ORIGINAL ARTICLE

The influence of working conditions and individual factors on the incidence of neck and upper limb symptoms among professional computer users

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Abstract

Objectives   To assess the influence of working conditions and individual factors on the incidence of neck and upper limb symptoms among professional computer users.

Methods   The study is a prospective cohort study with an observation period of 10 months. A baseline questionnaire about symptoms in the neck, shoulder and arm/hand during previous month, individual factors, work content, physical and psychosocial work-related exposures was answered by 1,283 computer operators (response rate 84%). Incidence data were collected by ten monthly questionnaires regarding the occurrence of symptoms categorized into three gross body regions: neck, shoulders and arms/hands. A case, in the specific gross body region, was defined as a subject who was classified as non-symptomatic in that region at baseline or during minimum one follow-up period and later reported symptoms ($\geq$3 days). Univariable and multivariable incidence rate ratios with 95% confidence intervals for first occurrence of neck, shoulder and arm/hand cases, respectively, were calculated with Cox regression analysis.

Results   The incidence rate was 67, 41 and 47 cases per 100 person years for neck, shoulder and arm/hand symptoms, respectively. In the multivariable analyses, comfort of the computer work environment and gender were related to the incidence of symptoms in all body regions (RR = 1.5–1.9 for low comfort and 1.8–2.1 for females, respectively). Duration of mouse use predicted arm/hand symptoms (RR = 1.7 for $\geq$3 h/day) and job strain (high demands and low decision latitude) predicted neck symptoms (RR = 1.6 and 2.2 for medium and high strain, respectively). Additionally, age was related to neck and shoulder symptoms.

Conclusion   Preventive strategies to reduce neck and upper limb symptoms among computer users should include measures to reduce mouse use, to increase the comfort of the work environment and to reduce job strain. Although the effect estimates were relatively weak to moderate, preventive measures may have a marked impact on the incidence of neck and upper limb symptoms in the general population because of the widespread use of computers in working life as well as at home.

Keywords   Computer work · Incidence rate ratios · Musculoskeletal symptoms · Prospective cohort study · Work-related risk factors

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Introduction

Seventy percent of the Swedish working population use computers at work and 15% report using a computer almost all the time (Work Environment Authority and Statistics Sweden 2008). Neck and upper limb symptoms are common among computer users (Ekman et al. 2000). In computer intensive work sectors as, e.g., office and customer service work, where 38% of the employees report using a computer almost all the time, 40% experience weekly pain in the upper back or neck and 37% experience pain in the shoulders or arms compared with 34 and 32%, respectively, in the general working population (Work Environment Authority and Statistics Sweden 2008).

These symptoms have multifactorial origin and individual and both work and non-work-related physical and psychosocial factors may contribute to the development and impairment (Bongers et al. 2006). Several cross-sectional studies have shown a relationship between exposures related to computer work and subjective complaints in the neck and upper limbs (Karlqvist et al. 1996; Blatter and Bongers 2002; Fogelman and Lewis 2002; Jensen et al. 2002a, b). Additionally, recent longitudinal studies support a cause–effect relationship between intensive computer use or other computer work-related exposures and complaints in the neck and upper limbs (Gerr et al. 2002; Marcus et al. 2002; Jensen 2003; Andersen et al. 2003; Korhonen et al. 2003; Kryger et al. 2003; Brandt et al. 2004; Juul-Kristensen et al. 2004; Lassen et al. 2004; Juul-Kristensen and Jensen 2005; Rempel et al. 2006; IJmker et al. 2007; Andersen et al. 2008).

The aim of this study was to assess the influence of working conditions and individual factors on the incidence of neck and upper limb symptoms among professional computer users.

Methods

Study design

This study is a prospective cohort study with an observation period of 10 months. A self-administered questionnaire at baseline was used to assess individual and life-style factors, work content, physical and psychosocial exposures during work, and information about symptoms in the neck and upper limbs. Incidence data were collected during the observation period, identifying cases by a monthly short questionnaire regarding the occurrence of symptoms in the neck and upper limbs.

Together with the employers and the Occupational Health Care Centers, 46 different worksites or departments from both the private and the public sector were selected to achieve contrasts regarding computer work duration and type of computer work tasks. The number of employees at these sites varied between 7 and 260 persons. All employees with seniority of at least 1 month in the present job and without any additional employment exceeding 25% of a full-time employment were included in the study population. The questionnaires were distributed and recollected by ergonomists at the Occupational Health Care Centers. The study was approved by the local ethics committee at the Karolinska Institute and the regional ethics committee at the University of Gothenburg. All participants gave their informed consent prior to their inclusion in the study.

Study population

The study population included 1,529 employees from a variety of occupations. The baseline questionnaire was answered by 1,283 subjects, 498 men and 785 women with a mean age of 44 years (range 20–65) (Fig. 1). The response rate was thus 84%, and the main reason for not participating was refusal. The average follow-up time from baseline was 320 days (range 0–540).

