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A SURVEY OF DESKTOP AND NOTEBOOK COMPUTER USE BY PROFESSIONALS

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Over the last quarter century, extensive research concerning work-related musculoskeletal discomfort has been conducted in the area of desktop computer (DPC) use, among professionals and clerical workers. Notebook style computers (NPC) are increasing in popularity and use, often replacing DPCs, yet limited information is available on workers' experience with NPCs. Results are presented from a survey that explored work-related use of desktop and notebook computers by professionals (n=335). Associations were found between musculoskeletal discomfort and work patterns and methods, including work-break patterns, notebook configuration, and notebook transportation mode.

INTRODUCTION

Computer use has increased rapidly over the last quarter century. In 1975, there were fewer than 200,000 computers in the USA (Juliussen & Petska-Juliussen, 1994); 1994 projections for 1995 exceeded 100,000,000 computers. Surveys reveal widespread use of computers, at work and outside of work. Half of employed adults in the USA used a computer for work in 1997 (Newburger, 1997). Statistics from the USA and UK show that over 80% of those who use computers for work, also use them at home (Newburger, 1997; Heasman, Brooks & Stewart, 2000), providing the potential for a high level of exposure among users.

Personal computers (PCs) account for 90 percent of all computers. Worldwide, the portable PC is a rapidly growing market segment. In 1997, it was estimated that mobile computers would constitute 34% of total USA PC shipments in 2000 (almost 10 million units). Portables already constituted 40% of total computer output in Japan at that time (Villanueva, Jonai & Saito, 1998); in 1998 they were 20% of the computers sold in the UK (Heasman et al., 2000). Initially, portable PCs were used by mobile workers. More recently, however, portables are being used as replacements for desktop computers (DPC), even for workers who do not require PC mobility.

Work requiring the use of desktop style computers has been associated with musculoskeletal discomfort in workers (Bernard, 1991; Hünting, Laubli & Grandjean, 1981; Sauter, Schleifer & Knutson, 1991), and other adverse physical and mental health outcomes (Smith, Cohen, Stammerjohn Jr & Happ, 1981; Bergqvist, Wolgast, Nilsson & Voss, 1995). Studies of workers who use desktop style computers on the job have identified four categories of influential factors: physical, psychosocial, work organization, and individual factors. The growing use of notebook computers (NPCs) raises concerns for development of discomfort and other adverse outcomes in their users, as well.

There has been little work published to date that has explored jobs requiring the use of portable (notebook) computers, with regard to their potential for having similar associations with

adverse health outcomes for workers. Laboratory studies, which address physical factors, have shown that NPC use can affect user posture, increase discomfort and muscle activity, and hamper performance, when compared with DPC use (Straker, Jones & Miller, 1997; Villanueva et al., 1998; Price & Dowell, 1998). One anecdotal report of "repetitive motion disorders" associated with the use of NPCs as dictation devices, by a group of new users, illustrated the potential for interplay between risk factor categories¹.

From two surveys, different perspectives of risk associated with notebook use, or jobs requiring notebook use, emerge. Diederich & Stewart (1997) concluded, from their survey of employees in an Australian company and their review of the literature, that the workers who used notebook computers in a stand-alone configuration were at increased risk for injury. More recently, however, frequency of stress symptoms and physical discomforts were found to be similar across four exclusive computer user classifications (stand-alone portable, portable with external monitor &/or keyboard, DPC, and multiple configurations), in a study of 2192 workers in the UK (Heasman et al., 2000). Of the 1197 NPC users surveyed, only 9% used a portable in a stand-alone configuration. By contrast, Diederich and Stewart (1997) reported 60% stand-alone use in their respondents.

