Original article

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Computer users' risk factors for developing shoulder, elbow and back symptoms

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Objectives This prospective study concentrated on determining factors of computer work that predict musculoskeletal symptoms in the shoulder, elbow, and low-back regions.

Methods A questionnaire on ergonomics, work pauses, work techniques, and psychosocial and work factors was delivered to 5033 office workers at baseline in early 1999 (response rate 69%) and to 3361 respondents at the time of the follow-up in late 2000 (response rate 77%). An increased frequency or intensity of symptoms was the outcome variable, including only nonsymptomatic respondents from the baseline questionnaire (symptom frequency below 8 days within the last 12 months or intensity score below 4 within the last 3 months).

Results In the follow-up, 10%, 18%, and 23% had symptoms more often in the elbow, shoulder, and low back, respectively, and 14%, 20%, and 22% had more intense symptoms. Women were more likely to be afflicted than men in all regions. In the full-fit multivariate logistic regression analysis, little influence on the timing of a rest pause and being disturbed by glare or reflection were significant predictors of shoulder symptoms, screen below eye height was a significant predictor for elbow symptoms, and previous symptoms was a significant predictor for symptoms in all regions. Computer worktime and psychosocial dimensions were not significant predictors.

Conclusions Influence on work pauses, reduction of glare or reflection, and screen height are important factors in the design of future computer workstations. Since previous symptoms was a significant predictor of recurrent symptoms in all three regions under study, it can be concluded that musculoskeletal symptoms are persistent.

Key terms computer work, Behavior in Information Technology follow-up study, glare, reflection, musculoskeletal symptoms, pause, prospective study, screen height.

In general, both physical and psychosocial factors of computer work, including daily duration of computer work, repetitive movements, static and nonneutral wrist, arm and neck work postures, lack of variation and psychosocial factors, have been found to be risk factors for musculoskeletal symptoms in different regions of the body (1, 2). In an extensive review of epidemiologic findings among computer users, evidence was found for determinants of postural strain, such as poor workstation ergonomics, to be involved in musculoskeletal problems among computer users, but, as mentioned earlier, most of the evidence is based on the results of cross-sectional studies (3). Most of the studies have concerned symptoms in the neck and shoulder, while few studies have focused on the elbow or low back.

Although it is well known that, in many precision-demanding computer tasks, shoulder muscles must work as stabilizers, and thereby they primarily perform static work (4, 5), a limited number of prospective studies on risk factors for symptoms in the neck or shoulder have been carried out among computer users. A 2-year follow-up study of 2500 computer users, called the BIT (Behavior in Information Technology) study, with the same population as in our present study found that screen height above eye level was a significant predictor of neck symptoms among women (6). In addition to physical factors, previous symptoms and little influence at work were predictors of symptoms in the neck and hand–wrist region (6). In another prospective study of 632 newly hired computer users, keying with the elbow

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below the height of the "J" key and the presence of a telephone shoulder rest were associated with an increased risk of neck–shoulder symptoms or disorders (7). A recent prospective study of 180 workers who used video display units (VDU) found a poor physical work environment and a poor placement of the keyboard to be predictors of neck pain (8).

Risk factors for symptoms in the elbow have been found to be forceful movements and the combination of force, repetitiveness, and nonneutral postures (9, 10), but contradictory results have been published with respect to computer work and the development of elbow pain. A prospective study of 5658 computer users (NUDATA study) showed that intensive use of a mouse (>20 hours a week) was a predictor of pain in the forearm, but with very few clinical signs in the forearm (11). A recent case-referent study (267 cases and 388 referents) found nonneutral postures, repetition, and, for women, low social support to be related to epicondylitis, while the results for precision-demanding movements were less consistent, because of the lack of exposed persons (10). Furthermore, individual factors, such as age, work seniority, and previous elbow complaints, had a significant influence (12).