The participants included the following occupations; administrators ($n = 115$), call-centre operators ($n = 57$), computer support personnel ($n = 23$), engineers ($n = 186$), graphics industry operators ($n = 121$), handling officers/investigators ($n = 138$), insurance officers ($n = 169$), librarians ($n = 83$) managers/marketing officers ($n = 92$), medical secretaries ($n = 72$), messengers ($n = 53$), occupational health personnel (39), receptionists (14), university teachers/researchers ($n = 121$). The participants had the same or similar work tasks since in average 12 years (SD 10) and had used computers since 11 years (SD 7). They worked in average 38 h/week (SD 5) and computer work represented
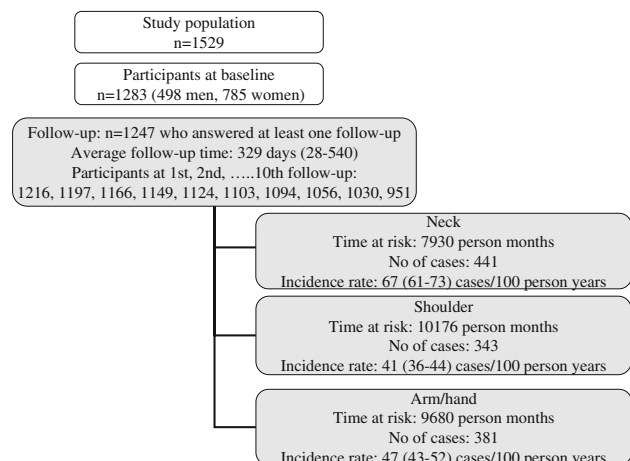

Fig. 1 Flow chart of the enrolled study population, participants at baseline and follow-up and incidence rates for neck, shoulder and arm/hand symptoms, respectively

in average 48% (SD 23) of their working hours. Information about computer work tasks, physical and psychosocial working conditions is presented elsewhere (Karlqvist et al. 2002).

Out of those 1,283 subjects who answered the baseline questionnaire, 1,247 answered at least one follow-up questionnaire whereof 1,216 subjects responded to the first and 951 to the last follow-up questionnaire (Fig. 1). The average follow-up time from baseline among those who answered at least one follow-up questionnaire was 329 days (range 28–540). There were some differences between dropouts and subjects remaining until the 10th follow-up. The prevalence of neck symptoms at baseline was significantly higher (55 and 45%, Chi-square $P = 0.002$) and the mean age slightly lower (43 and 44 years, Chi-square $P = 0.02$) among dropouts compared with subjects remaining. No significant differences were, however, observed regarding the prevalence of shoulder and arm/hand symptoms or daily duration of computer work.

Questionnaire

The occurrence of symptoms in the neck and upper limbs, work-related exposures during the preceding month and individual and life-style factors were assessed at baseline by a self-administered questionnaire containing 88 items (http://www.amm.se/eng). The questions about symptoms referred to the duration (days) of pain or ache during the preceding month in the following regions: the neck, right and left scapular area, shoulder joint/upper arm, elbow/forearm, wrist and hand/fingers (including numbness in the hand/fingers), respectively. Information about symptoms prior to the preceding month was not asked for.

The present paper includes exposures related to work content; daily duration of computer work, duration of data/text entry, duration and frequency of continuous computer work without breaks, duration of mouse (or other non-keyboard input device) use, variation of work tasks; physical exposures; mouse placement, comfort of the computer work environment, psychosocial exposures; job demands in relation to competence, job strain, social support and individual factors; sex, age and educational level. Additionally, potential effects of body mass index (BMI), number of children at home, nicotine use and physical training were investigated.

Description of work-related exposures and related questionnaire items

Duration of computer work　Computer work was one item in a question regarding the percentage of working time spent on nine specified work tasks; computer work, typewriting, telephoning, non-computer desk work (e.g.,

reading and writing, calculating, drawing by hand), copying and bringing material, teaching, meetings (formal), discussions with co-workers (informal), rest-breaks, and one unspecified "other" work task. The sum of the percentage given for each task comprised 100% of the working time and the duration, hours/day, of computer work was calculated from the percentage of time spent on this task and the number of working hours.

Duration of data/text entry　Data/text entry was one item in a question regarding the percentage of time spent on nine specified computer work sub-tasks; data/text entry from source document, authoring own texts, layout and graphics, construction and design, economic and personnel administration, data treatment and statistics, programming, e-mailing, internet search and one unspecified "other" computer task. The sum of the percentage given for each computer task comprised 100% of the duration of computer work and the duration, hours/day, of data/text entry was calculated from the percentage of time spent on this sub-task and the duration of computer work (above).

Duration and frequency of continuous computer work without breaks　Ratings of the longest period of continuous computer work without a break (>10 min), 7-graded scale from <1 to >6 h, in combination with ratings of how often this happened, 4-graded scale from very occasionally to daily or almost daily.

Duration of mouse (or other non-keyboard input device) use　Ratings of the percentage of the computer working time spent using the mouse (or other non-keyboard input devices) and the keyboard, respectively. The sum of the percentage given for each device comprised 100% of the duration of computer work and the duration, hours/day, was calculated from the percentage of time spent with mouse use and the duration of computer work (above).

Variation of work tasks　This exposure was based on the question regarding the percentage of working time spent on nine specified work tasks and the calculated duration, hours/day, of each task (see "Duration of computer work"). Exposure was categorized from the number of tasks that constituted on average of at least 30 min/day.

Mouse placement　The mouse position was marked on a drawing illustrating the work table and the operator's position. Mouse placement within forearms length and shoulder width was considered as "optimal", otherwise "non-optimal" exposure (Karlqvist et al. 1996).

Comfort of the computer work environment　Ratings of 11 variables related to the comfort of the computer work

environment (general lighting, workstation lighting, dazzling/reflections on the screen, noise level, indoor climate, chair, work posture, work space, screen position, keyboard and mouse position), a 9-graded scale from −4, very, very bad to +4, very, very good. Exposure was categorized from the sum score, range −44 to +44 (Karlqvist et al. 1996).

Job demands in relation to competence   Ratings of demands at work in relation to competence, 6-graded scale from "considerable above my level of competence" to "considerable below my level of competence" and "do not know".

