REVIEW

Should office workers spend fewer hours at their computer? A systematic review of the literature

S IJmker, M A Huysmans, B M Blatter, A J van der Beek, W van Mechelen, P M Bongers

....

Worldwide, millions of office workers use a computer. Reports of adverse health effects due to computer use have received considerable media attention. This systematic review summarises the evidence for a relationship between the duration of work time spent using the computer and the incidence of hand–arm and neck–shoulder symptoms and disorders. Several databases were systematically searched up to 6 November 2005. Two reviewers independently selected articles that presented a risk estimate for the duration of computer use, included an outcome measure related to hand–arm or neck–shoulder symptoms or disorders, and had a longitudinal study design. The strength of the evidence was based on methodological quality and consistency of the results. Nine relevant articles were identified, of which six were rated as high quality. Moderate evidence was concluded for a positive association between the duration of mouse use and hand–arm symptoms. For this association, indications for a dose–response relationship were found. Risk estimates were in general stronger for the hand–arm region than for the neck–shoulder region, and stronger for mouse use than for total computer use and keyboard use. A pathophysiological model focusing on the overuse of muscles during computer use supports these differences. Future studies are needed to improve our understanding of safe levels of computer use by measuring the duration of computer use in a more objective way, differentiating between total computer use, mouse use and keyboard use, attaining sufficient exposure contrast, and collecting data on disability caused by symptoms.

....

See end of article for
authors' affiliations
....

Correspondence to:
S IJmker, Body@Work TNO
VUmc, Institute for Research
in Extramural Medicine
(EMGO), Van der
Boechorststraat 7, 1081 BT
Amsterdam, The
Netherlands; s.ijmker@
vumc.nl

....

The large-scale introduction of computers in the workplace has led to hundreds of millions of computer users worldwide.[1][2] In many countries, the widespread use of computers has led to considerable media attention concerning potential adverse health effects.

In the scientific literature, the rise and fall of an epidemic of "repetitive strain injuries" (ie, workers reporting and claiming compensation for disorders of hand, arm, shoulder or neck) in Australia during the 1980s has been fuelling the debate of whether computer use at work is a potential occupational hazard.[3] Proponents stated that repetitive movements and static load due to constrained working postures caused the "injuries". Critics focused on the absence of objective clinical signs among patients and the role of a liberal compensation system, offering large sums of money to workers who were unable to work because of hand, arm, shoulder or neck symptoms.[4] Some authors argued that lost lawsuits of workers against their employers were main contributing factors to the decline of the epidemic.[5] In 1988, Bammer and Martin[4] concluded that the debate was characterised by a lack of empirical evidence to support many of the assertions made by both the proponents and the critics of the work-relatedness of repetitive strain injuries.

In this review, we focus on the empirical evidence available for an association between the duration of work time spent using the computer (referred to as "duration of computer use") and hand, arm, shoulder or neck symptoms and disorders. Previous reviews suggest that an association between the duration of computer use and disorders of hand, arm, shoulder or neck is present. In addition, computer use might be more strongly related to disorders of the hand and arm, than to disorders of the neck and shoulders.[6–9] However, the limitation of these reviews is that they are mainly based on cross-sectional studies.[6–8] Cross-sectional studies cannot disentangle causes and effects, and are therefore considered to be inferior to longitudinal studies.[10] The recent narrative review by Wahlström[9] includes only part of the available longitudinal studies.

To get a more conclusive insight into the relationship between the duration of computer use and the incidence of hand–arm and neck–shoulder symptoms and disorders, a systematic review of longitudinal studies was performed. Since information on potential dose–response relationships is lacking, specific attention will be paid to this issue.

METHODS
Search strategy
Publications were retrieved by a computerised search of the following databases: Medline (from 1950 to November 2005), NIOSHTIC 2, CISDOC, HSELINE, MHIDAS, OSHLINE (all from 1985 to April 2005) and PsycINFO (from 1967 to April 2005). The databases were searched for published articles up to 6 November 2005. The keywords included: retrospective, prospective, longitudinal, follow-up, computer, keyboard, mouse, office, display, VDU, VDT, terminal, neck, shoulder, elbow, wrist, hand, upper extremity, upper limb, musculoskeletal, pain, physical symptom and

....

