Scand J Work Environ Health 2003;29(3):197–205

Development of neck and hand-wrist symptoms in relation to duration of computer use at work

by Chris Jensen, PhD[1]

Jensen C. Development of neck and hand-wrist symptoms in relation to duration of computer use at work. *Scand J Work Environ Health* 2003;29(3):197–205.

Objectives This study attempted to identify risk factors for musculoskeletal symptoms in the neck and hand-wrist regions among employees using computers at work.

Methods Computer users (N=5033) first received a questionnaire in the beginning of 1999 (69% response rate, N=3475), and a follow-up questionnaire was mailed in December of 2000 to the 3361 respondents to the baseline survey (77% response rate, N=2576). Health outcome was defined as musculoskeletal symptoms for >7 days within the last year of follow-up among the nonsymptomatic respondents at baseline.

Results Men's and women's previous symptoms, women's low influence at work and high-placed computer screen, and men's short time in the same job and good computer skills were associated with neck symptoms. Hand-wrist symptoms were predicted by previous symptoms and low influence at work for both the men and women and sensorial demands for the women only. The duration of computer use predicted hand-wrist symptoms [eg, odds ratio (OR) of 2.3, 95% confidence interval (95% CI) 1.2–4.3, for almost continual computer use], but not neck symptoms. For those with almost continual computer use, hand-wrist symptoms were associated with mouse use for at least half of the worktime (OR 4.0, 95% CI 1.0–15.5) and not using the mouse at all (OR 4.0, 95% CI 1.1–14.4), as compared with mouse use for one-fourth of the worktime.

Conclusions Limiting computer use to less than three-fourths of the worktime would help to prevent hand-wrist symptoms. Furthermore, low influence at work predicts both neck and hand-wrist symptoms.

Key terms computer use, follow-up study, hand, wrist, mouse use, neck, psychosocial factors.

Neck and upper extremity symptoms have been reported in different types of jobs that involve intense computer use (1). My paper examines risk factors for neck and hand-wrist symptoms among computer users on the basis of a longitudinal study, the BIT study (BIT = behavior in information technology).

In a literature review, Punnett & Bergqvist (2) reported that poor workstation design, continuous computer use for the entire workday, and repetitive computer work such as data entry were associated with an increased risk of symptoms. Several studies have reported positive associations between duration of computer use and musculoskeletal symptoms (1, 3–7). Karlqvist et al (6) and Jensen et al (8) reported a high prevalence of musculoskeletal symptoms among CAD (computer-aided design) operators, who used a computer mouse intensively at work. In addition, other factors in jobs with intensive computer work, such as low job control, overtime work, and frequent deadlines, have been reported to be associated with musculoskeletal symptoms (5, 9, 10). However, most results were based on cross-sectional studies in which cause-response relationships were difficult to identify.

In a recent follow-up study on newly hired employees with computer use for more than 15 hours a week and a follow-up period of 3 years, incident neck-shoulder and hand-arm (including wrist) symptoms were frequent (11). The women were more at risk than the men, and the risk of developing hand-arm symptoms, but not neck-shoulder symptoms, increased with the duration of weekly keyboard use (11, 12). However, the effects of the total duration of computer use (including keying,

1 National Institute of Occupational Health, Copenhagen, Denmark.

Reprint requests to: Dr Chris Jensen, National Institute of Occupational Health, Lersø Parkalle 105, DK-2100 Copenhagen, Denmark. [E-mail: cj@ami.dk]

using the mouse, and reading on the screen) or mouse use were not studied. In addition, in one older follow-up study with two measurements at a 6-year interval, a positive association was found between weekly hours of computer use and hand-wrist symptoms, but not between weekly hours of compute use and neck-shoulder symptoms (13).

The aim of this follow-up study was to investigate risk factors for musculoskeletal symptoms in the neck and hand-wrist regions with special focus on the duration of computer use at work. The main hypotheses were that long hours of computer and mouse use are risk factors for the development of symptoms. Analyses were also performed to identify other potential risk factors. These were work-related psychosocial factors, physical factors related to workplace design, individual factors, and factors specifically related to computer use, such as computer skills and quality of technical support.

Subjects and methods

Subjects

Two questionnaires were delivered to computer users in 11 Danish companies and institutions. The companies were selected to provide employees with different types of computer work (ie, data entry, word processing, graphic work, etc). Thus the employees of the participating companies were computer users with different types of computer work, but the distribution of computer use or worktasks could not be assumed to be strictly representative of office work in general. The baseline questionnaire was delivered to 5033 computer users in the early part of 1999. All employees working in the entire company or in specific predefined departments were included except cleaning and kitchen personnel. Before the questionnaires were delivered to the workplace, the names of the employees were supplied by the company. The questionnaires were returned by mail or returned in sealed envelopes at their workplace and later collected by a representative from the National Institute of Occupational Health.