Job strain   Ratings of job demands (five items) and decision latitude (four items about possibilities to learn and develop and two about authority over decisions) used 4-graded scales from "almost never/never" to "often" (1–4) (Karasek 1979; Theorell et al. 1988; Toomingas et al. 1997). An index score for job demands was calculated by adding scores from the five items (range 5–20; the higher score the higher job demands). A similar index score for decision latitude was calculated by adding scores from the combined six items (range 6–24; the higher score the higher decision latitude). Exposure was categorized from the combinations of the job demand and decision latitude scores.

Social support   Ratings of social support at work, six items, 4-graded scales from "strongly agree" to "strongly disagree" (1–4) (Toomingas et al. 1997). An index score was calculated by adding scores from the six items (range 6–24; the higher score the better social support).

Follow-up

Incidence data were collected by ten monthly questionnaires regarding the occurrence of neck and upper limb symptoms. The questions referred to the time period following the preceding questionnaire, which usually covered approximately 1 month. This period could be longer due to vacations or other reasons for absence. If a follow-up questionnaire was not returned before the next one appeared, the time frame considered for reporting symptoms covered the whole period since the previous questionnaire, i.e., approximately 2 months. If two consecutive questionnaires were missing, the person–time for that subject was terminated at the time when the last questionnaire was completed.

Data treatment and analysis

Symptoms were defined as reports of pain or aches in any of the body regions asked about, or numbness in the hand/fingers, ≥3 days during the preceding month. Symptoms in the specific body regions were compiled into three gross body regions: (a) neck and/or scapular area (here called

neck), (b) shoulder joints/upper arms (here called shoulders), (c) elbows/forearms and/or wrists and/or hands/fingers (here called arms/hands). Subjects reporting symptoms ≤2 days in all regions included in the respective compiled region (a–c) were regarded as non-symptomatic for this region.

A case, in the gross body region, was defined as a subject who was classified as non-symptomatic in that region at baseline or during minimum one follow-up period and later reported symptoms. Only first-time cases were considered. The incidence rate was calculated as the frequency of cases divided by the total person–time at risk over the period (Rothman and Greenland 1998). Cases contributed with a person–time corresponding to the period between the dates of the questionnaires when they were non-symptomatic for the first time and when they for the first time during follow-up became a case. Subjects who did not become a case during the follow-up contributed with a person–time corresponding to the period between the dates when they were non-symptomatic for the first time and when they filled in their last follow-up questionnaire.

The subjects were categorized into a low exposed "reference" group and generally into two exposure levels, a "medium" and a "highly" exposed group (see "Results").

Univariable incidence rate ratios (relative risks, RR) with 95% confidence intervals (95% CI) were calculated for neck, shoulder and arm/hand cases, respectively. Adjusted RRs were subsequently calculated for each body region by multivariable Cox regression analyses for exposures where the 95% CI did not include 1.00 for any of the three outcome categories in the univariable analyses (Cox regression analysis, PHREG procedure, SAS statistical package, version 9.1.3, SAS Institute, Cary, NC, USA). Thus, for the sake of comparability, the multivariable analyses included the same exposures for all three outcomes.

The statistical test for trend was used to estimate if there was a linear trend across the exposure categories, i.e., if an exposure–response relationship was indicated. The test was based on one variable with three values (lowest to highest) in the multivariable analyses.

Results

During the observation period, 441 neck cases, 343 shoulder cases and 381 arm/hand cases were identified. The incidence rate was 67, 41 and 47 cases per 100 person years for neck, shoulder and arm/hand symptoms, respectively (Fig. 1). Several cases reported co-morbidity, 62% of the neck cases and 90 and 77% of the shoulder and arm/hand cases, respectively (Table 1).

Kaplan–Meier survival curves illustrate examples of the difference in non-case frequency during follow-up between

Table 1 Cases and frequency of co-morbidity with incident and/or prevalent symptoms in other body regions

Cases	n	Events only in the outcome region (%)	Co-morbidity in other body regions			
			Neck (%)	Shoulder (%)	Arm/hand (%)	Both other regions (%)
Neck	441	166 (38)		70 (16)	86 (20)	119 (27)
Shoulder	343	35 (10)	86 (25)	–	39 (11)	183 (53)
Arm/hand	381	86 (23)	96 (25)	35 (9)	–	164 (43)

low, medium and high exposures (Fig. 2a–c). Similar curves were observed for all exposures that indicated effects in the univariable analyses.

Univariable results

The work-related exposures duration and frequency of continuous computer work without breaks, comfort of the computer work environment, variation of work tasks and job strain predicted symptoms in all body regions (Table 2). Duration of computer work predicted neck and hand/arm symptoms and duration of mouse use predicted shoulder and arm/hand symptoms. Additionally, duration of data/text entry and demands in relation to competence predicted neck symptoms. Female gender showed an approximately twofold increased RR for all outcomes compared with men. In the intermediary age group, 36–50 years, an increased RR was observed for neck and shoulder symptoms and the oldest age group, >50 years, also showed an increased RR for shoulder symptoms. Low education predicted neck symptoms.

Apart from the exposures presented in Table 2, BMI, number of children at home, nicotine use and physical exercise were investigated. These determinants did not show any effect on the incidence of symptoms except for the medium category of physical exercise (1–7 times, ≥30 min/time, previous month) where a slight increase in incidence of neck and shoulder symptoms was indicated compared with both more and less exercise. However, none of these determinants had any marked effect on the multivariable results and were not included in the multivariable model.

Multivariable results

Comfort of the computer work environment predicted symptoms in all body regions, and exposure–response relationships was observed (Table 3). Additionally, duration of mouse use predicted shoulder and arm/hand symptoms, with an indicated exposure–response relationship for arm/hand symptoms. Job strain predicted symptoms in the neck and an exposure–response relationship was observed. Female gender was a marked risk factor for all outcomes. Intermediary age increased the RR for neck and shoulder

symptoms and the oldest age group also showed an increased RR for shoulder symptoms.