Abbreviations: NUDATA, Neck and Upper extremity Disorders Among Technical Assistants

physical health. After inclusion of the articles based on the selection criteria, references were checked for additional articles. Finally, personal databases of the authors were searched for relevant articles.

Selection criteria

Two reviewers (SIJ and MAH) independently selected relevant articles from the articles retrieved with the search strategy. The articles were selected based on the abstracts. If abstracts provided insufficient information, the full text of the articles was used. The selection criteria were: (1) the study population included computer workers; (2) the outcome included one or more syndromes, signs or symptoms related to pain or discomfort in hand, arm, shoulder or neck; (3) a risk estimate of the association between the duration of computer use, mouse use or keyboard use and a relevant outcome measure (see 2) was presented; (4) the study had a longitudinal design (ie, at least one follow-up measurement after baseline); and (5) the study was a full-text, peer-reviewed article, written in English, Dutch or German. Experimental studies, letters and abstracts were excluded.

Quality assessment

The articles that met the selection criteria were evaluated for methodological quality. We used a quality assessment list for prospective cohort studies, based on previous systematic reviews of risk factors for musculoskeletal disorders.[11–14] Box 1 presents the full list of items.

Two reviewers (SIJ and MAH) independently assessed the quality of the studies. All items were scored positive, negative or unclear (ie, meaning that insufficient information was available). For each item, the scoring of the two reviewers was compared. In case of disagreement, consensus was reached during a meeting. If agreement could not be reached, a third reviewer (AJvdB) decided the matter. Subsequently, the first author of the included articles was contacted to provide an opportunity to discuss the quality assessment of their articles. Methodological quality assessment was based on the percentage of positive items over the total number of items. A high-quality study was defined as scoring positive on >50% of the items, which is in concordance with previously published systematic reviews.[11–14]

Data extraction

Details on study population, exposure assessment, outcome assessment and data analysis were extracted from all articles. To examine the agreement between the two reviewers for the selection of articles and for the methodological quality assessment, Cohen's κ coefficients were calculated.

To evaluate the associations between the duration of computer use and hand, arm, shoulder and neck disorders, we decided to stratify according to the measure of computer use that was reported (total computer use, mouse use or keyboard use) and according to the location of the symptoms or disorders (ie, neck–shoulder or hand–arm). Elbow symptoms were classified as hand–arm symptoms.

An association was scored positive if the risk estimate (odds ratio (OR), rate ratio (RR) or hazard ratio (HR)) was statistically significant, or if at least one of the presented exposure categories showed a point estimate >2 (or <0.5).

Levels of evidence

To summarise the results of the studies, we used levels of evidence. Strong evidence was defined as consistent results for all tested associations, including at least two high-quality studies. We anticipated that one article could present multiple associations for different case definitions and that multiple articles could present associations for the same cohort of

---

Box 1 Quality assessment list for prospective cohort studies

- Study design

  - Was the participation rate at baseline at least 80% odds ratio (OR), if participation rate was <80%, not selective regarding exposure (ie, duration of computer use) and potential confounders (ie, at least for sex and age)?
  - Was the response at follow-up at least 80% OR, if the response was <80%, not selective regarding exposure (ie, duration of computer use), potential effect modifiers (ie, at least sex and age) and outcome (ie, hand, arm, shoulder and neck symptoms, or disorders)?

- Exposure assessment

  - Were the data on duration of computer use collected using standardised methods of acceptable quality?*
  - Were the data on ergonomic factors collected using standardised methods of acceptable quality?*
  - Were the data on psychosocial factors collected using standardised methods of acceptable quality?†
  - Were the data on physical factors during leisure time collected and used in the analysis?
  - Were the data on exposure change regarding the duration of computer use during the follow-up period (eg, due to job change) collected and used in the analysis?