Nonneutral work postures have been found to be risk factors for low-back symptoms in addition to lifting, forceful movements, heavy physical work, and whole-body vibration (9), but little has been published with regard to sitting and, especially, computer work in relation to the development of low-back symptoms. In a review (13), sitting at work was not associated with low-back pain when compared with standing, lifting and bending in seven studies. One cross-sectional study from this review found that the "poorer" the sitting habits, the higher the 1-year prevalence of low-back pain, but "poor sitting habits" was not defined (14). Another cross-sectional study from the review found that specific tasks performed while sitting (rather than sitting itself) in ergonomically unfit chairs were associated with low-back pain (15). In a 5-year follow-up study people changed jobs from physically hard work to sedentary work to a higher extent when having developed low-back pain, and sitting was therefore suggested to have a protective or neutral effect on the low back (16).

Altogether, few prospective studies have shown that factors related to computer work are significant predictors of musculoskeletal symptoms in the shoulder, elbow, and low back. The aim of this study was to investigate self-reported factors related to computer work in a prospective study as possible predictors of future musculoskeletal symptoms in shoulder, elbow, and low back. The main hypothesis was that the duration of worktime with a computer, ergonomic and psychosocial factors, other than individual factors, were risk factors for the development of symptoms in the shoulder, elbow, and low back.

Study population and methods

Study population

A baseline questionnaire concerning physical and psychosocial work conditions and health status was given to 5033 office workers in Denmark in the beginning of 1999, and 69% responded (N=3475). The target population was represented by a total of 11 Danish companies and institutions employing computer users, and the companies were selected to provide employees with different types of computer work (ie, data entry, word processing, graphic work, etc). 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. All the employees of an entire company or in specific predefined departments were included, except cleaning and kitchen personnel. The questionnaires were returned in sealed envelopes at their workplace and later collected by a representative from the National Institute of Occupational Health. Results from the cross-sectional study concerning psychosocial, physical, and individual factors and symptoms related to the duration of computer and mouse use have been presented previously (17, 18). A follow-up questionnaire primarily consisting of questions on health status was mailed at the end of 2000 to 3471 of the earlier respondents, whose home address was known from the baseline questionnaire. Of these, 108 respondents had changed their 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. Risk factors for neck and hand–wrist symptoms (6) have been focused on in another paper on the follow-up study. The questionnaires distributed at baseline and at the time of the follow-up contained questions on musculoskeletal symptoms (trouble, ache or pain, here denoted as symptoms) according to a modified version of the Nordic questionnaire (19).

We used two outcome parameters separately. First, case definition was defined by an increase in the frequency of days with musculoskeletal symptoms during the last 12 months, from <8 days in the baseline questionnaire (nonsymptomatic) to >7 days in the follow-up questionnaire (symptomatic). Frequency has been used as the outcome parameter in many recent epidemiologic and intervention studies (6, 20, 21), and it is, therefore, a variable that can be compared with the findings in other datasets. Second, case definition was defined by an increase in the mean intensity of musculoskeletal symptoms during the last 3 months, from <4, rated on a

scale from 0 to 9, to ≥4. The validity and reproducibility of this question has been tested and found to be satisfactory with respect to the 3-month period used in our study (22, 23). The case definitions for the shoulder and elbow stated that the participants had to change from nonsymptomatic on both the right and the left sides at baseline to symptomatic either on the right, the left, or both sides. The included workers also had to be nonsymptomatic in the nearby body regions at baseline, meaning, for the shoulder, also in the neck and elbow regions, for the elbow, also in the shoulder and hand, and, for the low back, also in the neck region.

Exposure parameters from the questionnaire

The exposure parameters from the baseline questionnaire consisted of physical, psychosocial, work-related, and individual questions. The physical parameters included the six ergonomic parameters of (i) whether the chair had been individually adjusted (yes, no), (ii) whether the desk had been individually adjusted (yes, no), (iii) whether there was enough space to rest the arms on the desk in front of the keyboard (yes, no), (iv) whether the upper line of the mostly used screen was below eye height (yes, no), (v) how much of the worktime was spent standing up at the desk (six categories dichotomized to never versus seldom-to-100% of the time), and (vi) how often there were disturbances of glare or reflection on the screen (four categories dichotomized as everyday-to-sometimes a week versus now-and-then to never). Additional physical parameters were included, consisting of the influence on when to take a rest pause (five categories dichotomized to always-to-often versus sometimes-to-never) and how often it was necessary to work very fast (five categories dichotomized to never-to-sometimes versus often-to-always).

