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Upper extremity biomechanics in computer tasks differ by gender

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Abstract

Objectives: This laboratory study examined gender differences in upper extremity postures, applied forces, and muscle activity when a computer workstation was adjusted to individual anthropometry according to current guidelines.

Methods: Fifteen men and 15 women completed five standardized computer tasks: touch-typing, completing a form, editing text, sorting and resizing graphical objects and navigating intranet pages. Subjects worked at a height-adjustable workstation with the keyboard on top of the work surface and the mouse to the right. Subjects repeated the text editing task with the mouse in two other locations: a "high" mouse position, which simulated using a keyboard drawer with the mouse on the primary work surface, and "center" mouse position with the mouse between the keyboard and the body, centered with the body's center line. Surface electromyography measured muscle activity; electrogoniometric and magnetic motion analysis system measured wrist, forearm and upper arm postures; load-cells measured typing forces; and a force-sensing mouse measured applied forces.

Results: Relative forces applied to the keyboard, normalized muscle activity of two forearm muscles, range of motion for the wrist and shoulder joints and external rotation of the shoulder were higher for women ($p < 0.05$). When subjects were dichotomized instead by anthropometry (either large/small shoulder width or arm length), the differences in forces, muscle activity of the shoulder and wrist posture and shoulder posture became more pronounced with smaller subjects having higher values. Postural differences between the genders increased in the high mouse position and decreased in the center mouse location.

Conclusions: When a workstation is adjusted per current guidelines differences in upper extremity force, muscle activity and postural factors still exist between genders. However, these were often stronger when subjects were grouped by anthropometry suggesting that perhaps the computer input devices themselves should be scaled to be more in proportion with the anthropometry and strength of the user.

Keywords: Gender; Computer work; Exposure; Upper extremity; Musculoskeletal disorders

1. Introduction

Computer work has been associated with musculoskeletal disorders of the upper extremity (e.g. Punnett and Bergqvist, 1997; Gerr et al., 2002). The prevalence of upper extremity disorders related to computer work is higher among females (Punnett and Bergqvist, 1999; Gerr et al., 2002; Lassen et al., 2005). A recent review (Treaster and Burr, 2004) reported that the higher prevalence of MSD in females exists even controlling for work-factors. However, 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. Only a limited number of studies 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.

Musculoskeletal disorders can occur when there is a mismatch between a worker's capabilities and the job design.

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For example, de Smet et al. (1998) found that musicians with smaller hands had more frequent musculoskeletal symptoms and overuse syndromes. Sauter et al. (1991) reported that the relative height of the keyboard is associated with neck and shoulder disorders. Interventions thus should be aimed at matching the workstation with the anthropometry of the worker (OSHA, 1997). The relationship between gender and anthropometric dimensions is significant to note, as women, on average, have smaller anthropometric dimensions compared to men (Jurgens et al., 1990; National Health Survey, 1985). Hence, failure to implement ergonomic principles may have greater consequences for people with smaller anthropometry.

A small number of laboratory studies have examined gender and anthropometric differences in upper extremity biomechanics. Wahlstrom et al. (2000) reported that women used higher relative forces (percentage of maximum voluntary contraction) and more non-neutral postures than men when operating a computer mouse during a text selection and deletion task. Karlqvist and Bernmark (1998) examined mouse tasks and reported more extreme postures in female computer operators as well as in those with narrower shoulders and shorter height, suggesting that the higher exposures of female subjects resulted at least in part from their smaller stature requiring greater extremes of reach. These studies, however, have not examined multiple factors (force, muscle activity, wrist and shoulder postures) during tasks that span a wide range computer tasks (Dennerlein and Johnson, 2006a).

In addition to general recommendations for workstation set-up, the positioning of the mouse is often utilized as an intervention for musculoskeletal symptoms. Dennerlein and Johnson (2006b) studied the biomechanical implications of four different mouse positions; the poorly positioned mouse yielded the least neutral posture and the highest level of muscle activity. Others have also studied alternative mouse positions, and the results have consistently shown that locating the pointing device close(r) to the midline of the body provides more neutral wrist and shoulder postures and reduces some muscle activity levels (Harvey and Peper, 1997; Sommerich et al., 2002; Cook and Kothiyal, 1998).

Our goal was to quantify differences in biomechanical measures (force, muscle activity and posture) between men and women in a controlled laboratory setting where the participants completed the same set of simulated work tasks at a workstation adjusted to fit each individual, with the mouse positioned to the right of the keyboard. This study tested the hypotheses that women utilize greater forces (absolute and relative), muscle activity and non-neutral wrist and shoulder postures. This study also sought to determine whether there was any correlation between these biomechanical parameters and the individuals' anthropometry. The study hypothesized that smaller anthropometry leads to greater forces, muscle activities and non-neutral postures. Finally, this study also examined how these differences between genders were affected by workstation configuration.

2. Methods

2.1. Subjects

Thirty subjects (15 males, 15 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 words per minute or higher, were recruited through a temporary employment agency. Based on a typing test performed before the experiment, the net typing speed of the subjects ranged from 41 to 77 words per minute. All anthropometric measurements were greater for men compared to women (Table 1). The Harvard School of Public Health Human Subjects Committee approved all protocols and consent forms.

2.2. Experimental protocol

The experiment consisted of subjects completing a series of five standardized computer tasks while seated at an adjustable workstation. The five different tasks were: typing (Type), text editing (Edit), completing a web based form (Form), a graphics manipulation task (Graphics), and web page browsing (Web). Each task designed to take approximately 5 min to complete and the five task required different combinations of mouse and keyboard interactions (Dennerlein and Johnson, 2006a).

The workstation consisted of an adjustable chair without arms, an adjustable work surface for the keyboard and mouse, and a flat-panel monitor on an adjustable monitor stand. The chair height was adjusted such that with the participant's feet flat on the ground their thighs were parallel to the ground. The height of the table was adjusted such that the surface was level with the resting elbow height for each individual while sitting for all experimental conditions. The keyboard was placed on the table surface near the edge of the workstation with the alphanumeric portion of the keyboard centered with the body's centerline. Forearm and wrist supports were not provided. For all of the tasks the mouse was positioned to the right of the keyboard in a standard configuration.

Subjects repeated the text-editing task with the mouse positioned in two other locations. One location was with the mouse beyond the keyboard and elevated 5 cm above the surface of the keyboard ("high mouse"). This high mouse position emulated a workstation with a keyboard tray vertically adjusted to the individuals' anthropometry with enough space for the keyboard only and the mouse is placed away from the user on the desk. The other location was with the keyboard pushed back 25 cm from the

Table 1
Selected subject anthropometry and strength measures

Parameter	Women ($n = 15$)	Men ($n = 15$)	p-Value
Height (cm)	**163 (5)**	**179 (7)**	**<0.001**
Weight (kg)	**59 (7)**	**79 (12)**	**0.001**
BMI (kg/m^2)	**22.3 (2.1)**	**24.7 (3.5)**	**0.03**
Shoulder width (cm)	**39.0 (2.5)**	**44.4 (1.5)**	**<0.001**
Arm length (cm)	**55.6 (2.7)**	**60.7 (4.0)**	**<0.001**
Hand length (cm)	**17.5 (0.7)**	**19.1 (1.5)**	**<0.001**
Index finger maximum voluntary contraction (N)	**37 (7)**	**52 (14)**	**<0.001**

Mean values (and standard deviations) across subjects within the gender groups are presented. Bolded values indicate p-values <0.05 for student t-tests between genders.