- Outcome assessment

  - Were the data on outcome collected using standardised methods of acceptable quality?‡

- Data analysis

  - Was the statistical method used appropriate for the outcome studied and was a measure of association presented, including 95% CI or p value?
  - Was the statistical analysis tested for confounding by sex and age?
  - Was the number of subjects in the multivariate analysis at least 10 times the number of independent variables?

*ICC >0.6 or κ >0.4 for test–retest reliability or interobserver reliability. Additionally, for self-reports: ICC >0.6 or κ >0.4 or r >0.75 for agreement with observation or direct measurement.
†ICC >0.6 or κ >0.4 for test–retest reliability. Additionally for self-reports, in the case of using scales: Cronbach's α >0.7 for the majority of scales used.
‡ICC >0.6 or κ >0.4 or r >0.75 for test–retest reliability or interobserver reliability, or if (modified) Nordic questionnaire was used.[15–17]

---

workers. Therefore, multiple positive associations from the same cohort of workers were counted as one study.

The criterion of consistent results was met if at least 75% of all tested associations for the risk factor were positive (ie, provided a statistically significant risk estimate, or a risk estimate >2 or <0.5).

Moderate evidence was defined as consistent results for all tested associations (with a minimum of three associations tested) or consistent results for at least two high-quality studies, irrespective of the findings from medium-quality studies for that association. Insufficient evidence was defined as inconsistent results for all tested associations, including the situation in which less than three associations were evaluated.

Dose–response analysis
The dose–response relationship was evaluated if at least moderate evidence was available for an increased risk of developing hand–arm or neck–shoulder symptoms or disorders. We assessed dose–response qualitatively by plotting the point estimates against the exposure categories. Therefore, we extracted the point estimates for all reported exposure categories. We used the middle value of the lower and upper limit to reflect the average duration of computer use for that exposure category. If there was no upper limit for the highest exposure category, we conservatively used the lower limits to reflect the duration of computer use. Some studies presented exposure categories as a percentage of working time. On the basis of the distribution of working hours at baseline, we estimated the average number of working hours for the whole population and multiplied this average with the percentage of computer use to calculate the average duration of computer use for each exposure category. A general increase of risk (ie, higher point estimates) over increasing duration categories for most studies was considered as evidence for a dose–response relationship.

RESULTS
Search results
The search strategy resulted in 277 hits. Applying the selection criteria resulted in nine articles. We excluded the longitudinal study by Lindström et al,[18] because cross-sectional analyses were performed. The two reviewers initially disagreed on the selection of one article, resulting in a κ of 0.94. The references of the included articles provided another article.[19] The final set of articles was based on five cohorts of workers: (1) the Behavior in Information Technology Study[20 21]; (2) the Neck and Upper extremity Disorders Among Technical Assistants (NUDATA) Study[22–25]; (3) Bergqvist et al[19]; (4) Marcus et al[26]; and (5) Korhonen et al.[27]Table 1 gives the characteristics and results of the included articles.

Methodological quality assessment
Table 2 presents the methodological quality assessment of the articles. The κ coefficient for the agreement between the ratings of the individual items (positive vs negative or unclear) of the two reviewers was 0.91 (disagreement on 5 of 108 scored items). One item needed a decision of the third reviewer (AJvdB); agreement on the other items was reached during the consensus meeting. Eight of nine corresponding authors replied to our invitation to discuss the quality assessment. On the basis of the information, five unclear scores were replaced by positive scores. Six studies had a quality score exceeding 50%, which we considered as the cut-off point for high quality.[22–27]

Levels of evidence
Figures 1 and 2 present point estimates and 95% CIs, derived from the original articles, for the associations between the duration of total computer use, mouse use and keyboard use and hand–arm and neck–shoulder symptoms and disorders, respectively. We excluded one of the associations studied by Bergqvist et al,[19] because the case definition involved anatomical locations from both the hand–arm and the neck–shoulder region. Risk estimates were in general larger for mouse use than for total computer use and keyboard use. For

neck–shoulder symptoms and disorders, fewer associations were positive than for hand–arm symptoms and disorders.