Psychosocial dimensions 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 (24). The psychosocial dimensions included the following five indices: cognitive demands (7 questions on decision making, memory demands, creativity and responsibilities, Cronbach's alpha=0.83), sensory demands, (3 questions on visual demands, precision and attentiveness, Cronbach's alpha=0.70), influence at work (7 questions on influence on what, how and when work is done, influence on quality of work and on who the work is done with, Cronbach's alpha=0.76), developmental possibilities (5 questions on skill demands, development of skills, demands for taking initiative and lack of monotony, Cronbach's alpha=0.81), and social support (4 questions on support from colleagues and superiors, Cronbach's alpha=0.71).

Furthermore, questions related to worktime with a computer (four categories) and three individual factors (gender, age, and previous symptoms) were included in the analyses.

Statistics

The data were analyzed for associations between the exposure parameters reported at baseline and an increased frequency or intensity of symptoms in the shoulder, elbow, or low back at the time of the follow-up. Multivariate logistic regression analyses were performed on three submodels, and a full-fit model, including a work-factor submodel (work time with the computer), an ergonomic submodel (chair, desk, armrest space, screen height, standing work, glare or reflection, influence of workpauses, necessity to work fast), a psychosocial submodel (cognitive and sensory demands, influence at work in general, developmental possibilities and social support), and a full-fit model including all the variables from the work-factor, ergonomic, and psychosocial submodels, including the variable of previous symptoms. Adjustment for gender and age was performed in all the logistic regression analyses. The final logistic regression models were recalculated using only the respondents that did not change jobs between the baseline examination and the follow-up. The procedures proc FREQ, MEAN and GENMOD in SAS (version 8.2, SAS Institute Inc, Cary, NC, USA) were used.

Results

Of the respondents, 20% at baseline and 25% at follow-up had symptoms for >7 days in four or more regions, and the mean number of symptomatic regions was 1.8 in the baseline examination and 2.1 at the time of the follow-up. With regard to the intensity of pain, the mean intensity at baseline was 1.5, and at follow-up it was 1.8. Of those who were defined as nonsymptomatic at baseline, 18%, 10%, and 23% showed an increase in the frequency of symptom days (table 1) for the shoulder, elbow, low-back region, respectively, at the time of the follow-up. In the follow-up, 20%, 14%, and 22% of those who were defined as nonsymptomatic at baseline had an increased intensity of musculoskeletal symptoms in the shoulder, elbow, and low-back regions, respectively (table 1). For all the regions, a higher percentage of women than men had undergone a change (table 1). For both the frequency and intensity outcomes, the region with the highest incidence was the low back, and the lowest incidence was found for the elbow region. The distribution of all the studied variables is presented in tables 2 and 3.

Table 1. Number of men and women who experienced musculoskeletal symptoms between the baseline and the follow-up examinations according to the frequency and intensity of the symptoms.

	Men			Women			Total		
	N	%	N_{total}	N	%	N_{total}	N	%	N_{total}
≥8 days with musculoskeletal symptoms during last 12 months [a]									
Shoulder	57	11	496	141	22	627	198	18	1123
Elbow	38	7	547	94	12	787	132	10	1334
Low back	95	20	484	154	27	580	249	23	1064
≥4 in intensity score of musculoskeletal symptoms during last 3 months [b]									
Shoulder	77	13	574	191	24	791	268	20	1365
Elbow	58	10	604	150	17	865	208	14	1469
Low back	111	20	568	193	24	803	304	22	1371

[a] All respondents with <8 days of musculoskeletal symptoms during the last 12 months at baseline were included.
[b] All respondents with an intensity score of <4 for musculoskeletal symptoms during the last 3 months at baseline were included.

Table 2. Distribution of the individual and physical exposure variables among the participants.

