Elbow and wrist/hand symptoms among 6,943 computer operators: A 1-year follow-up study (The NUDATA study)

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Elbow and Wrist/Hand Symptoms Among 6,943 Computer Operators: A 1-year Follow-Up Study (The NUDATA Study)

Christina Funch Lassen, MD,[1]* **Sigurd Mikkelsen,** MD, D MSc,[1]
Ann Isabel Kryger, MD, PhD,[1] **Lars P.A. Brandt,** MD, PhD,[3] **Erik Overgaard,** MD,[2]
Jane Frølund Thomsen, MD, PhD,[1] **Imogen Vilstrup,** MSc,[2]
and Johan Hviid Andersen, MD, PhD[2]

Background *The aim of this study was to examine relations between computer work aspects and elbow and wrist/hand pain conditions and disorders.*
Methods *In a 1-year follow-up study among 6,943 technical assistants and machine technicians self-reported active mouse and keyboard time, ergonomic exposures and associations with elbow and wrist/hand pain were determined. Standardized clinical examinations were performed among symptomatic participants at baseline and at follow-up.*
Results *For continuous duration of mouse time adjusted linear effects were statistically significant for all investigated pain conditions. For continuous duration of keyboard time the corresponding effects were statistically significant for wrist/hand pain conditions except incident 'severe' wrist/hand pain. There were no threshold effects above 0 hr per week (hr/w) of mouse exposure in association with pain conditions, while keyboard exposure showed a threshold effect with 12-month wrist/hand pain at follow-up. Clinical diagnoses were not associated with exposure.*
Conclusions *Detailed examination of self-reported exposures showed that mouse and keyboard time predicted elbow and wrist/hand pain from low exposure levels without a threshold effect, but mouse and keyboard time were not predictors of clinical conditions.*
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KEY WORDS: computer work; exposure-response models; threshold effects; occupational musculoskeletal symptoms; occupational musculoskeletal disorders

INTRODUCTION

The relationship between computer work and neck and upper extremity pain and clinical disorders have been a matter of public and scientific concern since the introduction of computerized data processing. The first longitudinal study, based on two cross-sectional studies in 1981 and 1987 of a fixed cohort of office workers, found positive associations between weekly hours of computer work and wrist/hand problems, but not neck-shoulder problems [Bergqvist et al., 1992]. In later cross-sectional studies potential causal risk factors like computer work duration, specific ergonomic and psychosocial factors were found to be associated with adverse outcomes in neck and upper limbs [Heyer et al.,

Abbreviations: hr/w, hours/week; BMI, body mass index; GAM, generalized additive model; OR, odds ratio; CI, confidence interval; SD, standard deviation.

[1]Department of Occupational Medicine, The Copenhagen County Hospital in Glostrup, Glostrup, Denmark
[2]Department of Occupational Medicine, Herning Hospital, Herning, Denmark
[3]Department of Occupational and Environmental Medicine, The University Hospital of Odense, Odense C, Denmark

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*Correspondence to: Christina Funch Lassen, Arbejdsmedicinsk klinik, Nordre Ringvej, DK 2600 Glostrup, Denmark. E-mail: funch@cancer.dk

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1990; Aronsson et al., 1992; Bernard et al., 1994; Faucett and Rempel, 1994; Karlqvist et al., 1996; Marcus and Gerr, 1996]. The risk factors were evaluated in a comprehensive review by Punnett and Bergquist [1997]. They concluded that the use of a computer or keyboard for more than 4 hr per day was directly causative of wrist/hand disorders. The evidence of a relation between computer work and neck-shoulder disorders was less consistent. A large British national survey found that keyboard usage for more than 4 hr per day increased the risk of wrist/hand and shoulder symptoms, but not neck and elbow symptoms [Palmer et al., 2001]. Later cross-sectional studies found increasing weekly or daily duration of computer work to be associated with increased risk of pain in neck-shoulders, elbow and wrist/hand regions [Blatter and Bongers, 2002; Jensen et al., 2002; Karlqvist et al., 2002]. A recent longitudinal study reported a linear increase of hand/arm symptoms and disorders, but not of neck/shoulder symptoms and disorders by increasing hours of keyboard usage over 15 hr per week [Marcus et al., 2002]. Effects of duration of mouse work were not presented. Only a few studies consider the effects of duration of mouse work [Franzblau et al., 1993; Faucett and Rempel, 1994; Blatter and Bongers, 2002; Jensen et al., 2002; Karlqvist et al., 2002; Jensen, 2003]. No studies have reported data with the effects of mouse and keyboard work analyzed in the same models.

In order to evaluate the seriousness of any adverse effects of computer work, including the rationale of workers compensation for certain conditions, knowledge of the prevalence and incidence of clinically relevant conditions is necessary. However, only a few studies have included a physical examination [Ferraz et al., 1995; Salerno et al., 2000; Gerr et al., 2002].

The relations between regional pain/disorders and duration of computer, keyboard or mouse work have been examined by only a few (2–4) categories of exposure duration, except for the study by Marcus et al. [2002]. However, category boundaries are arbitrary, and the significance of an increased risk depends on the number of subjects and outcomes in the specific categories. Furthermore, coarse categories may be inhomogeneous with respect to exposure related risks. Threshold effects of computer time, keyboard and mouse time based on results of coarse categories may therefore be unreliable.

The NUDATA study (Neck and Upper extremity Disorders Among Technical Assistants) is a large 1-year prospective study examining associations between computer work and musculoskeletal pain and clinical disorders of the neck and upper extremities. We aimed to obtain wide distribution contrasts on mouse and keyboard use and a sufficient number of subjects and outcomes to analyze exposure–response relations over the whole spectrum of narrow exposure categories, for pain states as well as clinical disorders. We further added spline regression techniques to examine these relations in more detail. This study presents the results on prevalence and 1-year incidences of elbow and wrist/hand pain conditions and clinical disorders. Results concerning neck/shoulder conditions (submitted 2003), symptoms of carpal tunnel syndrome [Andersen et al., 2003] and forearm pain conditions [Kryger et al., 2003] are published separately.