For hand–arm symptoms and disorders, moderate evidence was concluded for the association with duration of mouse use, because all studies showed a positive association, including three high quality studies based on the NUDATA cohort.[22 23 25] However, these were counted as one study. For the duration of total computer use and the duration of keyboard use, insufficient evidence was concluded, because inconsistent results were found. For the duration of total computer use, associations from three cohorts were available. Only the NUDATA cohort investigated the duration of keyboard use.

For neck–shoulder symptoms and disorders, insufficient evidence was concluded for the duration of mouse use and the duration of keyboard use, since inconsistent results were found. For both mouse use and keyboard use, only the NUDATA cohort investigated the association with neck–shoulder symptoms and disorders. For the duration of total computer use, all tested associations failed to show a positive association. Four cohorts investigated total computer use, including two high-quality studies.[26 27]

Dose–response analysis
Following the criteria set beforehand, we analysed the relationship between the duration of mouse use and the incidence of hand–arm symptoms. In general, an increase in risk over duration categories can be observed from fig 3. However, the association between mouse use and hand–wrist symptoms reported by Jensen[20] and the association between mouse use and ''severe'' hand–wrist pain found by Lassen et al[25] did not show a clear increasing risk over duration categories (fig 3). Jensen[20] reported an increased risk (OR 4) at a rather short duration of mouse use (ie, approximately 4.5 h per week), as well as an increased risk (OR 4) at a long duration of mouse use (ie, approximately 27 h per week). Lassen et al[25] presented a drop in risk from 4.8 to 2.3 for their highest exposure category (ie, >30 h per week).

DISCUSSION
The results of this review of longitudinal studies confirm the finding of previous reviews. The duration of computer use was more consistently associated with hand–arm than with neck–shoulder symptoms and disorders.[6 9] In addition, our review adds to the existing literature the observation that the duration of mouse use was more strongly and more consistently associated with the incidence of hand–arm symptoms than the duration of total computer use and keyboard use.

Methodological considerations
All the studies included in this review have substantial methodological quality, since they were based on longitudinal study designs, and all but one scored positive on the quality items with regard to statistical analysis. Still, the design of future studies might be improved by taking into account a number of methodological limitations that are present in the published studies.

First, all studies used self-report measurements to assess the duration of computer use. No study reported data on the test–retest reliability of these self-reports. Low test–retest reliability might be related to a poor validity of exposure measures. Moreover, several studies have shown that self-report measurements, on average, strongly overestimate the duration of computer use, resulting in misclassification.[28 29] Assuming that this misclassification is non-differential, this would lead to an underestimation of the true exposure–response relationship.[30] A recent development is the use of computer software to objectively measure the duration of computer use. Such