The response rate at baseline was 69% (N=3475). In the baseline questionnaire people were asked about their home address in order to mail the follow-up questionnaire to as many of the respondents from the baseline survey as possible. The follow-up questionnaire was mailed in December of 2000 to 3471 respondents who had provided their home address. Of those, 108 respondents had changed home address and were not traceable through postal service registers at the time of the follow-up. Thus 3363 respondents were finally assumed to have received the follow-up questionnaire, and 2576 people responded, corresponding to a response rate of 77%. The mean follow-up period was 21 (range 17–23) months.

Questionnaire

In a previous paper on the baseline survey, a model was described that included individual and work-related factors that could affect the development of musculoskeletal symptoms (1). The baseline questionnaire contained questions on the following factors (all factors, except age, referred specifically to conditions at work): age, duration of employment in same job, years of using a computer, duration of computer use, duration of mouse use, training in computer use, software skills, technical problems with computer, quality of technical support, space for arm support in front of keyboard, screen height, glare, repetitiveness, quantitative demands, sensorial demands, cognitive demands, influence, possibilities for development, and social support. Most of the individual and physical workplace factors were assessed on the basis of answers to one question for each factor. The question on duration of computer use was "How much of your worktime do you work with a computer (including overtime and worktime at home)?", and the answer categories were never-seldom or one-fourth, one-half, three-fourths or almost all of the worktime. The question on duration of mouse use was similar. Continuous variables were categorized in the analyses. Some of the categorical responses were merged into fewer categories to obtain a more balanced distribution of responses. Some, mostly psychosocial factors, were assessed by the construction of indices based on the answer to three to seven different questions each with five response categories (never, seldom, sometimes, often, always). The indices ranged from 0 to 100 for each factor (14). In the further analyses, the index values were categorized as "low" (index value within 0–25 percentile), "medium low" (index value within 25–50 percentile), "medium high" (index value within 50–75 percentile) and "high" (index value within 75–100 percentile).

Both the baseline and follow-up questionnaire contained questions on musculoskeletal symptoms (trouble, ache, or pain) according to a modified version of the Nordic questionnaire (15). Health outcome was defined as (i) neck symptoms (not including shoulder) or (ii) hand-wrist symptoms for more than 7 days within the last year of the follow-up period. Only nonsymptomatic respondents at baseline (no symptoms or symptoms for no more than 7 days within the last year) were included in the analyses. When the development of neck symptoms was analyzed, the respondents were only included if they had been nonsymptomatic at baseline in both the neck and shoulder regions. For the analyses on the development of hand-wrist symptoms, only the

respondents who had been nonsymptomatic at baseline in both the hand-wrist and elbow regions were included. Thus, while the case definitions were based specifically for the neck and hand-wrist regions, the inclusion of nonsymptomatic respondents at baseline also required that the adjacent regions be symptom-free (shoulder and elbow, respectively). The inclusion of subjects with symptoms for 1–7 days within the last year at baseline among the "nonsymptomatic" respondents allowed for the inclusion of the factor, "previous symptoms", in the analyses of factors that could predict the development of symptoms at follow-up.

Statistics

Analyses of associations between factors reported at baseline and symptoms at follow-up in the (i) neck and (ii) one or both hands-wrists were performed. Univariate analyses were performed using a significance level of $P<0.10$. The chi-square or Mantel Haenszel chi-square statistic was used. In multivariate logistic regression analyses, all the significant factors from the univariate analyses were initially included in the model for each body region. Factors were successively omitted from the models if the likelihood ratio test produced probabilities larger than 0.10. The final logistic regression models were recalculated using only the respondents who did not change jobs between the baseline and follow-up, to minimize potential effects related to a change in exposure during the follow-up period.

The factors "duration of computer use" and "duration of mouse use" were entered into separate logistic regression analyses including only subjects working for 32–41 hours a week (duration of computer and mouse use were assessed as fractions of the worktime) and who did not change jobs between the baseline and follow-up. The logistic regression model describing the association between symptoms and the duration of computer use was adjusted for gender, age, and all other factors that were significantly associated with symptoms in the previous analyses.

As the duration of mouse use is highly correlated with duration of computer use, the association between mouse use and symptoms was studied in a subgroup of women who worked all or almost all of their worktime at a computer. The men were excluded since there were only a few men working almost all their worktime at the computer. Logistic regression models between duration of mouse use and symptoms were calculated with adjustment for other factors associated with symptoms. The procedures FREQ, MEAN and GENMOD in SAS (version 6.02, Cary, NC, USA) were used. The likelihood ratio test probability was calculated for each factor in the logistic regression models with a significance level of $P< 0.10$.