MATERIALS AND METHODS

The NUDATA study cohort included the 9,480 members of the Danish Association of Professional Technicians, who were educated as engineering technical assistants (n = 7,252) and machine technicians (n = 2,228). They were employed in 3,527 public and private companies at the time they completed the baseline questionnaire (January 2000). The participants received a postal questionnaire at baseline, and responders at baseline received a questionnaire at follow-up (January 2001). Questions at baseline and at follow-up were identical.

Pain Variables

The questionnaires contained questions about pain in the neck and the right and left shoulder, elbow, forearm and wrist/hand. For each of the 9 regions participants reported: (1) any pain or discomfort during the past 12 month (yes, no); (2) pain during the past seven days (no pain, very mild, mild, mild to moderate, moderate, moderate to severe, severe and very severe pain); (3) the number of days with pain or discomfort within the past 12 months (0, 1–7, 8–30, 31–90, >90 days, every day); and (4) the degree to which pain or discomfort had troubled them during the past 12 months (not at all, very little, little, some, quite a lot, much, and very much).

Work Time Variables

Respondents estimated their average hours per week (hr/w) carrying out specified work tasks during the past 4 weeks before completion of the questionnaire. The work tasks specified are shown in Table I. Suggested work tasks were divided by subheadings ‘work tasks without a computer’ and ‘work tasks with a computer.’ The sum of hours for the latter is our measure of ‘computer time’ in hours per week. Respondents were also asked to estimate the proportion of computer time during which they actively worked with the mouse (clicking, dragging, or holding) and correspondingly with the keyboard (hitting the keys). They were asked whether they operated the computer mouse with the right hand or the left hand or alternated between both hands. Based on this information ‘mouse time’ (hr/w) for the right hand and the left hand and for both hands and ‘keyboard time’ (hr/w) were estimated.

TABLE I. Age, Gender, Present Job Title, and Work Characteristics of the Study Sample*

	Females	Males
No. of persons	4,347	2,596
Age (years) (%)		
20-29	9	11
30-39	36	38
40-49	34	28
50-59	20	20
+60	1	3
Present job title (%)		
Technical assistants	80.0	33.0
Machine technicians	1.5	34.0
Executive	1.5	12.0
Sales manager	3.0	4.0
Secretary	4.0	1.0
Other	10.0	16.0
Weekly working hours (hr/w[a]) (%)		
<20	1.0	0.0
20–29	4.5	0.5
30–36	25.0	4.0
37 (full time work)	69.5	95.5
Overtime past 4 weeks (%)	3.5	9.0
Work with a computer (hr/w[a]) [mean (SD[a])]		
Computer aided design	11.1 (12.0)	9.9 (10.9)
Lay out/graphics	1.4 (4.9)	0.8 (3.1)
Geographical information systems	1.7 (5.6)	0.5 (3.1)
Data entry	3.8 (6.1)	3.1 (4.8)
Other computer tasks	6.3 (7.5)	7.1 (7.6)
Work without a computer (hr/w[a]) [mean (SD[a])]		
Office work without a computer	6.9 (5.4)	7.2 (5.6)
Supervision outside work	0.8 (2.4)	3.2 (5.1)
Meetings	1.6 (2.1)	2.6 (2.8)
Other tasks without a computer	2.0 (3.8)	3.5 (6.1)
Input device usage (hr/w[a]) [mean (SD[a])]		
Active mouse time	14.7 (8.6)	12.5 (8.6)
Active keyboard time	9.3 (5.8)	8.0 (5.6)

*The NUDATA cohort, Denmark.
[a]hr/w, hours per week; SD, standard deviation.

Physical Ergonomic Workplace Factors

The questionnaire required participants to specify the most commonly employed desk positions of their keyboard and computer mouse (in front of the body, to the left or to the right of the body). Distances from the front edge of the desk were reported in 20-cm intervals, as were the distances from the right or left side of the body for mouse positions. Keyboard center positions in relation to the body were reported. The questionnaire was supplied with a ruler in cm to encourage specific measurements. No further instructions for measurements were given. Participants stated whether the forearm/wrist was supported during active mouse and keyboard usage, and whether their work chair and desk were adjusted to fit their needs. A question about general satisfaction with the physical workplace environment was included to account for factors that were not addressed by specific questions.

Psychosocial Workplace Factors

The Copenhagen Psychosocial Questionnaire developed by the Danish National Institute of Occupational Health was used to estimate psychosocial work-place risk factors [Kristensen et al., 2002]. The questionnaire has been used in consecutive Danish population surveys and is a modified version of the Karasek Job Content Questionnaire [Karasek et al., 1998]. Job demands, job control, and social support at work were addressed on ordinal scales. Response alternatives (always, often, sometimes, seldom, never/almost never) to each scale item were dichotomized between 'often' and 'sometimes,' given the scores 1 or 0. Scale scores were dichotomized between high and low values. A "high strain"-variable was defined as the combination of high job demands and low job control. One variable, termed 'time pressure,' was created from two dichotomized items about the ability to meet current deadlines and quality requirements of the work tasks ('How likely is it that you can meet the quality requirements of your present work tasks?' and 'How likely is it that you can meet the deadlines for your present work tasks?').

Personal Characteristics

Information about age, gender, height, and weight was obtained. Negative affectivity and type A-behavior were determined by two questions designed for the study: 'Do you tend to be worried, nervous or somewhat pessimistic?' and 'Do you tend to be competitive, jealous, ambitious, and somewhat impatient?' using a 7-point ordinal scale. The responses ('not at all,' 'very little,' 'a little,' 'somewhat,' 'quite a lot,' 'much,' and 'very much') were dichotomized between 'quite a lot' and 'much.' 'Physical activity in leisure time' was addressed using a 4-point ordinal scale, and 'support from private network' using a 6-point ordinal scale. Response categories were dichotomized into low and high levels.