Variable	N	%
Gender		
Men	766	39
Women	1221	61
Age		
>50 years	705	35
40–49 years	600	30
30–39 years	489	25
18–29 years	193	10
Worktime with computer		
<25% of the time never	302	15
50% of the time	369	19
75% of the time	470	24
Almost all the time	822	42
Chair adjusted		
No	181	11
Yes	1528	89
Desk adjusted		
No	319	19
Yes	1381	81
Armrest space		
No	529	27
Yes	1405	73
Screen below eye height		
No	587	30
Yes	1351	70
Standing		
Never	839	43
Seldom-to-always	1129	57
Glares or reflection		
Everyday-to-some times	356	18
Now and then-to-none	1569	82
Work pause		
Small influence	492	25
Large influence	1473	75
Necessary to work fast		
Always-to-some times	1178	60
Seldom-to-never	796	40

Table 3. Distribution of the psychosocial and exposure variables among the participants.

Variable	N	Index value	
		Mean	SD
Cognitive demands	1969	59	18
Sensory demands	1972	74	20
Influence at work	1965	60	18
Developmental possibilities	1971	67	19
Social support	1965	62	19

There was a tendency for worktime with a computer to be a predictor of symptoms in the lower back (table 4). In the ergonomic submodel (table 4), the influence of workpauses and being disturbed by glare or reflection were significant predictors of symptom development in the shoulder, and work with a screen below eye height predicted symptom development in the elbow. The influence of workpauses showed a tendency towards significance for symptoms in the lower back. In the psychosocial submodel (table 4) influence at work and developmental possibilities were significant predictors of symptoms in the shoulder, cognitive demands predicted symptoms in the elbow, and influence at work was a significant predictor for symptoms in the lower back.

In the final model, the full-fit multivariate logistic regression model (table 4), none of the psychosocial dimensions were significant predictors. Having had previous symptoms was significant for symptom development in all regions, both with respect to frequency and intensity, and previous symptoms were also the only significant predictor of symptoms in the back. Furthermore, the influence on workpauses and being disturbed by glare or reflection were significant predictors of symptoms in the shoulder, whereas work with a screen below eye height and a small necessity to work fast were significant predictors for symptoms in the elbow. In general, the highest odds ratios were having had previous symptoms 1–7 days during the last 12 months [odds ratio (OR) 1.40–4.45], little influence on the timing of workpauses (OR 1.87), and work with a screen below eye height (OR 1.85). None of the odds ratios changed markedly when adjusted for those who had the same job at follow-up.

Discussion

Having had previous symptoms 1–7 days during the last 12 months was a significant predictor of symptoms in all the body regions studied, little influence on the timing of workpauses, and being disturbed by glare or reflection were significant predictors of symptoms in the

Table 4. Logistic regression models for respondents with a higher frequency of days and a higher intensity of musculoskeletal symptoms at follow up in relation to work-related factors (adjusted for gender and age). (OR = odds ratio, 95% CI = 95% confidence interval)