To date there have been no studies published of surveys of NPC users in the USA. This paper presents selected results from a study of professionals who use NPCs and/or DPCs as work tools. The purposes of the study included: construction of a database of worker and work characteristics describing a large, diverse sample of NPC users; identification of similarities and differences in work factors, worker factors, and/or strain outcomes between NPC and DPC users. The study was comprehensive, in that it examined computer design and usage patterns, as well as psychosocial, work organization, and individual factors. The purpose of this presentation is to

¹ Laptop Computer usage and OSHA's 11c Program, Memorandum from Byron R. Chadwick, Regional Administrator – VIII to Roger A. Clark, Director, Directorate of Compliance Programs and Leo G. Carey, Director, Directorate of Field Programs. http://gabby.osha-slc.gov/OshDoc/Interp_data/INTERP_19940104.html

provide an introduction to the study and some of the findings, particularly those that can be compared with the few previous studies in this area.

METHODS

A web-based questionnaire was designed to gather information on work-related computer use, general information about work (including work organization and psychosocial aspects of work), musculoskeletal discomfort, activities outside of work, and individual factors (including personality type, general assessments of physical and mental health, and demographic information). The population of interest was professionals who use computers to help them perform their jobs. Both desktop and notebook users were included in the study, to facilitate comparisons made on type of computer used, and based on data from the same instrument and protocol.

Participants

Nine organizations agreed to participate in the study. Business interests were wide-ranging: manufacturing, software development, consulting, finance, information services, and insurance. They were located in the Southeast, Midwest, Southwest, and Western parts of the USA. The main study was preceded by two pilot efforts. The total number of respondents, based on a final web form that respondents completed to acknowledge their completion of the questionnaire, is listed in Table 1. Some subjects missed this form. As such, these numbers and rates are estimates. Another estimate of response numbers and rates was determined based on a tally of respondent identification codes. Response numbers and rates based on that data are 428 and 69%, respectively.

Table 1. Participants tally, based on number of confirmation forms submitted by respondents.

Organization	Number responding	Response rate, %
<i>Pilot 1</i>	29	97
<i>Pilot 2</i>	33	52
Engineering consulting services	17	85
Human factors consulting services (n=2)	11	92
	2	50
Information services	8	73
Computer solutions (n=2)	12	80
	24	53
Educational software	28	56
Furniture manufacturer	31	57
Diverse manufacturing	37	49
Insurance	142	62
Financial services	9	90
Total	383	62

Instrument

The questionnaire was divided into five sections and presented as several different web pages, in order to give respondents the option of completing the questionnaire in one sitting, or

responding as they had a few minutes over the course of several days (see Table 2). Where possible, previously validated questions and scales were utilized (particularly in Parts 3, 4, and 5).

Analyses

Respondents' data were included in the analyses based on correct completion of Parts 1 &/or 2, and Parts 3 and 4. Data from 335 respondents were included in the analyses: 95 DPC users, 207 NPC users, and 33 who used both. Responses were evaluated for normality. Cronbach's alpha was determined for scale items. Descriptive statistics were determined for all data; various parametric and non-parametric techniques were used to test for associations, where appropriate.

Table 2. Brief descriptions of organization and contents of questionnaire.

Part Number	Category	Question sources ^a
Part 1	DPC use (equipment, software, usage patterns, physical discomfort)	
Part 2	NPC use (equipment, software, usage patterns, physical discomfort, locations, handling, postures)	
Part 3	Work in general (work organization, psychosocial factors, etc)	Caplan, Cobb, French Jr., Van Harrison & Pinneau Jr., 1975; Carayon, 1994; Quinn, 1971
Part 4	Health (MSD symptoms, other health problems), demographics	Nordic Questionnaire, Kuorinka, et al, 1987
Part 5	Personal (personality, mood states, education, activities outside of work, etc)	Wickström, Pentti, Hyytiäinen & Uutela, 1989; Jenkins Activity Survey; SF-12; Reeder, Schrama & Dirken, 1973
Completion Form		

^a Listings are representative, not comprehensive.