Information whether respondents suffered from medical conditions, which might be associated with musculoskeletal pain (e.g. rheumatoid arthritis, neuritis, paralysis, cerebrovascular accident sequelae, and fibromyalgia) was collected.

Physical Examination

Participants with at least moderate pain in one or more regions (neck, shoulders, elbow, forearms, and wrist/hands) during the past 7 days were invited to a standardized clinical examination performed approximately 2 weeks after questionnaire completion at baseline and at follow-up. Respondents were excluded from the clinical examination, if they had an operation in relevant regions, if the investigated symptoms came after a fall or an accident, or if they suffered from medical conditions that might affect the present pain status (i.e. rheumatoid arthritis, neuritis, paralysis and cerebrovascular accident, etc.). A full examination of the neck and the upper extremities blinded with respect to data on exposure and pain responses was undertaken. Each anatomical region was subdivided into several delimited smaller regions, including lateral/medial and volar/dorsal aspects of the extremity. The surface of the regions was palpated systematically from the muscle's origin to the insertion and along the tendons. Palpation pressure was trained to be approximately 4 kg. Palpation tenderness was graded mild, moderate with retraction and severe with a jump sign. Two teams with two trained physicians performed the examinations according to a detailed protocol. Common training sessions before and during the study were conducted to ensure the quality of the clinical data.

A diagnosis of lateral epicondylitis required that respondents located their pain at the lateral epicondyle or the adjacent soft tissue (up to 4 cm distal to the epicondyle) by pointing. It was further required that the pain caused at least quite a lot of trouble during the previous 12 months, and that respondents indicated direct and indirect tenderness in the specified area. Positive epicondyle point tenderness included any degree of palpation tenderness. Epicondyle indirect tenderness was examined by resisted dorsal flexion of the wrist with the elbow stretched and the forearm pronated. A diagnosis of medial epicondylitis required the same symptom criteria and clinical findings except that the indicated area should be at the medial epicondyle, and indirect tenderness was examined by resisted volar flexion of the wrist. Wrist tendonopathy required wrist/hand pain to be located to the extensor or flexor tendons at the wrist combined with one or more of the clinical signs: tendon point tenderness, swelling or crepitance. De Quervain's syndrome was defined as radial wrist pain, point tenderness localized to the first dorsal compartment, and pain at the first dorsal compartment at passive ulnar deviation of the wrist with the thumb fixed [Finkelstein test; Moore, 1997].

Analysis

As outcomes, we decided to analyze two pain variables: 'any pain or discomfort' and 'severe' pain during the previous 12 months, at baseline and at follow-up. Definitions are shown in Table II. We further examined lateral and medial epicondylitis, wrist tendonopathy and De Quervain's syndrome.

We wanted to examine the effects of mouse and keyboard time, adjusting any effects of one of these types of work by the other type of work, i.e. including the two exposures in the same model. Respondents, who used the mouse with the right and left hand interchangeably ($n = 635$), were excluded from the analyses. Only 5% used the mouse with their left hand alone. We, therefore, decided only to analyze right-sided outcomes.

With multiple logistic regression analyses we examined the associations between the right-sided pain outcomes specified above and the following covariates: 'right hand mouse time,' 'keyboard time,' ergonomic factors, psychosocial workplace factors and personal factors. The covariates included in the models were all baseline data. Correlation coefficients between the included covariates were all lower than 0.25. Respondents with a specified baseline outcome were excluded from the analysis of the corresponding incident outcome.

Forearm/wrist support was included as two dummy variables ('yes, less than half of the time' and 'yes, more than half of the time' versus 'no support'). 'Abnormal mouse position' was defined as having the mouse positioned >40 cm to the right of the body and/or >40 cm from the desk front edge. 'Abnormal keyboard position' was defined as having the center of the keyboard positioned at any distance to the left or the right of the body. Psychosocial and personal characteristics were included as binary variables, except for age (continuous). All covariates were kept in the models whether statistically significant or not.

We examined three models for each outcome: one with 'right hand mouse time' and 'keyboard time' included as categorical dummy variables, one model with mouse and keyboard times included as continuous variables, examining their linear effects; and one model using spline modeling, examining the curvilinear effects in more detail. In the models with dummy variables we used the categories 0–<2.5, 2.5–<5, 5–<10, 10–<15, 15–<20, 20–<25, 25–<30, and ≥30 hr/week) with 0–<2.5 hr/w as the reference category (including subjects with any degree of left hand mouse use). Owing to a low number of cases the keyboard time-categories ≥20 hr/w were collapsed.

For nonparametric exploration of data we used the generalized additive model (GAM) [Hastie and Tibshirani, 1997]. We used the 'proc GAM' procedure, Statistical Analysis System software, version 8.2, SAS Institute (Carey, NC). In the GAM-model the complete set of covariates was linearly fitted except for mouse and keyboard times. The two continuous time-of-exposure variables were modeled by a nonparametric smooth term, using 5 degrees of freedom. Indications of mouse and keyboard time threshold effects were determined by visual assessment of plots of estimated log odds ratios versus mouse and keyboard times. *P*-values were generated from χ^2-tests evaluating the difference in deviance in models with and without the smoothed effects of

TABLE II. Case Definitions and Number of Baseline and Incident Cases*

Label in text	Case definition	Region	Participants at baseline[a] right (left)	Baseline: At risk right (left)	Lost to follow-up right (left)	Follow-up: At risk right (left)	Cases[b] right (left)	Prevalence at baseline and incidence at follow-up (%) right (left)
Baseline 12-month pain	Any pain or discomfort during the past 12 month	Elbow	6,865 (6,840)	—	—	—	1,888 (523)	27.5 (7.6)
		Wrist/hand	6,866 (6,844)	—	—	—	3,169 (754)	46.2 (11.0)
Severe pain	Pain or discomfort for >30 days and at least 'quite a lot of trouble' during the past 12 months	Elbow	6,846 (6,827)	—	—	—	374 (92)	5.5 (1.3)
		Wrist/hand	6,851 (6,833)	—	—	—	553 (118)	8.1 (1.7)
Follow-up 12-month pain	Any pain or discomfort during the past 12 months at follow-up, but not at baseline	Elbow	—	4,977 (6,317)	946 (1,166)	4,031 (5,151)	562 (372)	14.1 (7.2)
		Wrist/hand	—	3,697 (6,090)	724 (1,104)	2,973 (4,986)	617 (462)	21.0 (9.3)
Severe pain	Pain or discomfort for >30 days and at least 'quite a lot of trouble' during the past 12 months at follow-up, but not at baseline	Elbow	—	6,472 (6,735)	1,185 (1,240)	5,287 (5,495)	142 (55)	2.7 (1.0)
		Wrist/hand	—	6,298 (6,715)	1,150 (1,226)	5,148 (5,489)	206 (66)	4.0 (1.2)