Exposure factors	Shoulder			Elbow			Low back		
	OR	95% CI	P-value [a]	OR	95% CI	P-value [a]	OR	95% CI	P-value [a]
Work factor model									
Frequency									
Worked 50% of the time [b]	1.31	0.76–2.28	0.67	1.01	0.53–1.94	0.97	0.94	0.57–1.55	0.51
Worked 75% of the time [b]	1.22	0.72–2.08	..	0.97	0.52–1.81	..	1.03	0.64–1.65	..
Worked almost all the time [b]	1.06	0.63–1.77	..	1.08	0.60–1.93	..	1.25	0.80–1.95	..
Intensity									
Worked 50% of the time [b]	1.23	0.76–1.99	0.42	1.47	0.86–2.49	0.13	**0.86**	**0.54–1.36**	**0.092**
Worked 75% of the time [b]	1.01	0.63–1.62	..	1.02	0.59–1.76	..	**1.02**	**0.66–1.59**	..
Worked almost all the time [b]	1.31	0.84–2.04	..	1.50	0.92–2.47	..	**1.35**	**0.89–2.03**	..
Ergonomic model									
Frequency									
No adjusted chair	1.46	0.75–2.83	0.27	0.82	0.38–1.77	0.61	1.46	0.80–2.67	0.22
No adjusted desk	0.69	0.37–1.29	0.24	1.10	0.57–2.14	0.77	0.84	0.48–1.44	0.52
No armrest space	0.98	0.62–1.55	0.93	1.04	0.62–1.74	0.89	1.04	0.68–1.58	0.86
Screen below eye height	1.02	0.68–1.51	0.94	**1.79**	**1.10–2.93**	**0.015**	1.20	0.83–1.74	0.32
Never standing	1.09	0.72–1.65	0.67	0.81	0.51–1.28	0.38	1.04	0.72–1.50	0.83
Glares or reflection	1.21	0.76–1.92	0.43	1.24	0.74–2.07	0.43	0.94	0.59–1.50	0.79
Pauses, small influence	**1.50**	**0.94–2.39**	**0.090**	1.17	0.70–1.96	0.55	1.36	0.88–2.11	0.17
Necessary to work fast	1.08	0.72–1.61	0.72	1.30	0.82–2.04	0.26	1.04	0.72–1.48	0.84
Intensity									
No adjusted chair	1.29	0.74–2.26	0.37	1.20	0.62–2.32	0.60	1.11	0.65–1.91	0.70
No adjusted desk	1.09	0.66–1.80	0.73	0.90	0.50–1.63	0.73	1.15	0.72–1.83	0.56
No armrest space	1.06	0.71–1.57	0.78	0.94	0.60–1.46	0.77	0.92	0.63–1.35	0.66
Screen below eye height	1.13	0.79–1.60	0.51	1.22	0.82–1.81	0.32	0.98	0.70–1.36	0.89
Never standing	1.07	0.76–1.52	0.70	0.84	0.57–1.23	0.37	1.07	0.77–1.49	0.70
Glares or reflection	**1.51**	**1.04–2.20**	**0.034**	1.30	0.84–2.01	0.25	1.19	0.81-1.74	0.38
Pauses, small influence	**1.54**	**1.03–2.31**	**0.038**	1.31	0.83–2.05	0.24	**1.41**	**0.95–2.10**	**0.087**
Necessary to work fast	0.99	0.70–1.40	0.96	**0.68**	**0.47–1.00**	**0.048**	1.20	0.86–1.67	0.27
Psychosocial model (dimensions covering indices 0–100)									
Frequency									
Cognitive demands	1.00	0.99–1.01	0.87	**1.02**	**1.00–1.03**	**0.040**	1.01	0.99–1.02	0.28
Sensory demands	**1.01**	**1.00–1.02**	**0.094**	1.00	0.99–1.01	0.82	1.00	0.99–1.01	0.65
Influence at work	**0.99**	**0.98–0.99**	**0.036**	0.99	0.98–1.00	0.24	**0.99**	**0.98–1.00**	**0.053**
Developmental possibilities	1.00	0.99–1.02	0.66	0.99	0.98–1.01	0.35	0.99	0.98–1.01	0.33
Social support	1.00	0.99–1.01	0.93	1.00	0.99–1.01	0.56	1.00	1.00–1.01	0.40
Intensity									
Cognitive demands	1.01	1.00–1.02	0.12	1.01	1.00–1.02	0.18	1.00	0.99–1.01	0.45
Sensory demands	1.00	0.99–1.01	0.97	1.00	0.99–1.01	0.53	1.00	1.00–1.01	0.23
Influence at work	0.99	0.98–1.00	0.14	0.99	0.98–1.00	0.18	0.99	0.98–1.00	0.16
Developmental possibilities	**0.99**	**0.98–1.00**	**0.039**	0.99	0.98–1.00	0.17	1.00	0.99–1.01	0.45
Social support	1.00	0.99–1.01	0.93	1.00	0.99–1.01	0.79	1.00	0.99–1.01	0.65
Full-fit model									
Frequency									
Worked 50% of the time [b]	1.23	0.63–2.40	0.29	1.11	0.51–2.40	0.97	0.83	0.46–1.51	0.73
Worked 75% of the time [b]	1.00	0.51–1.94	..	0.95	0.43–2.10	..	0.90	0.50–0.61	..
Worked almost all the time [b]	0.69	0.34–1.39	..	1.08	0.48–2.39	..	1.11	0.61–2.02	..
No adjusted chair	1.53	0.77–3.03	0.23	0.68	0.30–1.56	0.36	1.41	0.75–2.61	0.29
No adjusted desk	0.66	0.35–1.26	0.20	1.03	0.51–2.09	0.93	0.82	0.47–1.44	0.49
No arm rest space	0.91	0.56–1.47	0.69	0.97	0.57–1.68	0.93	0.98	0.63–1.52	0.93
Screen below eye height	1.03	0.68–1.55	0.90	**1.85**	**1.11–3.08**	**0.014**	1.20	0.82–1.75	0.35
Never standing	1.12	0.72–1.72	0.92	0.86	0.53–1.40	0.54	1.16	0.79–1.70	0.46
Glares or reflection	1.08	0.66–0.78	0.76	1.20	0.70–2.07	0.53	0.83	0.51–1.36	0.46
Pauses, small influence	**1.87**	**1.05–3.33**	**0.033**	1.20	0.64–2.27	0.57	1.15	0.68–1.95	0.61
Necessary to work fast	1.01	0.70–1.73	0.68	1.15	0.69–1.92	0.59	1.05	0.71–1.54	0.82
Previous symptoms	**2.89**	**1.97–4.24**	**<0.0001**	**4.45**	**2.75–7.19**	**<0.0001**	**2.40**	**1.70–3.39**	**<0.0001**
Cognitive demands	1.00	0.98–1.02	0.99	1.01	1.00–1.03	0.14	1.01	0.99–1.02	0.30
Sensory demands	1.01	1.00–1.02	0.12	1.00	0.99–1.02	0.56	1.00	0.99–1.01	0.76
Influence at work	1.00	0.98–1.01	0.51	1.00	0.98–1.02	0.98	0.99	0.98–1.01	0.31
Developmental possibilities	1.00	0.99–1.02	0.77	0.99	0.98–1.01	0.46	0.99	0.98–1.01	0.46
Social support	1.00	0.99–1.01	0.66	1.00	0.98–1.01	0.53	1.01	0.99–1.01	0.73