Table 1 Characteristics and results of the included articles

Cohort (first author) quality score	Study population	Assessment duration of computer use	Case definition(s)	Results	Results continued
BIT, Jensen[20] (42%)	Employees from Danish companies and institutions. Selected companies provided employees with different types of computer work (data entry, word processing, graphic work, etc). Analyses were restricted to subjects working full time (32–41 hours/week), who had not changed jobs during follow-up. n=203–916	Self-report "How much of your work time do you work with your computer (including overtime and working at home)" Response categories: Seldom; 25%; 50%; 75%; 100%	Self-reported symptoms for more than 7 days within the last year of the follow-up period. Body regions studied: neck and hand-wrist	Neck Total computer use: – 0–25% of work time OR 1 – 50% of work time OR 1.5 (0.7–3.1) – 75% of work time OR 1.3 (0.6–2.7) – 100% of work time OR 1.6 (0.8–3.3) Mouse use: – Seldom OR 1.3 (0.4–4.3) – 25% of work time OR 1 – 50–100% of work time OR 1.7 (0.5–5.7)	Hand-wrist Total computer use: – 0–25% of work time OR 1.5 (0.7–2.4) – 50% of work time OR 1 – 75% of work time OR 2.0 (1.1–3.9) – 100% of work time OR 2.3 (1.2–4.3) Mouse use: – Seldom OR 4.0 (1.1–14.4) – 25% of work time OR 1 – 50–100% of work time OR 4.0 (1.0–15.5)
BIT, Juul-Kristensen[21] (42%)	See Jensen Analyses restricted to workers who held the same job during follow-up. n=2002	See Jensen	Duration outcome: Self-reported symptoms <8 days in the past 12 months at baseline and >7 days during follow-up Intensity outcome: Self-reported symptom intensity <4 (scale 0–9) during last 3 months at baseline and ≥4 during last 3 months at baseline + non-symptomatic at both sides (left and right) and non-symptomatic in nearby body regions Body regions studied: elbow and shoulder	Shoulder duration outcome Total computer use: – 0–25% of work time OR 1 – 50% of work time OR 1.23 (0.63–2.40) – 75% of work time OR 1.00 (0.51–1.94) – Almost all work time OR 0.69 (0.34–1.39) Shoulder intensity outcome Total computer use: – 0–25% of work time OR 1 – 50% of work time OR 1.07 (0.60–1.90) – 75% of work time OR 0.95 (0.53–1.70) – Almost all work time OR 0.78 (0.43–1.43)	Elbow duration outcome: Total computer use: – 50% of work time OR 1.11 (0.51–2.40) – 75% of work time OR 0.95 (0.43–2.10) – Almost all work time OR 1.08 (0.48–2.39) Elbow intensity outcome: Total computer use: – 50% of work time OR 1.12 (0.58–2.18) – 75% of work time OR 0.90 (0.47–1.74) – Almost all work time OR 1.08 (0.48–2.39)

Table 1 Continued

Cohort (first author) quality score	Study population	Assessment duration of computer use	Case definition(s)	Results	Results continued
NUDATA Andersen[22] 50%	Employees from the Danish Association of Professional Technicians, ie, —technical assistants (draughtsmen) and machine technicians from 3527 public and private companies. Job tasks included technical drawing tasks, administrative and graphical tasks. n = 5658	Self-report Participants estimated their average hours per week doing specified work tasks during the past four weeks (separately for tasks using the computer and tasks not using the computer). Questions for keyboard use and mouse use separately. Computer use (=mouse use +keyboard use) not used in the analysis due to high correlation with mouse use.	Possible carpal tunnel syndrome (CTS): Self-reported tingling or numbness in the right hand at least once a week within the last 3 months, with no or minor tingling/numbness at baseline. Body regions studied: wrist (possible CTS)	Wrist (possible CTS) Mouse use: —0—<2.5 hrs/wk* OR 1 —2.5—<5 hrs/wk OR 0.7 (0.3–1.9) —5—<10 hrs/wk OR 1.9 (0.9–4.0) —10—<15 hrs/wk OR 1.6 (0.8–3.3) —15—<20 hrs/wk OR 2.0 (0.9–4.2) —20—<25 hrs/wk OR 2.6 (1.2–5.5) —25—<30 hrs/wk OR 3.2 (1.3–7.9) Keyboard use: —0—<2.5 hrs/wk OR 1 —2.5—<5 hrs/wk OR 0.9 (0.4–1.8) —5—<10 hrs/wk OR 0.8 (0.4–1.5) —10—<15 hrs/wk OR 1.2 (0.6–2.5) —15—<20 hrs/wk OR 0.8 (0.4–1.5) —>=20 hrs/wk OR 1.4 (0.5–4.3)	
NUDATA Kryger[23] 42%	See Andersen	Self-report See Andersen	At least moderate to severe self-reported pain in the forearm within the past 7 days combined with quite a lot pain/discomfort during the past 12 months and at baseline none or less than moderate pain in the forearm in the past 7 days combined with less than "some" pain/tenderness during the past 12 months Body regions studied: forearm	Forearm Mouse use: —0–9 hrs/wk OR 1 —10–19 hrs/wk OR 2.2 (1.0–4.7) —20–29 hrs/wk OR 2.6 (1.0–6.6) —>=30 hrs/wk OR 8.4 (2.5–29) Keyboard use: —0–4 hrs/wk OR 1 —5–9 hrs/wk OR 1.2 (0.5–2.9) —10–14 hrs/wk OR 1.3 (0.5–3.4) —>=15 hrs/wk OR 2.6 (0.9–7.3)	