*The NUDATA cohort, Denmark.
[a]Number of participants, who responded to questions about right-sided (left-sided) pain conditions at baseline.
[b]Number of participants who met the case definitions at baseline or at follow-up.

mouse and keyboard times. If a threshold was suspected, the linear effect was modeled from increasing levels of mouse or keyboard time (0–37 hr/w with one hour increments) with registration of the residual deviance for each model of hourly increments. The model with the lowest residual deviance indicated a more precise threshold effect.

The clinical outcomes turned out to be too few to allow similar analyses including all covariates in the models. The clinical data therefore were only analyzed against duration of mouse and keyboard times using contingency table methods.

Ethics

Participation in the study was voluntary. The National Scientific Ethics Committee approved the study design and written informed consent was obtained from the respondents, who participated in the clinical examination.

RESULTS

Baseline distribution characteristics of the study sample by gender, age, job titles, and work tasks are shown in Table I. The participation rate at baseline was 73% (n = 6,943) and at follow-up 81% (n = 5,658). The mouse was used in the right hand or left hand by 5,773 and 327 participants, respectively. Two hundred eight participants did not use a mouse. One hundred and ten participants did not use a keyboard.

Pain and Discomfort

Tables III–VI show the results of the logistic regression analyses of baseline and incident 12-month pain and ‘severe’ pain with mouse and keyboard times included as continuous variables or as categorical variables. The results for the other covariates are from the models with continuous time variables. They were quite similar to the results from the models with dummy variables.

For continuous mouse time the adjusted linear effects were statistically significant for all of the eight examined pain states (Tables III–VI). The adjusted linear effects for continuous keyboard time were significant for wrist/hand pain states except incident ‘severe’ wrist/hand pain (Tables III–VI), but not for any of the elbow pain states.

When mouse and keyboard time was included as categorical variables, increasing mouse time was associated with increasing risk of pain with statistically significant effects already at 2.5–<5 or 5–<10 hr/w, except for incident ‘severe’ pain states. In this model the effect was statisti cally significant ≥20 hr/w. Statistically significant effects of keyboard time were found in the higher exposure categories in the models examining ‘baseline 12-month hand pain’ and incident ‘severe’ elbow pain.

GAM analyses showed that compared to linear effects smoothed effects of mouse times were statistically significant for all examined pain states, except baseline 12-month elbow pain. Likewise, smoothed effects of keyboard times were statistically significant predictors of baseline ‘severe’ elbow pain and of follow-up ‘severe’ pain conditions. There were no indications of potential threshold effects above 0 hr/w for mouse or keyboard time, except in the relation between keyboard time and incident 12-month wrist/hand pain, for which a possible threshold effect was found at 22 hr/w (data not shown).

Clinical Examinations

At baseline 24% (n = 1,666) of the 6,943 respondents were invited to the clinical examination. The participation rate was 82%. At follow-up 7.7% (n = 436) were incident cases in one or more regions. The participation rate in the clinical examination at follow-up was 75%.

At baseline we found 29 and 2 participants with lateral and medial epicondylitis, respectively. Nine participants met the criteria for De Quervain’s syndrome, while 17 and 20 participants met the criteria for flexor and extensor tendonopathy, respectively. At follow-up 7 participants developed lateral epicondylitis. Three participants met the criteria for De Quervain’s syndrome, while 6 and 2 participants met the criteria for flexor and extensor tendonopathy, respectively. A cross-tabulation including diagnoses and mouse and keyboard time categories showed no remarkable distribution pattern.

Physical Work Place Factors and Other Factors

There were no consistent pattern of associations between baseline physical ergonomic workplace factors and pain conditions. ‘Dissatisfaction with the work place arrangement’ was associated with approximately two-fold increased risks for most of the pain conditions. Female gender also increased risks approximately two-fold. A previous accident or a current medical condition increased risks two-fold up to three-fold, while there were only few and modest associations with high job demands, high time pressure, low job support, and low private network support.

DISCUSSION

The main results of our study were a general pattern of positive associations between elbow and wrist/hand pain conditions and self-reported mouse and keyboard times, weak and sporadic associations between self-reported physical ergonomic factors and pain conditions and weak associations between pain conditions and work-related psychosocial factors. Female gender, age, regional accidents and current medical conditions were associated with pain outcomes. Very few respondents met commonly accepted criteria for clinical diagnoses.