(continued)

Table 4. Continued.

Exposure factors	Shoulder			Elbow			Back		
	OR	95% CI	P-value [a]	OR	95% CI	P-value [a]	OR	95% CI	P-value [a]
Intensity									
Worked 50% of the time [b]	1.07	0.60–1.90	0.68	1.12	0.58–2.18	0.62	0.94	0.54–1.62	0.66
Worked 75% of the time [b]	0.95	0.53–1.70	..	0.90	0.47–1.74	..	1.20	0.70–2.07	..
Worked almost all the time [b]	0.78	0.43–1.43	..	1.08	0.48–2.39	..	1.25	0.72–2.18	..
No adjusted chair	1.14	0.64–2.05	0.66	1.22	0.61–2.43	0.57	1.21	0.76–1.95	0.89
No adjusted desk	1.11	0.66–1.86	0.71	0.90	0.49–1.65	0.73	1.21	0.76–1.95	0.43
No arm rest space	0.95	0.63–1.43	0.80	0.89	0.56–1.41	0.62	0.92	0.62–1.36	0.66
Screen below eye height	1.16	0.80–1.68	0.42	1.20	0.80–1.80	0.38	0.98	0.69–1.37	0.89
Standing, never	1.11	0.77–1.60	0.59	0.88	0.59–1.31	0.53	1.34	0.81–1.60	0.47
Glares or reflection	**1.55**	**1.05–2.30**	**0.031**	1.22	0.78–1.93	0.39	1.14	0.77–1.69	0.51
Pauses, small influence	**1.58**	**0.96–2.60**	**0.072**	1.06	0.62–1.82	0.83	1.37	0.85–2.22	0.20
Necessary to work fast	0.98	0.67–1.43	0.90	**0.59**	**0.39–0.90**	**0.014**	1.14	0.80–1.63	0.47
Previous symptoms	**1.64**	**1.18–2.29**	**<0.001**	**2.10**	**1.41–3.14**	**<0.002**	**1.40**	**1.02–1.92**	**0.045**
Cognitive demands	1.01	0.99–1.02	0.33	1.01	0.99–1.02	0.39	1.00	0.99–1.02	0.50
Sensory demands	1.00	0.99–1.01	0.65	1.01	0.99–1.02	0.31	1.00	0.99–1.01	0.65
Influence at work	0.99	0.98–1.01	0.34	0.99	0.98–1.00	0.14	1.00	0.99–1.01	0.56
Developmental possibilities	0.99	0.98–1.01	0.41	1.00	0.99–1.02	0.86	1.00	0.99–1.01	0.75
Social support	1.00	0.99–1.01	0.84	1.00	0.99–1.01	0.44	0.99	0.99–1.00	0.13