Discussion

A high incidence of neck and upper extremity symptoms were observed among professional computer users and the comfort of the computer work environment, duration of mouse use and job strain were the most prominent work-related risk factors.
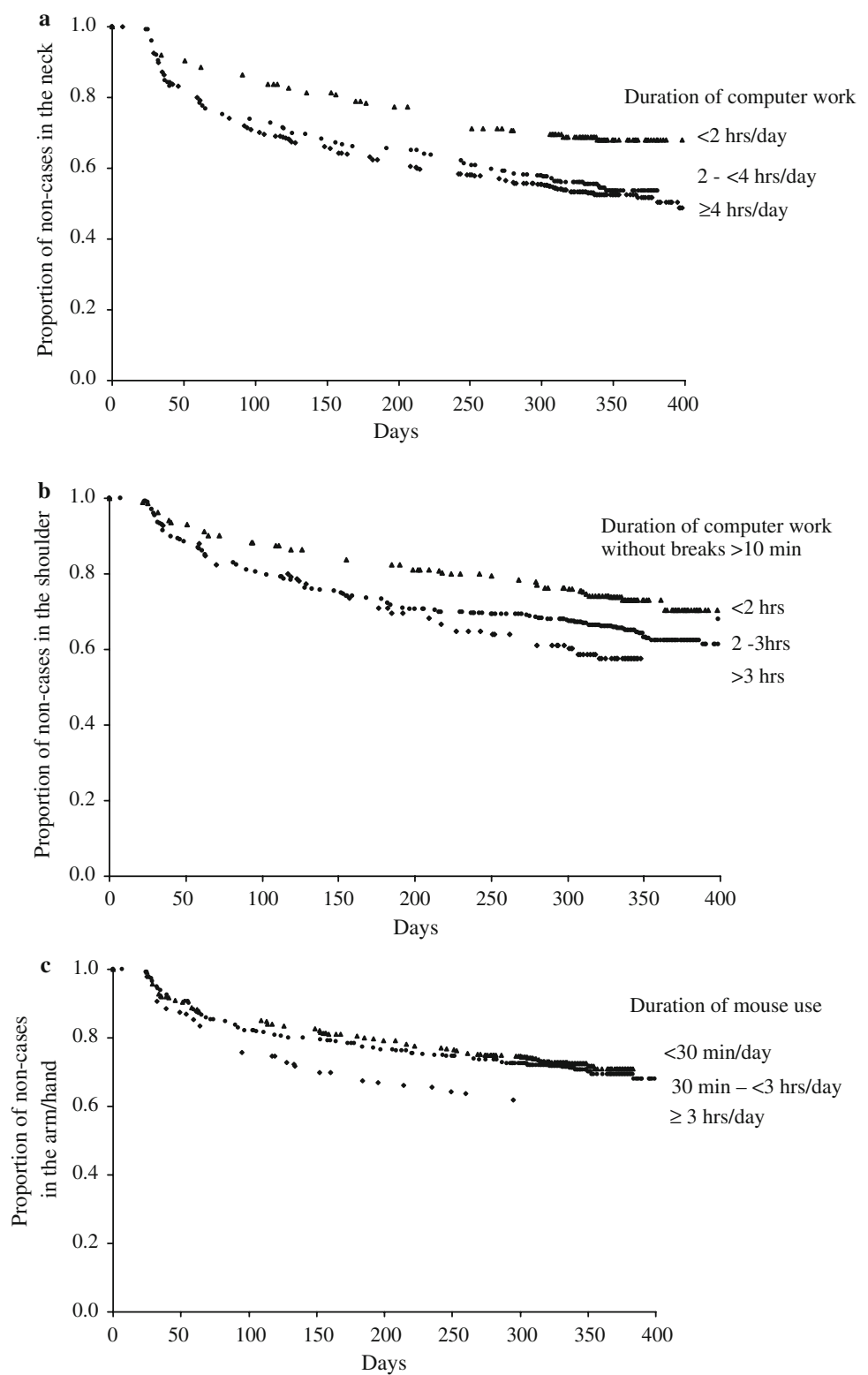
Incidence of symptoms

The highest incidence was observed for neck symptoms, 67 cases per 100 person years, followed by arm/hand and shoulder symptoms, 47 and 41 cases per 100 person years, respectively. The incidence rates observed are of the same magnitude as observed in a prospective study of computer users, by Gerr et al. (2002). In that study the incidence for neck/shoulder and hand/arm symptoms, respectively, was 58 and 39 cases per 100 person years, although the symptom case definition (symptoms during the preceding week combined with discomfort severity or medication) differed from the definition in our study.

The difference in incidence between the different body regions shows the same pattern as observed for the prevalence of symptoms observed at baseline in the present study, i.e., the highest prevalence was observed for neck symptoms, 48%, followed by arm/hand, 33%, and shoulder symptoms, 26% (Karlqvist et al. 2002).