TABLE III. Associations Between Baseline Exposures and Baseline 12-Month Pain*

	12-month elbow pain				12-month wrist/hand pain			
	Total	N (cases)	OR_{adj}	95% CI	Total	N (cases)	OR_{adj}	95% CI
Mouse time (continuous, 10 hr/w)	5,314	1,411	1.41	1.30–1.53	5,319	2,473	1.57	1.45–1.69
Mouse time categories (hr/w)								
0.0–<2.5	814	131	1.00		812	214	1.00	
2.5–<5	402	83	1.37	0.99–1.89	409	148	1.51	1.15–1.98
5.0–<10	744	171	1.57	1.19–2.06	741	291	1.78	1.41–2.26
10–<15	1,066	275	1.72	1.33–2.25	1,070	527	2.62	2.09–3.29
15–<20	955	296	2.28	1.75–2.97	956	503	2.91	2.31–3.66
20–<25	746	236	2.30	1.75–3.05	744	443	3.89	3.05–4.99
25–<30	330	126	3.13	2.26–4.36	330	197	4.00	2.97–5.46
≥30	257	93	3.04	2.09–4.41	275	150	3.76	2.66–5.30
Arm/wrist support (mouse)								
<50% of the time	540	155	1.26	0.97–1.63	542	265	1.41	1.12–1.78
≥50% of the time	3,856	1,062	1.08	0.89–1.32	3,857	1,879	1.27	1.06–1.51
Abnormal position (mouse)	422	116	1.09	0.86–1.37	423	195	0.96	0.78–1.19
Keyboard time (continuous, 10 hr/w)	5,314	1,411	1.04	0.92–1.18	5,319	2,473	1.18	1.06–1.32
Keyboard time categories (hr/w)								
0.0–<2.5	428	117	1.00		427	193	1.00	
2.5–<5	968	272	0.87	0.66–1.15	968	459	0.89	0.69–1.15
5–<10	1,824	494	0.94	0.73–1.20	1,826	847	0.91	0.72–1.14
10–<15	1,264	328	0.94	0.72–1.23	1,266	595	0.98	0.76–1.25
15–<20	599	153	0.92	0.68–1.25	602	270	0.96	0.73–1.26
≥20	231	47	0.88	0.58–1.33	230	109	1.61	1.13–2.28
Arm/wrist support (keyboard)								
<50% of the time	1,098	307	1.21	1.02–1.45	1,099	514	1.05	0.89–1.23
≥50% of the time	2,249	610	1.13	0.97–1.32	2,248	1,075	1.06	0.93–1.22
Abnormal keyboard position	748	232	1.29	1.08–1.54	749	368	1.10	0.94–1.30
Work chair unadjusted	165	51	1.31	0.92–1.87	165	92	1.39	0.99–1.95
Work desk unadjusted	1,340	315	0.76	0.64–0.90	1,341	619	0.95	0.82–1.11
Unsatisfied with workplace design	715	227	1.47	1.21–1.80	718	406	1.52	1.26–1.83
High strain-index	607	184	0.79	0.60–1.04	609	341	1.11	0.86–1.42
High job demands	2,173	608	1.24	1.06–1.46	2,177	1,002	1.05	0.90–1.21
Low decision latitude	1,712	501	1.08	0.91–1.28	1,714	916	1.15	0.98–1.34
Low social support at work	2,171	664	1.28	1.12–1.46	2,173	1,098	1.15	1.02–1.30
High time pressure	1,306	404	1.22	1.05–1.41	1,305	676	1.23	1.07–1.41
Female gender	3,345	1,015	1.69	1.47–1.96	3,346	1,751	1.76	1.55–1.99
Age (continuous, 10 year increase)			1.09	1.01–1.18			0.87	0.81–0.93
Former accident	78	41	3.49	2.20–5.58	98	64	2.72	1.76–4.27
High physical activity in leisure time	2,255	582	1.03	0.90–1.17	2,256	992	0.95	0.85–1.07
Low private network support	459	143	1.11	0.89–1.39	462	239	1.15	0.94–1.41
Plus type A behavior	713	178	0.96	0.79–1.16	716	289	0.81	0.68–0.96
Negative affectivity	735	230	1.19	0.99–1.42	739	392	1.24	1.05–1.46
High BMI	286	82	1.13	0.86–1.48	287	144	1.16	0.90–1.49
Low BMI	171	53	1.07	0.76–1.50	171	95	1.10	0.80–1.53
Current medical condition	345	98	1.10	0.85–1.41	347	171	1.37	1.08–1.73

*Results of logistic regression analyses. The NUDATA cohort, Denmark.