[a] P-value refers to the likelihood-ratio test, and those below 0.10 are in bold face.
[b] With a computer.

shoulder, whereas work with a screen below eye height was a significant predictor of symptoms in the elbow.

An important strength of our study was its prospective design, including measurements of the exposure prior to the occurrence of symptoms. In comparison with the design of previous cross-sectional studies, this approach offered the possibility to identify predictors of increased symptoms. People who change jobs are more likely to be relieved of their pain (25). In order to control for exposure at follow-up, we repeated the use of the final model for each of the three regions including only the workers who, in the follow-up questionnaire, had not changed jobs since the baseline examination. In these analyses the predictors for becoming symptomatic were confirmed, as the odds ratios did not change markedly.

As in most epidemiologic studies, our outcome and exposure variables were self-reported. In order to obtain a broad pattern of symptoms, we used two variables as the self-reported outcome variables, the frequency and intensity of symptoms. The question concerning frequency, which covered days of symptoms within the last 12 months, rated on a 5-point scale, was fairly easy to answer, although recall bias may have caused a problem, as in many other epidemiologic studies. Furthermore, it is the most used outcome variable in recent epidemiologic and intervention studies. The mean intensity of symptoms, which covered only the last 3 months, rated on a 0–9 point scale, was a more complicated problem, as it had to be weighted individually according to the worst and least intensity of the same period. It is a variable that is becoming used more and more in epidemiologic studies as a supplement to the frequency variable. The cut-off point of ≤7 days and the intensity score of ≤3 were selected as arbitrary cut-off points so that a large study population would be included. Moderate correlations (R^2 0.36–0.45) were found between the frequency and intensity variable. This result indicated that frequency and intensity are different measures of self-reported symptoms. Furthermore, as only a few of the significant predictors were the same for the frequency and the intensity outcome variables, we considered it important to include both outcome variables in the analyses. Although many studies have used the terminology neck–shoulder as one region, we defined the two regions separately in this study, shown in the drawing of the questionnaire lay-out, and, thereby, retained the possibility to look for specific risk factors in the regions separately. In addition, only a few of the respondents (9.8% for frequency and 11.2% for intensity) had developed symptoms in both the neck and shoulder region by the time of the follow-up.

As with the outcome variable, the general problem of using self-reported data in epidemiologic studies also exists for exposure variables, and, consequently, only the variables easily assessed by respondents can be studied. Self-reported exposures measure perceived job demands and therefore do not necessarily reflect objective measured job demands (26). Other conditions that may influence self-reported exposures are the presence of musculoskeletal symptoms (27). One of the exposure variables " influence on when to take a workpause", was not included in the variable "influence at work", although a significant and relatively high correlation (R^2=0.55) was found between the two variables. In the full-fit model, however, only the influence on workpauses was

significant. When we omitted the pause variable for each of the three body-region models, influence at work did not become significant. This result confirmed that the two represented different conditions and emphasized the importance of having both variables in the statistical models.

Having had previous symptoms was a significant predictor of symptoms in the shoulder, the elbow, and the low back, as has also been found in previous studies (6, 12, 28). This finding underlines a chronicity aspect (ie, that musculoskeletal pain may have a progressive course towards chronicity) that begins with intermittent periods of pain and ends in a more continuous or persistent period of pain.