Results

In the follow-up, 1721 women and 855 men responded. At baseline the mean age of the female respondents was 42 (SD 10) years, and, on the average, they had used a computer at work for 11 (SD 6) years. The mean age of the men was 43 (SD 10) years, and they had also used a computer at work for 11 (SD 7) years.

At baseline 66.5% of the 3475 respondents and at follow-up 66.8% of the 2576 respondents were women. At baseline the prevalence of neck and hand-wrist symptoms for more than 7 days within the last year was 44.7% (N=2533) and 25.8% (N=2539), respectively, when only the subjects who responded at the follow-up were included. At follow-up the prevalence of neck symptoms was 46.4% (N=2558), and the prevalence of hand-wrist symptoms was 31.1% (N=2514). However, at baseline, the prevalences of symptoms of those who responded at follow-up were similar to the prevalences of symptoms for all the participants who responded at baseline (including those who dropped out at follow-up). Thus 43.9% reported neck symptoms (N=3400), and 25.9% reported hand-wrist symptoms (N=3405) at baseline.

For those who held the same job at follow-up (N=2002), as compared with those who did not (N=458), the prevalence of neck symptoms (44% and 46%, respectively) and hand-wrist symptoms (27% and 22%, respectively) was also similar at baseline. The percentage of the respondents with computer use for the whole worktime was 47% for those who held the same job at follow-up and 43% for those who did not.

For the respondents who were nonsymptomatic at baseline, the percentages of incident cases at follow-up are shown in table 1. A greater percentage of the women than the men developed symptoms in both body regions.

Those with previous symptoms (1–7 days within the last year at baseline) were more likely to develop symptoms (>7 days in the follow-up period) than the respondents who reported no symptoms at baseline (table 2). Furthermore, in the univariate analyses, high sensorial demands, low influence at work, high degree of repetitiveness, low social support, and disturbance by glare

Table 1. Incident cases at follow-up. Only respondents with symptoms for ≤7 days during the year preceding the baseline survey have been included.

Region	Women			Men		
	N	%	N_{total}[a]	N	%	N_{total}[a]
Neck	168	25.5	660	82	15.4	532
Hand-wrist	223	21.6	1035	78	12.5	626

[a] N_{total} = total number of nonsymptomatic respondents at baseline.

Table 2. Percentages of the female and male respondents with symptoms at follow-up according to individual and exposure factors at baseline (percentage of women and men with symptoms >7 days during the last year of the follow-up period). P-value refers to chi-square or Mantel Haenszel chi-square test of association.

Factor	Women						Men					
	Neck symptoms			Hand-wrist symptoms			Neck symptoms			Hand-wrist symptoms		
	%	P-value	N_{total} [a]	%	P-value	N_{total} [a]	%	P-value	N_{total} [a]	%	P-value	N_{total} [a]
Age												
18–29 years	28	0.28	71	19	0.59	113	20	0.004	46	7	0.99	59
30–39 years	28	·	163	23	·	278	21	·	115	15	·	147
40–49 years.	25	·	228	23	·	363	18	·	193	14	·	228
≥50 years	23	·	198	19	·	281	8	·	178	11	·	192
Previous symptoms												
No	15	<0.001	298	15	<0.001	690	8	<0.001	295	8	<0.001	426
Yes, 1–7 days	34	·	362	35	·	345	24	·	237	22	·	200
Duration of employment in same job												
<1 year	25	0.22	127	25	0.25	194	22	0.034	91	12	0.38	107
1–3 years	32	·	190	21	·	294	16	·	178	16	·	210
≥4 years	22	·	331	21	·	522	13	·	253	11	·	300
Experience with computer use												
0–3 years	31	0.26	81	21	0.87	132	15	0.90	67	9	0.60	217
4–7 years	28	·	98	23	·	161	11	·	81	13	·	208
8–12 years	23	·	235	23	·	355	21	·	180	13	·	101
>12 years	25	·	218	20	·	345	13	·	183	12	·	80
Quantitative demands												
High	25	0.51	215	23	0.12	346	16	0.28	242	12	0.51	290
Medium high	29	·	134	23	·	243	19	·	100	11	·	124
Medium low	28	·	140	20	·	208	13	·	83	13	·	100
Low	21	·	165	18	·	226	12	·	104	15	·	110
Cognitive demands												
High	26	0.86	176	20	0.84	279	17	0.094	187	13	0.65	225
Medium high	22	·	179	21	·	294	19	·	161	12	·	190
Medium low	32	·	126	26	·	200	9	·	82	10	·	102
Low	23	·	172	20	·	250	11	·	96	16	·	105
Sensory demands												
High	28	0.049	259	26	0.040	415	12	0.15	90	11	0.68	114
Medium high	27	·	175	18	·	285	21	·	156	12	·	185
Medium low	19	·	80	13	·	112	18	·	95	16	·	108
Low	21	·	140	21	·	215	10	·	187	12	·	215
Influence at work												
Low	32	<0.001	170	28	<0.001	287	17	0.58	54	12	0.050	60
Medium low	30	·	151	25	·	256	16	·	100	17	·	122
Medium high	23	·	166	19	·	220	17	·	127	16	·	171
High	17	·	166	13	·	257	14	·	45	8	·	268
Developmental possibilities												
Low	28	0.44	150	24	0.17	255	10	0.74	62	14	0.53	72
Medium low	23	·	118	19	·	185	18	·	72	14	·	76
Medium high	27	·	210	24	·	342	18	·	190	12	·	238
High	24	·	176	17	·	241	14	·	204	12	·	237
Repetitiveness												
Repetitive tasks and movements	31	0.080	163	27	0.013	270	14	0.86	35	16	0.42	38
Repetitive movements	25	·	196	21	·	301	18	·	73	14	·	93
Varied work	23	·	300	19	·	456	15	·	421	12	·	491
Social support												
Low	32	0.087	114	28	0.086	173	13	0.21	105	10	0.21	121
Medium low	25	·	143	21	·	223	12	·	115	12	·	149
Medium high	24	·	179	21	·	271	18	·	146	12	·	165
High	23	·	217	20	·	355	17	·	161	15	·	186
Training in software use												
Insufficient	26	0.98	109	19	0.36	172	10	0.066	104	12	1.00	129
Sufficient	26	·	543	22	·	850	17	·	420	12	·	491
Computer skills												
Bad or somewhat good	27	0.89	84	23	0.34	124	6	0.088	110	8	0.20	118
Good	25	·	307	22	·	491	19	·	267	14	·	333
Extremely good	26	·	261	20	·	407	15	·	149	13	·	172