TABLE IV. Associations Between Baseline Exposures and Baseline 'Severe' Pain*

	'Severe' elbow pain				'Severe' wrist/hand pain			
	Total	N (cases)	OR_{adj}	95% CI	Total	N (cases)	OR_{adj}	95% CI
Mouse time (continuous, 10 hr/w)	5,302	255	1.45	1.22–1.72	5,309	405	1.58	1.37–1.83
Mouse time categories (hr/w)								
0.0–<2.5	813	18	1		809	30	1	
2.5–<5	400	15	1.84	0.88–3.82	408	20	1.29	0.69–2.34
5.0–<10	741	36	2.55	1.40–4.81	740	51	2.01	1.23–3.33
10–<15	1,066	49	2.49	1.38–4.68	1,069	63	1.60	0.98–2.67
15–<20	952	56	2.97	1.66–5.55	954	99	2.87	1.81–4.68
20–<25	745	30	2.04	1.06–4.01	744	62	2.33	1.41–3.92
25–<30	330	23	3.26	1.60–6.71	330	38	3.49	1.98–6.21
≥30	255	28	5.57	2.70–11.76	255	42	5.68	3.11–10.49
Arm/wrist support (mouse)								
<50% of the time	540	34	1.25	0.75–2.07	541	43	1.05	0.68–1.63
≥50% of the time	3,850	183	0.86	0.57–1.31	3,851	306	1.06	0.76–1.50
Abnormal position (mouse)	422	20	1.11	0.67–1.76	421	25	0.74	0.47–1.12
Keyboard time (continuous, 10 hr/w)	5,302	255	1.10	0.85–1.43	5,309	405	1.29	1.05–1.60
Keyboard time categories (hr/w)								
0.0–<2.5	427	17	1		425	30	1	
2.5–<5	966	62	1.24	0.70–2.29	967	84	0.90	0.56–1.46
5–<10	1,819	83	1.07	0.63–1.92	1,823	131	0.99	0.65–1.55
10–<15	1,261	49	0.86	0.48–1.60	1,263	86	1.01	0.64–1.64
15–<20	599	35	1.29	0.70–2.49	601	55	1.20	0.73–2.01
≥20	230	9	1.11	0.44–2.62	230	19	1.68	0.86–3.22
Arm/wrist support (keyboard)								
<50% of the time	1,096	58	1.44	1.00–2.06	1,099	86	1.14	0.85–1.52
≥50% of the time	2,246	111	1.33	0.97–1.83	2,243	170	1.05	0.82–1.36
Abnormal position (keyboard)	743	44	1.26	0.88–1.76	745	71	1.27	0.96–1.67
Work chair unadjusted	164	9	1.12	0.51–2.18	163	16	1.17	0.64–1.99
Work desk unadjusted	1,334	53	0.62	0.43–0.89	1,337	93	0.72	0.54–0.96
Unsatisfied with workplace design	712	55	2.30	1.58–3.32	717	85	1.90	1.39–2.57
High strain-index	607	49	0.87	0.51–1.47	607	83	1.11	0.72–1.69
High job demands	2,269	136	1.70	1.20–2.42	2,172	198	1.41	1.06–1.88
Low decision latitude	1,709	102	1.21	0.82–1.76	1,712	176	1.22	0.90–1.63
Low social support at work	2,166	129	1.20	0.92–1.58	2,170	214	1.34	1.08–1.67
High time pressure	1,304	88	1.38	1.04–1.84	1,302	133	1.28	1.01–1.61
Female gender	3,338	208	2.77	1.99–3.92	3,342	328	2.59	1.99–3.41
Age (continuous, 10 year increase)			1.28	1.10–1.50			0.95	0.83–1.08
Former accident	78	9	2.70	1.22–5.37	98	17	3.03	1.68–5.21
High physical activity in leisure time	2,248	101	0.99	0.76–1.29	2,250	172	1.19	0.96–1.47
Low private network support	457	24	0.89	0.55–1.37	461	51	1.31	0.96–1.47
Plus type A behavior	710	45	1.46	1.02–2.06	713	61	1.22	0.90–1.64
Negative affectivity	735	46	1.22	0.85–1.71	737	81	1.40	1.01–1.83
High BMI	285	17	1.23	0.70–2.02	287	27	1.28	0.81–1.92
Low BMI	171	10	1.05	0.50–1.96	171	21	1.35	0.80–2.15
Current medical condition	345	22	1.24	0.76–1.95	347	39	1.75	1.20–2.51

*Results of logistic regression analyses. The NUDATA cohort, Denmark.

TABLE V. Associations Between Baseline Exposures and Incident 12-Month Pain*

	12-month elbow pain				12-month wrist/hand pain			
	Total	N (cases)	OR_{adj}	95% CI	Total	N (cases)	OR_{adj}	95% CI
Mouse time (continuous, 10 hr/w)	3,136	443	1.55	1.35–1.78	2,261	492	1.32	1.16–1.51
Mouse time categories (hr/w)								
0.0–<2.5	553	39	1.00		473	57	1.00	
2.5–<5	255	24	1.47	0.84–2.54	211	39	1.57	0.99–2.51
5.0–<10	457	66	2.35	1.51–3.70	363	85	2.16	1.46–3.22
10–<15	636	85	2.20	1.42–3.45	433	101	2.05	1.37–3.07
15–<20	509	88	3.12	2.01–4.92	345	95	2.46	1.65–3.72
20–<25	413	75	3.21	2.03–5.17	236	56	2.07	1.32–3.26
25–<30	169	38	4.83	2.79–8.40	108	33	3.16	1.82–5.46
≥30	144	28	4.74	2.51–8.95	92	26	3.05	1.63–5.67
Arm/wrist support (mouse)								
<50% of the time	301	48	1.32	0.86–2.02	215	42	1.22	0.78–1.88
≥50% of the time	2,253	330	1.04	0.75–1.44	1,579	380	1.55	1.14–2.13
Abnormal position (mouse)	234	31	1.04	0.68–1.53	176	40	1.01	0.69–1.47
Keyboard time (continuous, 10 hr/w)	3,136	443	1.19	0.97–1.46	2,261	492	1.29	1.06–1.57
Keyboard time categories (hr/w)								
0.0–<2.5	250	27	1.00		184	41	1.00	
2.5–<5	560	77	1.04	0.65–1.69	415	87	0.63	0.41–0.98
5–<10	1,056	169	1.47	0.98–2.26	764	159	0.73	0.50–1.07
10–<15	772	104	1.33	0.85–2.11	549	123	0.80	0.53–1.20
15–<20	340	46	1.29	0.78–2.17	248	58	0.87	0.55–1.38
≥20	158	20	1.98	0.96–3.95	101	24	1.04	0.51–2.04
Arm/wrist support (keyboard)								
<50% of the time	615	83	1.07	0.79–1.44	454	107	1.14	0.85–1.51
≥50% of the time	1,326	199	1.27	0.99–1.62	940	207	0.96	0.75–1.23
Abnormal keyboard position	400	58	1.01	0.74–1.37	304	65	0.97	0.71–1.31
Work chair unadjusted	89	13	0.93	0.48–1.69	53	13	1.05	0.52–1.98
Work desk unadjusted	805	125	1.24	0.95–1.60	551	138	1.30	1.00–1.68
Unsatisfied with workplace design	384	78	1.63	1.18–2.23	238	57	0.99	0.69–1.40
High strain-index	327	70	1.21	0.78–1.87	215	51	0.87	0.55–1.38
High job demands	1,213	199	1.33	1.02–1.74	896	182	0.98	0.75–1.27
Low decision latitude	985	164	1.03	0.78–1.38	661	170	1.26	0.95–1.65
Low social support at work	1,205	191	1.09	0.87–1.36	836	189	1.02	0.81–1.27
High time pressure	704	115	1.11	0.86–1.42	478	113	1.18	0.91–1.52
Female gender	1,915	315	1.59	1.26–2.02	1,301	317	1.32	1.06–1.66
Age (continuous, 10 year increase)			1.35	1.19–1.53			0.94	0.84–1.07
Former accident	42	5	1.26	0.46–2.98	27	5	1.54	0.59–3.65
High physical activity in leisure time	1,313	180	0.94	0.76–1.15	988	212	1.03	0.84–1.27
Low private network support	260	44	1.12	0.77–1.59	174	41	1.04	0.70–1.52
Plus type A behavior	408	50	0.83	0.59–1.15	259	63	0.93	0.68–1.26
Negative affectivity	396	63	1.02	0.74–1.37	303	78	1.08	0.78–1.49
High BMI	171	28	1.20	0.77–1.82	114	31	1.45	0.92–2.22
Low BMI	93	13	0.91	0.47–1.64	65	21	1.49	0.84–2.55
Current medical condition	191	31	1.11	0.72–1.66	124	31	1.33	0.85–2.03

*Results of logistic regression analyses. The NUDATA cohort, Denmark.