Although many cross-sectional studies have found that worktime with a computer is a risk factor for almost all body regions (29), our study did not confirm this finding for any of the tested regions. In addition our results are in contrast to the findings of a cross-sectional study of the same population (17, 18). This difference emphasized the importance of performing prospective studies when risk factors are to be studied. Thus, so far, the best evidence for worktime with a computer as a predictor of future musculoskeletal symptoms has been found in prospective studies on the hand and wrist (6, 7, 30), and also for those on the duration of mouse use with respect to the forearm and shoulder (11, 31).

A small influence on when to take a rest pause, which includes biomechanical elements such as decreased restitution periods leading to pain or even clinical diagnoses, has been found in several studies. A cross-sectional study found a lower frequency of muscular rest periods (EMG gaps) in the shoulder muscle (trapezius) of persons with pain in the trapezius area than in healthy controls (32). A few prospective studies have also found that a low frequency of muscular rest periods for the trapezius muscle is a predictor of trapezius myalgia (33) and that repetitive work with a low recovery time was a predictor of symptoms and of clinical signs in the neck and shoulder area (34).

In addition, being disturbed by glare or reflection was a significant predictor of symptoms in the shoulder as well; this finding may be explained by a changed work posture being adopted in order to avoid or decrease the inconvenience of the glare or reflection, which have also been found to predict neck symptoms (6). In general, a large index number within the psychosocial dimensions has previously been found to be associated with increased symptoms in the shoulder in cross-sectional and prospective studies of repetitive work (35–38). Surprisingly, none of these dimensions were significant in our full-fit model, although in the psychosocial submodel sensory demands, influence at work and developmental possibilities were significant predictors of symptoms in the shoulder, cognitive demands predicted symptoms in the elbow, and influence at work predicted symptoms in the low back. In an earlier report from the BIT study, low influence at work was reported to be a predictor of symptoms primarily in the hand and wrist (6), but our study did not confirm this finding.

For women, a computer screen placed in a high position (above eye height) has been found to be a predictor of neck symptoms (6), whereas, in our study, a screen below eye height was a significant predictor of symptoms in the elbow. This difference may be explained by a combined low screen and keyboard height, which would decrease the possibility to rest and relax the elbow and forearm sufficiently. A low satisfaction with the physical arrangement of the computer workstation and workers' perception of their workstation as being poor ergonomically has also been found to be associated with an increased prevalence of pain in the neck and upper extremities in cross-sectional studies (39, 40). Important risk factors for lateral epicondylitis are nonneutral postures of the hands and arms and a combination of nonneutral postures of hands and arms, repetition, and forceful work (10). One of the main diagnoses related to forearm pain, lateral epicondylitis, has been found to include degenerative signs of the tendons around the lateral epicondyle (especially the tendon of the radial extensor muscle of the wrist) (41). As often found during the use of traditional computer input devices (text-entering and text-editing work), characterized as low force pronation and wrist extension, the radial extensor muscle of the wrist has high muscle activity (42). The fact that a great necessity to work fast decreased the risk of symptoms in the elbow could not be explained.

None of the variables studied were significant for the development of symptoms in the low back in the final full-fit model, despite tendencies towards significance for influence on pauses, influence at work, and worktime with the computer in the ergonomic and psychosocial submodels. A small influence on when to take a workpause, meaning a longer duration of sitting, was expected to have an influence on the back, as also found previously (15). In contrast, a systematic review found no evidence of an effect on low-back pain for prolonged sitting (43).

In conclusion, a small influence on when to take a workpause and being disturbed by glare and reflection of the screen were predictors of symptoms in the shoulder, while a screen below eye height was a significant predictor of symptoms in the elbow. Having had previous symptoms was a predictor of future symptoms in all the regions studied, and this result emphasizes the persistence of musculoskeletal symptoms. In contrast to the results of other studies, worktime with the computer and psychosocial dimensions were not significant predictors of symptoms in the shoulder, elbow, or low back.

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