(continued)

Table 2. Continued.

Factor	Women						Men					
	Neck symptoms			Hand-wrist symptoms			Neck symptoms			Hand-wrist symptoms		
	%	P-value	N_{total} [a]	%	P-value	N_{total} [a]	%	P-value	N_{total} [a]	%	P-value	N_{total} [a]
Technical problems with computer												
Daily or at least once a week	29	0.096	280	22	0.39	451	19	0.12	140	14	0.30	170
At least once a month	24	·	194	22	·	295	17	·	172	13	·	211
Less than once a month	22	·	176	19	·	273	13	·	213	11	·	241
Quality of technical support												
Dissatisfactory	27	0.38	154	20	0.94	231	16	0.62	99	18	0.029	120
Satisfactory	25	·	405	22	·	642	16	·	334	12	·	395
Very satisfactory	21	·	76	20	·	124	13	·	82	8	·	92
Space for arm support in front of keyboard												
No	··	·		24	0.27	243	··	·	·	14	0.57	195
Yes	··	·		21		773	··	·	·	12	·	410
Screen height												
Top above eye level	31	0.071	216	··	·	·	15	0.76	143	··	·	·
Top at or below eye level	23	427	··	··	·	·	16		380	··	·	·
Disturbed by glare												
Daily or several times a week	32	0.056	115	24	0.043	187	15	0.88	82	18	0.024	101
Every once in a while	25	·	192	25	·	324	17	·	147	14	·	179
No	23	·	326	18	·	482	15	·	289	10	·	334

[a] N_{total} = total number of nonsymptomatic respondents at baseline.

were risk factors for the development of symptoms among the women. Furthermore, persons with incident neck symptoms more often experienced technical problems with the computer and reported that their screen was placed with the top above eye level. Factors associated with the development of neck symptoms among the men in the univariate analyses were age and duration of employment (negative associations), high cognitive demands, sufficient training in software use, and good computer skills. Low influence at work, dissatisfactory quality of technical support, and disturbance by glare were associated with the development of hand-wrist symptoms among the men.

In the multivariate logistic regression models, two to three factors remained that contributed significantly to predicting the development of symptoms (tables 3 and 4). Previous symptoms remained in all the models as the most powerful predictor of developing more symptoms. In addition, influence at work remained in both models for the women (neck and hand-wrist models) and in the model for hand-wrist symptoms for the men as a significant predictor. Those with the highest risk of developing symptoms were women with low influence at work and men with medium low influence at work. Furthermore, a highly placed computer screen predicted neck symptoms among the women. Sensorial demands showed a U-shaped association with hand-wrist symptoms among the women. Among the men a short duration of employment in the same job and good computer skills predicted the development of neck

Table 3. Logistic regression models for neck and hand-wrist symptoms among the women. The P-value refers to the likelihood-ratio test for the models with all women.