RESULTS & DISCUSSION

All participants

Personal demographics. The mean age of the respondents was 42.2 yrs (sd=9.8). 61% were male, 39% female. 92% had educational experience beyond high school; 32% had advanced degrees.

Employment demographics. Participants averaged 4.6 years (sd=4.8) in their current jobs; 10.7 years (sd=9.0) with their current employers. 96% classified themselves as full-time

permanent employees. Common job titles and areas included analyst, director, engineer (software, others), human factors specialist, manager (products, groups), purchaser, underwriter, and (technical) specialist. Two-thirds of respondents worked at sites with more than 1000 people, while 15% worked at sites with under 100 people.

Computer demographics. The average length of time participants had been using computers was 17 years (sd=6). Use of computers outside of work was high: 85% used a DPC outside of work, 69% used an NPC. Average time on computers, outside of work, was 5.3 hrs/wk (sd=6.2). This level of computer use outside of work is consistent with other reports (Heasman et al., 2000; Newburger, 1997).

Exposure to physical stressors at work. Participants were asked about frequency of exposure to heavy or repetitive lifting, forceful or repetitive gripping or pinching, and standing or sitting for longer periods of time. 69% of respondents reported sitting for long periods of time either *fairly* or *very often*. All other exposure prevalences, at those frequencies, were below 9%. Briefcases, books, backpacks, NPCs, NPCs in briefcases, binders, and boxes were the heaviest items most participants regularly handled in the course of their work days.

Discomfort prevalence. Based on responses to a modified Nordic-style questionnaire, 12-month prevalence ranged from 76% for eye discomfort to 35% for upper back; 7-day prevalence ranged from 43% for eye discomfort to 19% for upper back. Potential work-related cases were defined as those participants who reported discomfort that was not in a body part that had experienced trauma, that began after the start of the current job, and which either lasted at least 1-2 weeks or occurred at least once per month. Percentages of cases ranged from 38% for eye discomfort to 0% for low back. Differences were seen between male and female subjects

across the various definitions of discomfort, and are illustrated in Figure 1. Generally, discomfort prevalence for females was equal to or greater than that for males. Other studies have also shown differences in prevalence based on definition and sex, including a study by Jensen, Borg, Finsen, Hansen, Juul-Kristensen, & Christensen (1998) that focussed on professionals (CAD operators).

Respondents were also asked to report the frequency with which they experienced discomfort that they associated with work-related computer use. A PCPain score (potential range of 0-13) derived from those responses, was calculated as the quantity of body parts in which participants experienced discomfort *quite often* or *almost always*. Across all subjects, the average PCPain score was 1.1 (sd=1.7; median=0, max=8); the averages for males and females were 0.8 and 1.7, respectively, which were significantly different from each other ($p<.0001$).

Work and computer use patterns. Average work schedules for participants included working 5 days/wk (sd=0.5), 44.9 hrs/wk (sd=6.9), 8.8 hrs/day (sd=1.0), and 3.4 hrs on weekends (sd=2.4). Average amounts of work-related computer use appear in Table 3. Self-reported hours of use did not differ between males and females.

Table 3. Computer use among participants.

User	Hours	As a Percentage of Work Hrs.
DPC only	5.8 (1.7)	69 (19)
NPC only	5.3 (1.8)	60 (21)
DPC, uses both	5.1 (1.8)	57 (22)
NPC, uses both	3.3 (2.2)	37 (26)

