1992 Feb 12;267(6):838-42.

Wahlstrom J, Svensson J, et al, Differences between work methods and gender in computer mouse use. Scand J Work Environ Health. 2000 Oct;26(5):390-7.