Region	All women			Women with same job in follow-up	
	OR	95% CI	P-value	OR	95% CI
Neck	N_{total}[a]=637			N_{total}[a]=516	
Previous neck or shoulder symptoms					
No	1.0	·	<0.001	1.0	·
1–7 days	2.8	1.9–4.1		2.9	1.9–4.5
Screen height relative to eye level					
Below	1.0	·	0.046	1.0	·
Above	1.5	1.0–2.2	·	1.4	0.9–2.2
Influence at work					
High	1.0	·	0.013	1.0	·
Medium high	1.4	0.8–2.5		1.2	0.7–2.3
Medium low	2.1	1.2–3.6		2.0	1.1–3.6
Low	2.2	1.3–3.7		1.6	0.9–2.9
Hand-wrist	N_{total}[a]=1016			N_{total}[a]=800	
Previous hand, wrist or elbow symptoms					
No	1.0	·	<0.001	1.0	·
1–7 days	3.3	1.6–2.4		3.5	2.5–5.1
Sensorial demands					
Low	1.0	·	0.015	1.0	·
Medium low	0.6	0.3–1.1	·	0.7	0.3–1.4
Medium high	0.8	0.5–1.3	·	0.8	0.5–1.5
High	1.3	0.8–2.0	·	1.3	0.8–2.1
Influence at work					
High	1.0	·	<0.001	1.0	·
Medium high	1.5	0.9–2.5	·	1.6	0.9–2.9
Medium low	2.3	1.5–3.8	·	2.8	1.6–4.7
Low	2.4	1.5–3.8	·	2.7	1.6–4.6

[a] N_{total} = total number of respondents included in the logistic regression model.

Table 4. Logistic regression models for neck and hand-wrist symptoms among the men. The P-value refers to the likelihood-ratio test for the model with all the men.

	All men			Men with same job in follow-up	
Region	OR	95% CI	P-value	OR	95% CI
Neck	N_{total}[a]=517			N_{total}[a]=399	
Previous neck or shoulder symptoms					
No	1.0	·	<0.001	1.0	·
1–7 days	3.8	2.3–6.5	·	4.7	2.6–8.5
Duration of employment in same job					
>3 years	1.0	·	0.091	1.0	·
1–3 years	1.4	0.8–2.5		1.8	1.0–3.4
<1 year	2.1	1.1–3.9		2.1	1.0–4.5
Computer skills					
Very good	1.0	·	0.005	1.0	·
Good	1.2	0.7–2.1	·	1.3	0.7–2.5
Less than good	0.4	0.1–0.9	·	0.4	0.2–1.1
Hand-wrist	N_{total}[a]=621		N_{total}[a]=479		
Previous hand, wrist or elbow symptoms					
No	1.0	·	<0.001	1.0	·
1–7 days	3.3	2.0–5.3		3.3	1.9–5.7
Influence at work					
High	1.0	·	0.021	1.0	·
Medium high	2.2	1.2–4.0	·	2.0	1.0–3.
Medium low	2.5	1.3–4.8	·	2.4	1.2–5.1
Low	1.6	0.6–4.0	·	1.1	0.4–3.6

[a] N_{total} = total number of respondents included in the logistic regression model.

Table 5. Odds ratios (OR) and 95% confidence intervals (95% CI) for symptoms in relation to the duration of computer use at work (as a fraction of the worktime) and the duration of mouse use at work (as a fraction of the worktime). The odds ratios were controlled for gender (model for duration of computer use), age and other factors that were associated with the development of symptoms (see tables 3 and 4). Only subjects who worked full-time (32–41 hours/week) and remained in the same job during the follow-up period were included. The models with mouse use were further restricted to the women who used a computer almost continually. The P-values refer to the likelihood-ratio test.

Region	OR	95% CI	P-value	N
Neck				
Worktime at computer				
0–25%	1.0	·	0.541	645
50%	1.5	0.7–3.1	·	·
75%	1.3	0.6–2.7	·	·
100%	1.6	0.8–3.3	·	·
Worktime using mouse				
Seldom	1.3	0.4–4.3	0.718	203
25%	1.0	·	·	·
50–100%	1.7	0.5–5.7	·	·
Hand-wrist				
Worktime at computer				
0–25%	1.5	0.7–3.4	0.062	916
50%	1.0	·	·	·
75%	2.0	1.1–3.9	·	·
100%	2.3	1.2–4.3	·	·
Work time using mouse				
Seldom	4.0	1.1–14.4	0.050	331
25%	1.0	·	·	·
50–100%	4.0	1.0–15.5	·	·

symptoms in the multivariate analyses. When the final logistic regression models were recalculated with only the respondents who held the same job in the follow-up period, the odds ratios were similar to those of the models in which also the respondents who had changed jobs were included (tables 3 and 4). The only exceptions were the odds ratios for low influence at work, which were reduced when the respondents who had changed jobs were excluded. In addition, when the duration of computer use (as a fraction of worktime) was included in the models, the odds ratios for the other factors were similar to those of the models without this factor (results not shown).