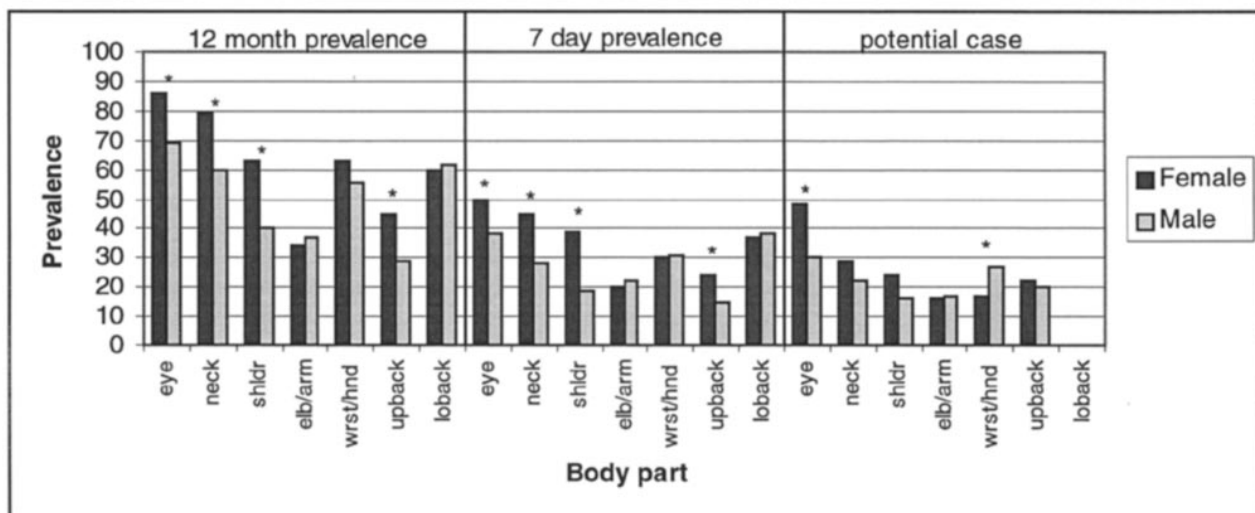


Figure 1. Prevalence of self-reported body part discomfort, by prevalence definition and sex, asterisks indicate significant differences, based on Fisher's exact test.

In addition to work time, participants were also asked about the kinds of breaks they took throughout their work days. Five kinds of breaks were described:

1. very brief breaks (restroom, coffee, water, etc.)
2. a 10-15 minute break in the first half of the work day
3. a 10-15 minute break in the second half of the work day
4. mid-day break that is < 30 min long
5. mid-day break that is at least 30 min long

One-third of participants reported only taking brief breaks during the day. Another third took only brief breaks and a longer mid-day break. 41% reported only taking one type of break; 44% reported taking only two types of breaks.

Given the participants' apparently high exposure to sitting for long periods of time and rather low exposure to breaks, the data were examined for an association between PCPain and sitting patterns during PC work. Participants were asked about the frequency with which they tended to work at the PC for at least X amount of time without taking a break (where X=30, 60, 90, and 120 minutes). A PCSit score was derived as a weighted average value across the four time periods. Discomfort frequency scores for individual body parts and for PCPain were examined for associations with the PCSit score. All correlations were significant (Table 4), with higher correlations for PCPain, eyes, and body parts belonging to the torso. When the associations were calculated separately for male and female subject groups, some differences were seen. In particular, while most of the associations remained significant for the males, several of the associations were non-significant for the female group.

Table 4. Discomfort related to composite score for time sitting with PC; Spearman correlation; non-significant associations are shaded.

Pain location	r, all S	p, all S	r, Fem.	p, Fem.	r, Male	p, Male
PCPain	.307	<.0001	.294	.0006	.287	<.0001
Eyes	.260	<.0001	.258	.0030	.229	.0009
Upper back	.233	<.0001	.166	.0568	.248	.0003
Neck	.227	<.0001	.239	.0058	.172	.0132
Low Back	.214	<.0001	.157	.0752	.217	.0018
Buttocks	.207	.0001	.087	.3279	.289	<.0001
Lt. hnd/wrst	.207	.0001	.194	.0270	.227	.0011
Rt. hnd/wrst	.175	.0012	.148	.0919	.174	.0127
Headache	.161	.0031	.096	.2757	.174	.0128
Rt. Elbow	.160	.0033	.146	.0981	.156	.0259
Lt. Shoulder	.138	.0114	.092	.2992	.151	.0313
Legs	.137	.0118	.069	.4333	.171	.0144
Lt. Elbow	.125	.0212	.153	.0808	.100	.1543
Rt. Shoulder	.113	.0380	.004	.9603	.148	.0342