Table 1 Continued

Cohort (first author) quality score	Study population	Assessment duration of computer use	Case definition(s)	Results	Results continued
NUDATA Brandt[24] 42%	See Andersen	Self-report See Andersen	Self-reported pain in the last 7 days of at least moderate degree and pain during the last 12 months of follow-up that bothered at least quite a lot and no complaints in the region during the 12 months prior to the baseline examination and less than moderate pain in the regional area during the last 7 days at baseline. Body regions studied: neck and shoulder	Neck Mouse use: –0–9 hrs/wk OR 1 –10–19 hrs/wk OR 1.1 (0.6–1.9) –20–29 hrs/wk OR 0.9 (0.4–1.9) –>=30 hrs/wk OR 2.4 (0.8–6.8) Keyboard use: –0–4 hrs/wk OR 1 –5–9 hrs/wk OR 1.1 (0.5–2.2) –10–14 hrs/wk OR 1.0 (0.4–2.2) –>=15 hrs/wk OR 1.8 (0.8–3.9)	Shoulder Mouse use: –0–9 hrs/wk OR 1 –10–19 hrs/wk OR 1.2 (0.7–2.1) –20–29 hrs/wk OR 1.9 (1.0–3.5) –>=30 hrs/wk OR 3.3 (1.2–8.9) Keyboard use: –0–4 hrs/wk OR 1 –5–9 hrs/wk OR 1.3 (0.7–2.6) -10–14 hrs/wk OR 1.6 (0.8–3.3) –>=15 hrs/wk OR 2.2 (1.0–4.9)
NUDATA Lassen[25] 42%	See Andersen	Self-report See Andersen	Case Any self-reported pain or discomfort during the past 12 months, but not at baseline Severe case Self-reported pain or discomfort lasting for >30 days and causing at least "quite a lot of trouble" during the past 12 months at follow-up, but not at baseline Body region studied: elbow and hand-wrist	Elbow case Mouse use: –<2.5 hrs/wk OR 1 –20–<25 hrs/wk OR 3.21 (2.03–5.17) –25–<30 hrs/wk OR 4.83 (2.79–8.40) –>=30 hrs/wk OR 4.74 (2.51–8.95) Keyboard use: –0–<2.5 hrs/wk OR 1 –2.5–<5 hrs/wk OR 1.04 (0.65–1.69) –5–<10 hrs/wk OR 1.47 (0.98–2.26) –10–<15 hrs/wk OR 1.33 (0.85–2.11) –15–<20 hrs/wk OR 1.29 (0.78–2.17) –>=20 hrs/wk OR 1.98 (0.96–3.95) Hand-wrist case Keyboard use (continued): –10–<15 hrs/week OR 0.80 (0.53–1.20)	Hand-wrist case Mouse use: –<2.5 hours/week OR 1 –2.5–<5 hrs/wk OR 1.57 (0.99–2.51) –5–<10 hrs/wk OR 2.16 (1.46–3.22) –10–<15 hrs/wk OR 2.05 (1.37–3.07) –15–<20 hrs/wk OR 2.46 (1.65–3.72) –20–<25 hrs/wk OR 2.07 (1.32–3.26) –25–<30 hrs/wk OR 3.16 (1.82–5.46) –>=30 hrs/wk OR 3.05 (1.63–5.67) Keyboard use: –Increase of 10 hrs/wk OR 1.29 (1.06–1.57) –0–<2.5 hrs/wk OR 1 –2.5–<5 hrs/wk OR 0.63 (0.41–0.98) –5–<10 hrs/wk OR 0.73 (0.50–1.07)