The duration of computer use was not significantly associated with neck symptoms (table 5). However, duration of computer use predicted hand-wrist symptoms (table 5). Those with computer use for about one-half of their worktime showed the lowest risk, and in comparison those with almost continual computer use showed an odds ratio of 2.3 for hand-wrist symptoms.

The association between mouse use and neck symptoms was analyzed for women with almost continual computer use (table 5). No significant association was found. However, mouse use was associated with hand-wrist symptoms. Thus mouse use for at least half of the worktime as compared with mouse use for one-fourth of the worktime showed an odds ratio of about 4. Intensive computer use without mouse use also showed an odds ratio of about 4, in comparison with mouse use for one-fourth of the worktime.

Discussion

Response rates

The response rate was 77% in the follow-up, and there could have been selection bias, especially if people without musculoskeletal symptoms were more likely to drop out at follow-up than symptomatic ones. However, the prevalence of symptoms at baseline was similar among those who remained in the study and those who responded at baseline. This finding indicates that there was no selection bias due to musculoskeletal health status. In addition, no sign of selection bias regarding gender was observed. Still, almost half of the subjects who received a questionnaire at baseline did not respond either at baseline or at follow-up, and therefore some uncertainty remains about the size of the reported effects.

Analysis strategy

Durations of computer and mouse use were not included in the first logistic regression models, where all other

factors were potential candidates for inclusion (tables 3 and 4). One purpose of these analyses was to identify general risk factors among computer users, as they have seldom been verified in follow-up studies. The time span between the registration of potential risk factors and outcome (symptoms >7 days within the last year) increased the possibility that the identification of risk factors was due to cause-response relationships when a comparison is made to previous cross-sectional studies. The final models were repeated including only subjects who had not changed jobs in the follow-up period. In the follow-up, questions on most of the exposure factors were not repeated, and therefore the confirmation that the subject had not changed jobs was the best way of minimizing errors associated with a change in exposure during the follow-up period. However, this approach affected the final models only marginally. There was no tendency towards a higher frequency of respondents with symptoms or intense computer use among those who had changed jobs; this finding indicates that the computer users mainly changed jobs for other reasons. In addition, the respondents with symptoms at baseline did not show a greater tendency towards a reduced duration of computer use at follow-up than those without symptoms (data not shown).

Another purpose of the first analysis was to control for identified risk factors in the analyses of relationships between duration of computer use and symptoms in order to estimate the effect of computer use per se. Furthermore, the question on duration of computer use was answered in relation to the total workhours of each subject. Thus the analyses of the effect of duration of computer use were also limited to subjects who worked full-time (32–41 hours/week) and had not changed jobs so that exposures would be as comparable as possible between the subjects and time periods. Therefore, the effects of duration of computer use were analyzed in separate logistic regression models. The effects of duration of mouse use were also analyzed separately, as the analyses were restricted to subjects with almost continual computer use in addition to the same restrictions used in the former analyses of the effects of duration of computer use.

Computer and mouse use

The duration of computer use at work predicted hand-wrist symptoms but not neck symptoms. The risk of developing symptoms was increased in work with the computer for three-fourths or more of the worktime as compared with one-half of the worktime or less. The odds ratios were similar before and after control for other factors that affected the development of symptoms. The importance of the duration of computer work for the development of symptoms has previously been indicated by several cross-sectional studies (1, 4, 6, 7, 10). In the follow-up study by Marcus et al (12), the risk of developing hand-arm symptoms increased with hours of keying among newly hired computer users with more than 15 hours of computer use per week. The risk increased more than twofold with an increase of 20 hours of keying, whereas the risk of developing neck-shoulder symptoms did not increase significantly with hours of keying. This finding is probably consistent with my present findings, even though hours of keying was not studied independently. In the present study the analyses were restricted to those working "normal" hours (ie, 32–41 hours/week). Thus it is not known whether longer workhours increase the risk of developing hand-wrist symptoms further, as computer users who typically work longer hours may have other types of jobs, and other factors may influence the development of symptoms more or less than for the "normal" computer user.

Using the computer mouse for more than one-half of the worktime also increased the risk of developing hand-wrist symptoms for women when compared with using the mouse for about a quarter of the worktime. This finding is consistent with the results of previous cross-sectional studies (6, 8). Typical worktasks requiring intensive mouse use would be graphic design and multimedia editing. However, intense computer use without a mouse also increased the risk of developing hand-wrist symptoms, probably due to the performance of rather repetitive worktasks with intense keyboard use, such as call-center work or data entry.