TABLE VI. Associations Between Baseline Exposures and Incident 'Severe' Pain*

	'Severe' elbow pain				'Severe' wrist/hand pain			
	Total	N (cases)	OR_{adj}	95% CI	Total	N (cases)	OR_{adj}	95% CI
Mouse time (continuous, 10 hr/w)	4,077	110	1.52	1.17–1.98	3,951	167	1.67	1.35–2.08
Mouse time categories (hr/w)								
0.0–<2.5	646	9	1		630	13	1	
2.5–<5	310	5	1.16	0.34–3.54	311	5	0.73	0.23–2.01
5.0–<10	566	13	1.42	0.58–3.64	554	19	1.55	0.74–3.34
10–<15	824	28	2.14	0.93–5.32	809	27	1.40	0.68–3.01
15–<20	709	15	1.45	0.59–3.78	671	27	1.68	0.82–3.58
20–<25	578	19	2.88	1.18–7.54	553	45	4.21	2.12–8.85
25–<30	249	10	4.16	1.45–12.13	242	22	4.81	2.18–10.99
≥30	195	11	6.91	2.21–22.53	181	9	2.30	0.83–6.26
Arm/wrist support (mouse)								
<50% of the time	397	14	2.23	0.99–5.18	392	17	1.57	0.78–3.16
≥50% of the time	2,977	85	1.46	0.76–3.07	2,868	132	1.31	0.77–2.34
Abnormal position (mouse)	310	11	1.35	0.67–2.49	305	15	1.22	0.67–2.06
Keyboard time (continuous, 10 hr/w)	4,077	110	1.42	0.96–2.08	3,951	167	1.34	0.96–1.86
Keyboard time categories (hr/w)								
0.0–<2.5	326	7	1		308	12	1	
2.5–<5	724	20	1.09	0.44–3.00	711	34	1.14	0.58–2.38
5–<10	1,389	33	1.58	0.71–4.03	1,354	55	0.99	0.54–1.95
10–<15	1,011	33	2.49	1.08–6.53	975	40	1.46	0.76–2.98
15–<20	439	13	2.86	1.08–8.12	424	21	1.89	0.90–4.10
≥20	188	7	3.79	0.91–14.11	179	5	1.60	0.43–4.94
Arm/wrist support (keyboard)								
<50% of the time	820	18	0.76	0.42–1.33	806	28	0.74	0.46–1.16
≥50% of the time	1,740	49	1.01	0.64–1.59	1,677	73	0.87	0.60–1.26
Abnormal position (keyboard)	554	20	1.45	0.85–2.36	539	20	0.84	0.50–1.32
Work chair unadjusted	124	4	1.35	0.40–3.47	115	8	1.93	0.82–3.98
Work desk unadjusted	1,012	23	0.69	0.39–1.16	971	33	0.69	0.43–1.07
Unsatisfied with workplace design	523	20	1.92	1.06–3.37	494	28	1.67	1.02–2.67
High strain-index	438	11	0.83	0.34–1.95	419	22	0.82	0.42–1.60
High job demands	1,587	44	1.07	0.65–1.73	1,536	66	1.18	0.77–1.80
Low decision latitude	1,317	34	0.86	0.50–1.45	1,271	66	1.30	0.85–1.96
Low social support at work	1,634	46	0.91	0.60–1.39	1,567	67	0.91	0.64–1.27
High time pressure	964	29	1.14	0.71–1.80	926	42	1.08	0.73–1.58
Female gender	2,586	78	1.32	0.85–2.07	2,489	127	1.70	1.17–2.51
Age (continuous, 10 year increase)			1.33	1.06–1.69			0.98	0.80–1.18
Former accident	49	2	1.35	0.22–4.51	53	1	1.31	0.31–3.65
High physical activity in leisure time	1,701	47	1.02	0.69–1.51	1,658	69	1.03	0.75–1.43
Low private network support	358	17	1.93	1.07–3.29	341	14	1.00	0.53–1.73
Plus type A behavior	517	11	0.79	0.40–1.45	496	24	1.29	0.80–2.00
Negative affectivity	552	14	0.73	0.39–1.28	519	20	0.81	0.48–1.31
High BMI	219	2	0.34	0.06–1.07	214	11	1.23	0.61–2.23
Low BMI	130	5	1.56	0.53–3.63	123	7	1.14	0.47–2.37
Current medical condition	257	14	2.14	1.13–3.80	240	16	1.94	1.08–3.30

*Results of logistic regression analyses. The NUDATA cohort, Denmark.

Mouse and Keyboard Times

If a biomechanical load causes musculoskeletal pain, a threshold effect would be assumed. With a large study population and a wide distribution of mouse and keyboard times we hoped to be able to demonstrate a threshold level for adverse effects on pain states and clinical disorders. However, in 15 out of 16 models the curvilinear patterns of associations in the GAM analyses did not indicate a threshold level for the pain states examined. We found irregular curvilinear relations with an underlying tendency of risk increasing with mouse and keyboard times, starting at 0 hr and leveling off or declining from approximately 30 hr/w. If these deviations, of which we had no prior hypotheses, are disregarded, the simplest models for the associations between mouse and keyboard times and outcomes were simple linear relations starting at 0 hr/w.