Table 1 Continued

Cohort (first author) quality score	Study population	Assessment duration of computer use	Case definition(s)	Results	Results continued
				−15−<20 hrs/week OR 0.87 (0.55−1.38) −>=20 hrs/week OR 1.04 (0.51−2.04) Severe elbow case Mouse use: −<2.5 hrs/wk OR 1 −2.5−<5 hrs/wk OR 1.16 (0.34−3.54) −5−<10 hrs/wk OR 1.42 (0.58−3.64) −10−<15 hrs/wk OR 2.14 (0.93−5.32) −15−<20 hrs/wk OR 1.45 (0.59−3.78) −20 to <25 hrs/wk OR 2.88 (1.18−7.54) −25 to <30 hrs/wk OR 4.16 (1.45−12.13) −>=30 hrs/wk OR 6.91 (2.21−22.53) Keyboard use: −<2.5 hrs/wk OR 1 −2.5−<5 hrs/wk OR 1.09 (0.44−3.00) −5−<10 hrs/wk OR 1.58 (0.71−4.03) −10 to <15 hrs/wk OR 2.49 (1.08−6.53) −15 to <20 hrs/wk OR 2.86 (1.08−8.12) −>=20 hrs/wk OR 3.79 (0.91−14.11)	Severe hand-wrist case Mouse use: −<2.5 hrs/week OR 1 −2.5−<5 hrs/wk OR 0.73 (0.23−2.01) −5−<10 hrs/wk OR 1.55 (0.74−3.34) −10−<15 hrs/wk OR 1.40 (0.68−3.01) −15−<20 hrs/wk OR 1.68 (0.82−3.58) −20 to <25 hrs/wk OR 4.21 (2.12−8.85) −25 to <30 hrs/wk OR 4.81 (2.18−10.99) −>=30 hrs/wk OR 2.30 (0.83−6.26) Keyboard use: −<2.5 hrs/wk OR 1 −2.5−<5 hrs/wk OR 1.14 (0.58−2.38) −5−<10 hrs/wk OR 0.99 (0.54−1.95) −10 to <15 hrs/wk OR 1.46 (0.76−2.98) −15 to <20 hrs/wk OR 1.89 (0.90−4.10) −>=20 hrs/wk OR 1.60 (0.43−4.94)
Bergqvist et al Bergqvist[19] 42%	Employees working for seven companies in Stockholm, Sweden: travel agencies, a newspaper production company, postal office, and an insurance company. Included employees worked at least 75% of a full time contract. n=341	Self-report "How many hours per week did you work at the Visual Display Terminal?" Responses were categorized into three categories: no or occasional; <30 hours/week; >30 hours/week	Current self-reported pain or discomforts. Symptoms that occurred only occasionally and were of insignificant intensity were not taken into account. Body regions studied: neck-shoulder; hand-wrist	Neck-shoulder Total computer use: −>30 hrs/wk versus no or occasional total computer use RR 1.25 (0.76−2.05) [univariate analysis] Hand-wrist Total computer use −>30 hrs/wk versus no or occasional total computer use RR 3.75 (0.89−15.81) [univariate analysis]	

Table 1 Continued

Cohort (first author) quality score	Study population	Assessment duration of computer use	Case definition(s)	Results	Results continued
Marcus et al Marcus[26] 75%	Newly hired workers who 1) anticipated using a computer for at least 15 hrs/wk, and 2) anticipated using a computer keyboard for at least as many hrs/wk as in their previous job. Job sectors included insurance, finance, food production, health care, and education. n=436–520	Self-report, daily diary on hours spent keying	**Musculoskeletal symptoms** Self-reported discomfort in weekly diary which was present at least one day during previous week and pain score (VAS) >6 or using medication for control of the discomfort. Musculoskeletal disorders Positive if case definition for musculoskeletal symptoms was met and physical examination was positive. Body regions studied: hand-arm, neck-shoulder	Neck-shoulder symptoms Total computer use: —Increase of 1 hr/wk HR 1.01 (0.99–1.03) —35 hrs/wk versus 15 hrs/wk HR 1.22 (0.82–1.81) Neck-shoulder disorders Total computer use: —Increase of 1 hr/wk HR 1.01 (0.99–1.04) —35 hrs/wk versus 15 hrs/wk HR 1.22 (0.82–2.19)	Hand-arm symptoms Total computer use: —Increase of 1 hr/wk HR 1.04 (1.02–1.06) —35 hrs/wk versus 15 hrs/wk HR 2.19 (1.49–3.20) Hand-arm disorders Total computer use: —Increase of 1 hr/wk HR 1.04 (1.02–1.06) —35 hrs/wk versus 15 hrs/wk HR 2.19 (1.49–3.20)
Korhonen et al Korhonen[27] 50%	Full time working employees from three municipal administrative units. n=138	Estimate how many percent of your working time during the preceding month you have used for each task of the following tasks (VDU work includes using keyboard or other input or control device, including short thinking periods and checking the results on the screen). Response categories: <50%, >50% of work time	Local or radiating self-reported neck pain at follow-up for at least 8 days during the last 12 months AND experiencing local or radiating neck pain <8 days at baseline. Body regions studied: neck	Neck Total computer use: —<50% of work time OR 1 —>=50% of work time OR 1.0 (0.6–2.9) [univariate analysis]	