Work-related risk factors

The general pattern of associations between several computer related duration variables and the incidence of neck, shoulder and arm/hand symptoms, respectively, observed in the univariable analyses was not evident in the multivariable analyses: Here, only the duration of mouse use was quite clearly related to arm/hand symptoms and, although only statistically significant for the medium exposure category, also to shoulder symptoms. These results are in agreement with a recent systematic review of the relationship between the duration of working time spent using the

Fig. 2 Kaplan–Meier survival
curves showing the difference in
a neck, **b** shoulder and **c** arm/
hand non-case frequency,
respectively, during follow-up
between low, medium and high
computer work-related
exposures

computer and the incidence of arm/hand and neck/shoulder
symptoms and disorders (IJmker et al. 2007). The authors
conclude that there is moderate evidence, with a dose–
response relationship, for a positive association between
duration of mouse use and hand/arm symptoms. The risk

estimates were generally stronger for the hand/arm region
than for the neck/shoulder region, and stronger for mouse
use than for keyboard and total computer use (IJmker et al.
2007). A recent prospective study, with continuous objec-
tive recordings of computer usage, showed that for each

Table 2 Univariable incidence rate ratios (RR) with 95% confidence intervals (95% CI) for neck, shoulder and hand/arm symptoms

Exposure	Neck			Shoulder			Hand/arm		
	No of exp.	No of cases	RR (95% CI) univariable	No of exp.	No of cases	RR (95% CI) univariable	No of exp.	No of cases	RR (95% CI) univariable
Duration of computer work (h/day)									
<2	200	61	1.00	219	53	1.00	216	56	1.00
2 to <4	363	152	1.61 (1.19–2.16)	414	120	1.32 (0.95–1.82)	402	123	1.30 (0.95–1.78)
≥4	510	228	1.73 (1.30–2.30)	564	170	1.35 (0.99–1.84)	552	202	1.56 (1.16–2.09)
Duration of data/text entry (h/day)									
<0.5	718	282	1.00	799	222	1.00	781	257	1.00
0.5 to <3	232	102	1.19 (0.94–1.49)	264	73	1.02 (0.78–1.33)	258	78	0.95 (0.74–1.22)
≥3	113	53	1.36 (1.02–1.83)	122	43	1.33 (0.96–1.85)	119	41	1.12 (0.81–1.56)
Duration and freq. of cont. computer work without breaks (breaks > 10 min)									
<2 h	417	154	1.00	460	122	1.00	453	136	1.00
2–3 h daily or >3 h <few times/week	496	214	1.28 (1.04–1.57)	549	153	1.08 (0.85–1.37)	536	175	1.16 (0.93–1.45)
>3 h at least a few times/week	159	73	1.43 (1.08–1.89)	186	68	1.55 (1.15–2.08)	179	70	1.51 (1.13–2.01)
Duration of mouse use (h/day)									
<0.5	270	99	1.00	297	68	1.00	286	73	1.00
0.5–<3	634	269	1.24 (0.99–1.57)	709	216	1.41 (1.07–1.85)	697	235	1.41 (1.09–1.84)
≥3	144	62	1.28 (0.93–1.76)	161	46	1.31 (0.90–1.90)	161	63	1.74 (1.24–2.43)
Mouse placement									
Optimal	287	115	1.00	316	86	1.00	312	87	1.00
Non-optimal	785	326	1.09 (0.88–1.35)	878	257	1.11 (0.87–1.42)	855	294	1.31 (1.03–1.67)
Comfort of the computer work environment (score −44 to +44)									
High (≥25)	280	105	1.00	304	72	1.00	299	86	1.00
Medium (3–24)	518	210	1.08 (0.85–1.36)	567	159	1.23 (0.93–1.63)	552	170	1.09 (0.84–1.41)
Low (≤2)	225	109	1.48 (1.13–1.93)	264	89	1.64 (1.20–2.24)	261	105	1.61 (1.21–2.15)
Variation of work tasks									
≥5 work tasks (≥30 min)	246	87	1.00	274	72	1.00	271	74	1.00
3–4 work tasks (≥30 min)	475	189	1.22 (0.95–1.57)	520	140	1.06 (0.79–1.40)	506	166	1.25 (0.95–1.65)
≤2 work tasks (≥30 min)	299	140	1.55 (1.19–2.03)	345	114	1.37 (1.02–1.83)	338	123	1.51 (1.13–2.01)
Demands in relation to competence									
In accordance with competence	706	281	1.00	778	207	1.00	761	244	1.00
Lower than competence	238	95	1.07 (0.85–1.35)	274	86	1.27 (0.99–1.63)	267	87	1.11 (0.87–1.42)
Higher than competence	125	64	1.46 (1.12–1.92)	141	48	1.32 (0.96–1.80)	138	48	1.19 (0.87–1.62)

Table 2 continued

Exposure	Neck			Shoulder			Hand/arm		
	No of exp.	No of cases	RR (95% CI) univariable	No of exp.	No of cases	RR (95% CI) univariable	No of exp.	No of cases	RR (95% CI) univariable
Job strain (demands, score 5–20, decision latitude, score 6–24)									
Low (demands <13 + decision lat. >19)	138	39	1.00	152	33	1.00	149	38	1.00
Medium	861	372	*1.78 (1.28–2.47)*	958	283	*1.46 (1.02–2.09)*	935	309	*1.48 (1.05–2.07)*
High (demands ≥16 + decision lat. ≤15)	42	22	*2.39 (1.41–4.02)*	50	17	1.71 (0.95–3.07)	50	20	*2.02 (1.17–3.47)*
Social support (score 6–24)									
High (>20)	303	126	1.00	337	94	1.00	328	108	1.00
Medium (16–20)	665	266	0.99 (0.80–1.22)	741	215	1.06 (0.83–1.35)	724	227	1.00 (0.79–1.25)
Low (≤15)	87	41	1.40 (0.98–1.99)	101	30	1.21 (0.80–1.82)	100	39	*1.44 (1.00–2.08)*
Education									
Higher than high school	501	186	1.00	545	143	1.00	537	165	1.00
High school	262	108	1.18 (0.93–1.50)	294	75	1.01 (0.77–1.34)	295	96	1.11 (0.86–1.43)
Lower than high school	225	107	*1.38 (1.09–1.75)*	256	84	1.30 (0.99–1.70)	241	77	1.05 (0.80–1.37)
Sex									
Male	448	141	1.00	475	86	1.00	474	111	1.00
Female	625	300	*1.92 (1.57–2.35)*	722	257	*2.28 (1.79–2.92)*	696	270	*1.95 (1.56–2.43)*
Age (years)									
≤35	277	103	1.00	306	66	1.00	301	91	1.00
36–50	445	212	*1.38 (1.09–1.75)*	497	154	*1.48 (1.11–1.97)*	487	152	1.03 (0.79–1.33)
>50	351	126	0.97 (0.75–1.25)	394	123	*1.51 (1.12–2.04)*	382	138	1.25 (0.96–1.63)