Analyses including categorical self-reported exposure times showed statistically significant elevated risks associated with mouse time categories 2.5–5 hr/w and higher, and with keyboard time in a few higher exposure categories. In a recent study on computer work measurement methods it was demonstrated that self-reported computer time was overestimated, when compared to objective computer time. The overestimation was specifically pronounced, when objective exposure levels were very low [Homan and Armstrong, 2003]. This pattern was confirmed in a subgroup of our cohort ($n = 2{,}146$), for whom objective data on mouse and keyboard work was obtained with daily recordings during 1 year. Details from these data will be published separately.

Associations between exposure time and outcomes could be distorted by selection and information bias. We examined whether baseline 'severe' pain cases had lower mouse and keyboard times at follow-up compared to non-cases. If such migration between exposure categories was present, participants with 'severe' pain might have migrated in the same direction before study onset. Some baseline cases might then be symptomatic subjects with a previous high exposure level, who experienced work-related pain and consequently reduced their workload. Analyses only indicated a very limited effect of such a mechanism.

High-exposure symptomatic subjects may exaggerate pain and symptomatic subjects may exaggerate exposures, if they think that pain is caused by exposure. Although the NUDATA study was introduced as a general survey on health and occupation, the public media discussions may have introduced expectations on associations between computer work aspects and musculoskeletal health with biased responses to the questions on exposure and pain as a consequence, contributing to the appearance of the exposure–response relations. Such a mechanism has been proposed previously in the study by Palmer et al. [2001], who found lower risk estimates for neck and upper limb pain among computer users in a national survey compared to results from previous studies on groups of computer users.

Assuming a threshold effect as hypothesized, how could biases explain the observed relations between mouse and keyboard times and regional pain? Besides adjusting for the effect of ergonomic variables, risk estimates were adjusted for psychosocial and personal factors that have been also shown to affect musculoskeletal outcomes in earlier studies [Bernard et al., 1994; Hales et al., 1994; Polanyi et al., 1997; Andersen et al., 2002]. We cannot rule out that alternative methods for measurements of the model covariates besides mouse and keyboard usage could alter the associations with mouse and keyboard times somewhat. However, we do not think that residual confounding with respect to these aspects of our data can explain for the difference between our hypotheses and the results.

Selection before study onset may influence the exposure–response relation even of incidence data. If symptomatic subjects move to lower exposure levels, they may become asymptomatic or have less than 'severe' pain, but may retain vulnerability and thus be prone to develop recurrent pain. Furthermore, through selection some subjects at risk at baseline might constitute a survivor population not prone to develop pain in relation to computer work. If such a mechanism was present with strongest effect at the highest levels of exposure, this could be part of the explanation of the risk decline for the high exposure groups found in several analyses (data not shown). Further analyses of selection mechanisms, however, spoke against any pronounced survivor effect.

Physical Ergonomic Workplace Factors

Computer users may experience pain related with specific postures or use of certain in-put devices, and consequently change exposures, if possible. Changes in exposures may also occur due to routine renewal of worn-out tools and furniture. In the present study respondents reported whether they made changes to computer work due to pain in the neck, shoulders, arms, or hands during follow-up. They did not report at what time changes were made. Seventeen percent made changes, e.g. change of hand for mouse use, alternation between hands for mouse use, or rearrangement of the workstation etc (data not shown). Apart from that ergonomic factors were only reported at baseline. An alternative clarification of associations between postures, tool usage, and pain conditions could have been obtained by longitudinal reports concerning weekly keyboard and mouse time together with changes in ergonomic factors and symptoms. Likewise, latency periods between onset of computer work and initiation or worsening of pain might be assessed in such a design. Ergonomic exposure changes and functions of exposure time frames related to onset of pain have only been considered in one previous study, which was by Gerr et al. [2002]. Computer users, who were pain-free at baseline, recorded ergonomic baseline conditions followed by consecutive ergonomic changes during follow-up, and they recorded keying time and symptom development daily for 3 years as well. In this study some ergonomic factors were associated with pain development: higher keying activation force, use of keyboard with the j-key >3.5 cm above the table surface, and increased radial wrist deviation during mouse use predicted hand/arm affection [Gerr et al., 2002].

Symptoms and Disorders

The baseline level of complaints was high in the NUDATA study. Interview-data were obtained from 8% of non-responders at baseline, whose 12-month and 7-days prevalence of right-sided elbow pain or wrist/hand pain was 8–9% and 3%, respectively. This was considerably lower than the level among baseline respondents (Table I), while the non-responders' average level of computer work equaled the level among responders. This indicates that pain conditions were somewhat overestimated, when solely calculated from respondents' data.

Diagnoses were few. Among the respondents 0.4% met our criteria for lateral epicondylitis at baseline, a level comparable to the baseline prevalence among keyboard operators in a recent study [Gerr et al., 2002]. The 0.1% incidence of lateral epicondylitis was lower than in an older population study [Allander, 1974]. Findings related to tendons were less than in a recent prospective study [Gerr et al., 2002]. If we from our criteria excluded our requirements that the pain should have caused at least 'quite a lot of trouble' and that the participants should localize their pain to the region in focus on the day of the clinical examination, the prevalence of the diagnoses was 1.5–2 times higher. The latter set of criteria may be more comparable to those of other studies on musculoskeletal disorders.

One thousand two hundred eighty-five participants from baseline were lost to follow-up. Baseline prevalence of pain and clinical signs among those, who did not respond at follow-up, did not differ from those, who remained during follow-up. The 283 respondents without employment at follow-up did not differ on pain or clinical signs from those, who remained employed. Selection bias, therefore, is hardly the explanation for the few clinical diagnoses.

In conclusion, self-reported mouse and keyboard time predicted elbow and wrist/hand pain from low exposure levels without threshold effects. Mouse and keyboard time were not predictors of clinical conditions. It would be interesting to further determine longitudinal ergonomic exposure and mouse and keyboard time changes combined with pain development in future studies, which would considerably extend our knowledge concerning computer work-related exposure–response relations.

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