Gender and age

Women were more likely to develop symptoms than men. In most cross-sectional studies of computer users, the prevalence of musculoskeletal symptoms has also been about twice as high for women as for men (3, 10). In a recent follow-up study, the effect of gender was slightly smaller, as women showed a 1.6–1.7 times higher risk of developing symptoms than men (11). However, the risk of developing clinically assessed hand-arm disorders was 2.4 times higher for women than for men in the same study. Part of the explanation may be that women often perform other worktasks or jobs than men, such as call-center work. Furthermore, other studies have shown that identical worktasks at the computer may be performed with more strenuous postures by women than by men (16, 17), probably due to anthropometric differences.

Age did not remain a predictor in the multivariate models. However, having performed the same worktasks for less than a year prior to the baseline survey was associated with a higher risk of developing neck symptoms among the men than having performed the same tasks for more than 3 years. This finding indicated that

employees who have little experience in performing their worktask have a higher risk of developing musculoskeletal problems than their more experienced colleagues. Differences in job content or healthy worker selection may partly explain this result. This finding is also consistent with the findings of Gerr et al (11), who reported a considerable increase in the occurrence of musculoskeletal symptoms during the first year after being hired in a new job.

Previous symptoms

The strongest predictor of new musculoskeletal symptoms for more than 7 days within the last year was previous symptoms (ie, symptoms for <7 days in the year prior to the baseline survey). Westgaard et al (18) used previous symptoms as an indicator of individual sensitivity to the development of symptoms; however, previous symptoms were defined differently than in the present paper. If some office workers almost never experience symptoms, "previous symptoms" may also here indicate a higher sensitivity among some persons. However, the high incidence relative to the prevalence also indicated that the nature of musculoskeletal symptoms is dynamic even from one year to another. Thus most respondents with symptoms may experience infrequent symptoms during some years and more frequent symptoms during others. An additional explanation for the relatively high risk associated with previous symptoms could be misclassification of the duration of symptoms. Thus respondents with symptoms for 1–7 days within the last year at baseline were more likely to report >7 days of symptoms at follow-up than respondents with no symptoms at baseline simply due to errors of recall. Thus no conclusive interpretation of the risk associated with this factor can be made.

Psychosocial factors

Low influence at work was a risk factor for the development of neck symptoms. Among the women low or medium low influence at work was also a risk factor for hand-wrist symptoms. Questions on influence at work primarily referred to the possibilities for the employees to organize their own work. The higher risk of developing symptoms for those with low influence could be due to the lack of possibilities to take breaks if needed and to plan the sequence of worktasks in a way that was most comfortable for the individual employee.

Women with high sensorial demands were more likely to develop hand-wrist symptoms than women with medium low demands. This finding emphasized the importance of specific job demands and job control as work environment factors that predict the health of computer users. Faucett & Rempel (5) also reported that low job control was associated with an increased prevalence of symptoms. In my study several dimensions of job demands were examined, as it is important to identify the specific dimension(s) that predict the development of symptoms. The dimensions (indices) and the questions contained in each index were developed by Kristensen et al (14), who used these questions in psychosocial surveys of people from the general workforce. When compared with their data, respondents who used computers for a large part of their worktasks in the present study were exposed to high sensorial demands when compared with those with many other job types. Furthermore, high sensorial demands provide an especially relevant focus during computer work, as a poorly designed user interface may increase the demands for vision and precision more than necessary. Such demands may increase the duration of static work postures and thereby the risk of developing musculoskeletal symptoms.

A surprising finding in the present study was the lower risk of developing neck symptoms among the men with less than good computer skills as compared with those with good skills. Probably low skills do not have a preventive effect, but other factors that could explain this association were not characterized well enough to exclude computer skills from the final model of the multivariate analyses. The association was not found for the women.

Workplace design

It is generally agreed that workplace design can affect the risk of developing musculoskeletal symptoms (2). A recent longitudinal study used workplace observations to identify postural factors that were risk factors for the development of symptoms among computer users in relation to workplace design (12). However, the study also reported a lack of association between several postural factors and the development of symptoms. Except for factors easily assessed by respondents, it is difficult to study or control factors related to workplace design in a questionnaire study. In the present study a screen height with the top of the screen above eye level was found to predict neck symptoms among women. This finding is consistent with generally accepted recommendations for optimal workplace design. However, the same phenomenon was not found for the men. The risk of developing symptoms when workplace design is nonoptimal may be due to work in postures that are constrained and involve more static muscle loads than otherwise needed.