The values in italics fulfill the criteria for a suggested effect (95% CI does not include 1.00)

Table 3 Multivariable incidence rate ratios (RR) with 95% confidence intervals (95% CI) for neck, shoulder and hand/arm symptoms

Exposure	Neck		Shoulder		Hand/arm	
	RR (95% CI) multivariable	Trend P value	RR (95% CI) multivariable	Trend P value	RR (95% CI) multivariable	Trend P value
Duration of computer work (h/day)						
<2	1.00	0.4963	1.00	0.2355	1.00	0.6005
2 to <4	1.20 (0.82–1.74)		0.74 (0.49–1.13)		0.82 (0.54–1.22)	
≥4	1.19 (0.79–1.81)		0.66 (0.41–1.07)		0.87 (0.55–1.38)	
Duration of data/text entry (h/day)						
<0.5	1.00	0.5786	1.00	0.4506	1.00	0.6073
0.5 to <3	0.88 (0.67–1.15)		0.87 (0.63–1.19)		0.87 (0.64–1.18)	
≥3	0.97 (0.66–1.43)		1.17 (0.75–1.83)		1.03 (0.68–1.58)	
Duration and freq. of cont. computer work without breaks (breaks > 10 min)						
<2 h	1.00	0.0861	1.00	0.1412	1.00	0.7660
2–3 h daily or >3 h <few times/week	1.14 (0.89–1.46)		0.91 (0.68–1.21)		0.94 (0.72–1.23)	
>3 h at least a few times/week	1.34 (0.95–1.88)		1.30 (0.89–1.90)		1.06 (0.73–1.55)	
Duration of mouse use (h/day)						
<0.5	1.00	0.6040	1.00	0.0568	1.00	0.0816
0.5 to <3	1.08 (0.80–1.45)		*1.62 (1.12–2.34)*		*1.44 (1.01–2.05)*	
≥3	0.88 (0.58–1.33)		1.30 (0.77–2.19)		*1.70 (1.07–2.70)*	
Mouse placement						
Optimal	1.00		1.00		1.00	
Non-optimal	0.94 (0.74–1.20)		0.89 (0.67–1.19)		1.26 (0.95–1.67)	
Comfort of the computer work environment (score −44 to +44)						
High (≥25)	1.00	*0.0352*	1.00	*0.0056*	1.00	*0.0012*
Medium (3–24)	1.03 (0.79–1.34)		1.35 (0.98–1.87)		1.13 (0.83–1.53)	
Low (≤2)	*1.41 (1.04–1.92)*		*1.90 (1.32–2.73)*		*1.71 (1.22–2.39)*	
Variation of work tasks						
≥5 work tasks (≥30 min)	1.00	0.1581	1.00	0.2162	1.00	0.3970
3–4 work tasks (≥30 min)	1.10 (0.82–1.47)		1.09 (0.77–1.54)		1.16 (0.84–1.60)	
≤2 work tasks (≥30 min)	1.28 (0.91–1.81)		1.40 (0.93–2.10)		1.36 (0.93–2.01)	
Demands in relation to competence						
In accordance with competence	1.00	0.1198	1.00	0.1946	1.00	0.5990
Lower than competence	1.01 (0.76–1.34)		1.25 (0.91–1.71)		1.10 (0.81–1.49)	
Higher than competence	1.34 (0.98–1.85)		1.33 (0.92–1.92)		1.19 (0.82–1.71)	
Job strain (demands, score 5–20, decision latitude, score 6–24)						
Low (demands <13 + decision lat. >19)	1.00	*0.0050*	1.00	0.7226	1.00	0.3465
Medium	*1.65 (1.12–2.43)*		1.00 (0.67–1.50)		1.22 (0.84–1.78)	
High (demands ≥16 + decision lat. ≤15)	*2.15 (1.16–3.99)*		1.06 (0.51–2.18)		1.11 (0.55–2.25)	
Social support (score 6–24)						
High (>20)	1.00	0.5909	1.00	0.5295	1.00	0.1569
Medium (16–20)	0.97 (0.76–1.24)		1.13 (0.84–1.51)		0.94 (0.72–1.23)	
Low (≤15)	1.24 (0.82–1.89)		1.19 (0.72–1.98)		1.39 (0.90–2.15)	
Education						
Higher than high school	1.00	0.0791	1.00	0.6574	1.00	0.2626
High school	1.09 (0.83–1.42)		1.03 (0.75–1.42)		1.07 (0.81–1.42)	
Lower than high school	1.30 (0.98–1.73)		1.23 (0.89–1.72)		0.84 (0.61–1.17)	
Sex						
Male	1.00		1.00		1.00	
Female	*1.87 (1.47–2.36)*		*2.06 (1.54–2.75)*		*1.80 (1.39–2.34)*	

Table 3 continued

Exposure	Neck		Shoulder		Hand/arm	
	RR (95% CI) multivariable	Trend P value	RR (95% CI) multivariable	Trend P value	RR (95% CI) multivariable	Trend P value
Age (years)						
≤35	1.00	0.6343	1.00	*0.0282*	1.00	0.1315
36–50	*1.39 (1.05–1.83)*		*1.59 (1.13–2.25)*		1.00 (0.74–1.36)	
>50	0.97 (0.71–1.33)		*1.48 (1.02–2.14)*		1.30 (0.94–1.79)	

The values in italics fulfill the criteria for a suggested effect (95% CI does not include 1.00). Additionally, P values for a linear trend across exposure categories, indicating possible exposure–response relationships are presented. The values in italics fulfill the criteria for a suggested exposure–response relationship (P < 0.05)

quartile increase in mouse usage the risk for acute neck pain increased by 4% and the risk for acute shoulder pain by 10% (Andersen et al. 2008).