Notebook use

Locations where NPCs are used. Notebook computers were most commonly used in the respondent's office located at the employer's facility. Over half the respondents also used NPCs in hotel guest rooms, at home, on planes, or in meeting rooms (including auditoriums and classrooms), but less than half used their NPCs anywhere other than the office with any degree of frequency (that is, more than *rarely*). The average number of locations was 5.3 (sd=2.2). This is higher than the average of 3 locations reported by Heasman et al. (2000).

Relocating NPCs. Participants were asked about the average number of times they moved their NPCs during the day, and how they were transported. 30% reported that they did not typically move the computer during the day. 52% reported moving it just 1-2 times, while 16% typically moved it 3-5 times per day. The most common way to move the NPC was supported by one shoulder, using a shoulder strap or shoulder bag (79% of respondents). 53% reported they carried the computer in their hand. 14% supported the NPC with both shoulders (backpack style). Only 9% used a rolling cart.

Participants were asked to indicate whether or not they experienced discomfort in any body parts which they associated with moving the NPC. Discomfort prevalence for each body part is shown in Table 5. Analyses of 2x2 tables constructed for each body part (pain/no pain v. transport mode used/not used) showed that the most commonly reported method for carrying the computer (over one shoulder; 79% of NPC users) was also strongly associated with shoulder pain prevalence (p=.0002). Carrying the computer by the hand (53% of users) was associated with discomfort in the distal upper extremity, though was "protective" for the shoulder. Two-shoulder support for the NPC (14% of users) did not impact shoulder discomfort, but was associated with upper back discomfort. No discomfort was associated with the least common mode of transport, the rolling cart. Due to the small number of participants that used this mode (9% of users), it would be premature to conclude that that mode is not generally associated with discomfort.

Table 5. Discomfort associated with moving the NPC.

Body Part	Discomfort Prevalence, %	Transport mode associated with discomfort ^a
Shoulder	57	1 shoulder + hand -
Neck	33	1 shoulder +
Upper back	19	2 shoulders +
Low back	17	
Hand	9	hand +
Forearm	8	hand +
Wrist	6	hand +
Elbow	3	hand +

^a + and - indicate direction of significant association between transportation mode and discomfort in body part

NPC configuration. Two definitions were used in classifying an NPC as being used in a stand-alone configuration or not. Defined as using no peripheral devices with the NPC (SA1), 7% of the notebook-only respondents and 15% of the respondents who used both an NPC and a DPC met this definition. Defined as using only an external pointing device (SA2), the percentages were 21 and 55%, respectively. Heasman et al. (2000) defined a docked NPC as one used with an external keyboard or monitor, so SA2 should be comparable to their stand-alone definition. As it turns out, stand alone usage in the current study is within the range of previous findings (Heasman et al., 2000; Diederich and Stewart, 1997). While Heasman et al. (2000) reported no difference in discomfort between stand-alone and docked NPC participants, crude analysis of the current data indicate that by either stand-alone definition, PCPain was greater for those using a stand-alone configuration (Kruskal-Wallis test: $p_{SA1}=.0026$, $p_{SA2}=.0188$).

CONCLUSION

The prevalence of discomfort seen in this sample of working professionals indicates that their experience of physical discomfort is similar to other samples of computer users. Work patterns and computer configuration appear to be associated with their discomfort. NPC users have additional exposures to consider, beyond those of DPC users, including more configuration options and materials handling issues. These are mentioned as areas that offer opportunities for future research in the area of office ergonomics, in order to develop sound recommendations for users.

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