Concluding remarks

To prevent hand-wrist symptoms among computer users with normal workhours (32–41 hours/week) computer

use should be limited to less than three-fourths of the worktime. Worktasks requiring mouse use for at least one-half of the worktime were found to be associated with an increased risk of hand-wrist symptoms. Furthermore, low and medium low influence at work predicted both neck symptoms for women and hand-wrist symptoms for women and men. Associations between symptoms and sensorial demands, good computer skills, low duration of employment in the same job, and screen height were not consistently observed for both women and men and should therefore be interpreted with caution.

Acknowledgments

The BIT study was initiated as part of research collaboration involving both epidemiologic and laboratory studies focusing on the musculoskeletal problems of computer users. Therefore, I thank K Hansen, AK Blangsted, L Finsen, K Søgaard, CU Ryholt, H Burr, E Villadsen, and H Christensen for their efforts during the course of the BIT study.

References

1. Jensen C, Finsen L, Søgaard K, Christensen H. Musculoskeletal symptoms and duration of computer and mouse use. Int J Ind Ergron 2002;30:265–75.
2. Punnett L, Bergqvist U. Visual display unit work and upper extremity musculoskeletal disorders: a review of epidemiological findings. Stockholm: National Institute for Working Life; 1997. p 1–161. Ergonomic expert committee document no 1.
3. Jensen C, Ryholt CU, Burr H, Villadsen E, Christensen H. Work-related psychosocial, physical and individual factors associated with musculoskeletal symptoms in computer users. Work Stress 2002;16(2):107–20.
4. Bernard B, Sauter S, Fine L, Petersen M, Hales T. Job task and psychosocial risk factors for work-related musculoskeletal disorders among newspaper employees. Scand J Work Environ Health 1994;20:417–26.
5. Faucett J, Rempel D. VDT-related musculoskeletal symptoms: interactions between work posture and psychosocial work factors. Am J Ind Med 1994;26:597–612.
6. Karlqvist L, Hagberg M, Köster M, Wenemark M, Ånell R. Musculoskeletal symptoms among computerassisted design (CAD) operators and evaluation of a self-assessment questionnaire. Int J Occup Environ Health 1996;2:185–94.
7. Fogleman M, Lewis RJ. Factors associated with self-reported musculoskeletal discomfort in video display terminal (VDT) users. Int J Ind Ergon 2002;29:311–8.
8. Jensen C, Borg V, Finsen L, Hansen K, Juul-Kristensen B, Christensen H. Job demands, muscle activity and musculoskeletal symptoms in relation to work with the computer mouse. Scand J Work Environ Health 1998;24:418–24.
9. Bergqvist U, Wolgast E, Nilsson B, Voss M. Musculoskeletal disorders among visual display terminal workers: individual, ergonomic, and work organizational factors. Ergonomics 1995;38:763–76.
10. Polanyi MFD, Cole DC, Beaton DE, Chung J, Wells R, Abdolell M, et al. Upper limb work-related musculoskeletal disorders among newspaper employees: cross-sectional survey results. Am J Ind Med 1997;32:620–8.
11. Gerr F, Marcus M, Ensor C, Kleinbaum D, Cohen S, Edwards A, et al. A prospective study of computer users: I. Study design and incidence of musculoskeletal symptoms and disorders. Am J Ind Med 2002;41:221–35.
12. Marcus M, Gerr F, Monteilh C, Ortiz DJ, Gentry E, Cohen S, et al. A prospective study of computer users: II. Postural risk factors for musculoskeletal symptoms and disorders. Am J Ind Med 2002;41:236–49.
13. Bergqvist U, Knave B, Wibom R, Voss M. A longitudinal study of VDT work and health. Int J Hum Comput Interact 1992;4:197–219.
14. Kristensen TS, Borg V, Hannerz H. Socioeconomic status and psychosocial work environment: result from a national Danish study. Scand J Public Health 2002;30:41–8.
15. Kuorinka I, Jonsson B, Kilbom Å, Vinterberg H, Biering-Sørensen F, Andersson G, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl Ergon 1987;18:233–7.
16. Karlqvist L, Bernmark E, Ekenvall L, Hagberg M, Isaksson A, Rostö T. Computer mouse and trackball operation: similarities and differences in posture, muscular load and perceived exertion. Int J Ind Ergon 1999;23:157–69.
17. Wahlström J, Svensson J, Hagberg M, Johnson PW. Differences between work methods and gender in computer mouse use. Scand J Work Environ Health 2000;25:390–7.
18 Westgaard RH, Jensen C, Hansen K. Individual and work-related risk factors associated with symptoms of musculoskeletal complaints. Int Arch Occup Environ Health 1993;64:405–13.

Received for publication: 21 August 2002