Comfort of the computer work environment predicted symptoms in all three outcome regions with a significant effect in the multivariable analyses and an exposure–response relationship for all outcomes. This determinant is a crude measure of overall comfort and besides comfort regarding different aspects of the computer workstation layout and work postures it also includes lighting, noise and indoor climate conditions. The ratings of comfort regarding different aspects of computer workstation layout have been validated in relation to ergonomic observations and the concordance between ratings and observations were reasonably good to good (Lindegård et al. 2005). In a prospective study of Finnish office employees with VDU work, self-rated poor physical work environment and VDU-related ergonomics predicted incident neck pain (Korhonen et al. 2003). A recent cross-sectional study among call-centre operators showed strong associations between comfort of the work environment and neck/shoulder and arm/hand symptoms, respectively (Norman et al. 2008). Although cause–effect relations cannot be evaluated from the above cross-sectional study our longitudinal results support a possible cause–effect relation.

Job strain was the strongest work-related predictor for neck symptoms with a significant exposure–response relationship. There are increasing evidence that psychosocial work-related factors may increase muscle tension and play an important role in the development of neck and upper limb symptoms and disorders (Theorell 1996; Lundberg 2002; Bongers et al. 2006). A recent review of longitudinal relationships between the demand-control-support dimensions and upper limb symptoms shoved that high work demands or low control at work are often related to these symptoms but the relationship is neither very strong nor very specific (Bongers et al. 2006). The combination of high demands and low control, i.e., high job strain, seemed to have more impact on neck/shoulder symptoms than on

arm/wrist symptoms (Bongers et al. 2006). Although the etiologic mechanisms are still insufficiently understood several plausible explanations have been suggested (Theorell 1996; Toomingas et al. 1997; Lundberg 2002; Melin and Wigaeus Tornqvist 2005). Compared with physical exposures, psychosocial exposures are usually more lasting and may contribute to elevated muscle tension also during breaks and after work (Lundberg 2002). Thus, reducing job strain, and other adverse psychosocial conditions, is probably of great importance to prevent neck pain.

Individual risk factors

Women were approximately twice as likely as men to develop neck, shoulder as well as arm/hand symptoms. Similar results were observed in other longitudinal studies (Gerr et al. 2002; Jensen 2003; Kryger et al. 2003; Juul-Kristensen et al. 2004; Andersen et al. 2008). The difference between men and women seems to only partly be explained by the gender segregated labor market since differences within the same occupations are also observed (Melin and Wigaeus Tornqvist 2005). Women may be at higher risk than men due to different work tasks within the same job but gender differences have also been observed in jobs where men and women have identical work tasks, e.g., among call-centre operators (Karlqvist et al. 2002; Norman et al. 2004). In addition, women do generally have more household duties and childcare and thus a larger total work-load and less possibility to recover after work. Studies have also shown that women may perform the same computer work tasks with more non-optimal postures than men, which may be due to anthropometric differences (Karlqvist et al. 1999; Wahlström et al. 2000). Biological/physiological differences may also contribute to the observed gender differences and both subjective and objective measurement methods have demonstrated greater sensitivity to pain in women than in men (Hellström and Lundberg 2000; Hallin 2003). Additionally, women may have a lower threshold than men to report symptoms. However, a prospective

study of computer users showed that women, compared with men, had a 1.7 and 1.6 times higher risk for developing neck/shoulder and arm/hand symptoms, respectively, whereas the risk of developing examination-confirmed neck/shoulder or arm/hand disorders was 1.9 and 2.4, respectively (Gerr et al. 2002). Additionally, in a case–control study of the influence of work-related exposures on seeking care due to neck and shoulder disorders 71% of the women who sought care received a confirmed diagnosis compared with 58% of the men (Wigaeus Tornqvist et al. 2001). These observations do not support that women have a lower threshold to report symptoms than men do.

In the multivariable analyses medium age (36–50 years) was a risk factor for neck symptoms and both high (>50 years) and medium age was a risk factor for shoulder symptoms, whereas age did not predict arm/hand symptoms. These findings are consistent with other prospective studies of computer users showing increased age as a risk factor for neck and shoulder symptoms (Gerr et al. 2002; Andersen et al. 2008), but not for hand/wrist symptoms (Gerr et al. 2002; Lassen et al. 2004).

Co-morbidity

This study showed a high co-morbidity; 62% of the neck cases experienced symptoms also in the shoulder and/or arm/hand and corresponding figures for shoulder and arm/hand cases were 90 and 77%, respectively. This reduces the possibility to identify risk factors specific for different body regions and the general pattern of risk factors observed in the univariable analyses was quite similar for the three outcome regions. However, the multivariable analyses do indicate that duration of mouse use seem to have a greater impact on arm/hand compared with neck symptoms, which is in agreement with the review by IJmker et al. (2007). Additionally, the multivariable analyses do also indicate that job strain have a greater impact on neck symptoms compared with arm/hand symptoms, which is in agreement with the review by Bongers et al. (2006).

Methodological considerations

The major strength of this study is its longitudinal design allowing for identification of cause–effect relationships. One problem in longitudinal studies is dropouts during the follow-up period. In the present study, 76% of those who answered at least one follow-up questionnaire participated at the final 10th follow-up. There was a slight selection bias, dropouts had a higher prevalence of neck symptoms at baseline and was slightly younger compared with subjects who remained until the last follow-up. The higher prevalence of neck symptoms among drop-outs may have entailed a slight reduction of neck cases since previous

symptoms predict the development of "new" symptoms (Jensen 2003; Juul-Kristensen et al. 2004). It is, however, unlikely that this selection bias would entail overestimation of effects. Another problem in longitudinal studies is that exposure is usually only determined at one point in time, but may vary during the observation period. In this study, changes of work-related exposures were included in the short monthly questionnaire, but potential effects of these changes were not considered in the present paper. Potential changes in exposures are, however, unlikely to cause overestimation of effects, but would rather cause an underestimation of effects due to non-differential misclassification of exposure.

One limitation in the present study is that both exposures and outcomes were self-reported. The validity of self-reported physical exposures has been questioned. Studies have shown that self-reported duration and proportions of computer work is overestimated, and only moderately associated with objective measurements (Faucett and Rempel 1996; Heinrich et al. 2004; Homan and Armstrong 2003; Mikkelsen et al. 2007). Self-reports explained about one-fourth to one-third of objective recordings and the overestimation was large at low levels and less pronounced at higher objectively measured exposures (Mikkelsen et al. 2007). If the misclassification of exposure is independent of the outcome, this non-differential misclassification will entail an underestimation of effects and, as the overestimation of computer time variables were more marked at low exposures the underestimation of effects will be even more prominent. Therefore, in the present study, misclassification may have diluted the effect estimates for the computer-time-related exposures and some risk factors may not have been identified. If, however, the misclassification differs between cases and non-cases this can lead to overestimation of effects. In the above validation study of self-reported computer time variables there was a small bias in self-reported computer time variables related to arm pain (Mikkelsen et al. 2007), while other studies found no symptom-related bias (Faucett and Rempel 1996; Heinrich et al. 2004). Theoretically, differential misclassification should not be a problem in this study because exposure was assessed before the outcome. However, as the these symptoms often are recurrent events it is possible that subjects who experience symptoms now and then may unconsciously overestimate exposures that they relate to feelings of fatigue or pain even if they are symptom-free during the month when they report exposure. As prior symptoms are a risk factor for "new" events (Jensen 2003; Juul-Kristensen et al. 2004), we cannot exclude the possibility of differential misclassification. To avoid such possible bias it is necessary to study the incidence of pure first time cases. An optimal design would be to follow subjects from when exposure starts. However, as computer use starts early in

life and young people experience symptoms before they enter into the working life, such design is not easy to accomplish (Palm et al. 2007). Additionally, the debate in media about computer- and mouse-related symptoms may bias self-reported exposure and outcome.

In the present study, we chose self-reported symptoms for 3 days or more during the previous month as the outcome measure. By asking the participants to answer a short questionnaire each month, we anticipated that subjects would remember potential symptoms, and that the risk of unidentified events was minimized. The reason for not including symptoms less than 3 days during the previous month was to exclude muscle soreness after physical training. As the case definition does not include any criteria for pain intensity or disability the outcome may include cases with mild as well as more severe symptom intensity. Between 16 and 18% of the cases did, however, report reduced computer work productivity owing to musculoskeletal symptoms (Hagberg et al. 2007). Several studies have shown that a relatively low proportion of symptomatic computer users can be classified into specific diagnostic categories (Andersen et al. 2003; Brandt et al. 2004; Lassen et al. 2004), although other studies report that a relatively large proportion of symptom cases met the criteria for specific disorders (Gerr et al. 2002). However, the proportion between diagnosed and symptom cases depends on the diagnostic criteria used, the seriousness of the symptoms and the study population. Reasons for a low concordance between complaints and specific diagnoses may be that the complaints are mild and early cases of a specific disease, that the complaints are related to multiple diagnosis or that the pain processes do not fit into (yet) accepted diagnoses (Sluiter et al. 2001). Additionally, beliefs regarding associations between exposure and symptoms may bias symptom reporting. Although several computer work-related exposures have been associated with neck and upper-extremity musculoskeletal complaints, studies where disorders are verified by physical findings as outcomes have not been able to confirm the results based on subjective complaints and a recent review indicate only limited evidence for a causal relationship between computer use and wrist tendonitis and neck pain with physical findings (Veierstedt et al. 2006).

However, regardless of a confirmed diagnosis or physical findings, prevention of neck and upper extremity pain is important as these symptoms may cause individual suffering, increased costs for employers and society due to, e.g., sickness absenteeism, and also "hidden" costs due to reduced productivity (Hagberg et al. 2002, 2007). Although the risk factors for neck and upper limb symptoms generally show weak to moderate effect estimates, subjects are often exposed to several risk factors. The relative risk for symptoms increases with increasing number of risk factors and their concomitant effect may explain the relatively high incidence of symptoms observed (Wigaeus Tornqvist et al. 2001). Preventive strategies should therefore be multifactorial and focus on risk factors confirmed in independent studies, e.g., comfort of the work environment, duration of computer mouse use and job strain (Korhonen et al. 2003; IJmker et al. 2007; Bongers et al. 2006). Interventions to confirm the preventive impact of reducing these exposures are warranted.

Conclusion

The results suggest that preventive strategies to reduce neck and upper limb symptoms among computer users should include measures to reduce mouse use, to increase the comfort of the computer work environment and to reduce job strain (high demands and low decision latitude). Although the effect estimates were relatively weak to moderate, preventive measures may have a marked impact on the incidence of neck and upper limb symptoms in the general population because of the widespread use of computers in working life as well as at home.

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