*hours per week

Table 2 Results of the methodological quality assessment

Cohort (first author)	Study design		Exposure and outcome assessment						Data analysis			Score* (%)
	Participation rate	Response at follow-up	Duration computer use	Ergonomic factors	Psychosocial factors	Physical factors leisure time	Exposure change	Outcome	Statistical model	Confounding	Statistical power	
BIT												
Jensen[20]	?†	?	?	?	?	−	+	+	+	+	+	45
Juul-Kristensen[21]	?	?	?	?	?	−	+	+	+	+	+	45
NUDATA												
Andersen[22]	?	+	?	?	?	+	+	+	+	+	+	64
Kryger[23]	?	+	?	?	?	+	?	+	+	+	+	55
Brandt[24]	?	+	?	?	?	+	?	+	+	+	+	55
Lassen[25]	?	+	?	?	?	+	?	+	+	+	+	55
Bergqvist et al												
Bergqvist[19]	+	+	?	?	?	?	+	?	+	−	+	45
Marcus et al												
Marcus[26]	+	+	?	+	?	+	+	?	+	+	+	73
Korhonen et al												
Korhonen[27]	+	?	?	?	?	+	?	+	+	+	+	55
Positive (%)	33	67	0	11	0	67	56	78	100	89	100	

BIT, Behavioural Inattention Test; NUDATA, Neck and Upper extremity Disorders Among Technical Assistants.
*The percentage of positive items over the total number of items.
†+, positive; −, negative; ?, unclear (insufficient information available).

software showed good agreement with observation,[31] and has already been used in an epidemiological study.[29]

Second, most studies in this review solely measured the duration of total computer use. General measures of the duration of computer use might not be able to detect the variability in the duration of mouse and keyboard use. This might explain the stronger risk estimates for the duration of mouse use in comparison with those for the duration of total computer use. However, within the NUDATA cohort total computer use was not analysed, since it was highly related to mouse use.[22]

Third, all included articles had study populations consisting solely of computer users. This might have led to a limited exposure contrast (ie, only the contrast present within the group of computer users) and a limited power to explain the contributing factors to the incidence of hand, arm, shoulder and neck symptoms among computer users.[6]

Fourth, most case definitions were based on arbitrary cut-off points, based on the number of days on which pain or discomfort was experienced. In the NUDATA Study,[24 25] few participants met the criteria for a clinical diagnosis during follow-up (ie, <2% incidence for both neck–shoulder and hand–arm disorders). In addition, self-reports showed mild disability. In contrast with the NUDATA Study, the study by Marcus et al[26] (see Gerr et al[32]) showed a high incidence of clinical diagnoses (ie, 35% incidence of neck–shoulder disorders and 21% incidence of hand–wrist disorders). One of the explanations for this difference between studies might be that the population studied by Marcus et al consisted of newly hired workers. Newly hired workers might be more prone to health problems, because they are not experienced with the physical and psychosocial exposures that they have to deal with in the new job. The difference might also be attributed to selection effects within the NUDATA cohort: workers who are susceptible to or have had hand, arm, shoulder or neck symptoms and disorders might have migrated to jobs with lower durations of exposure or might have left the workforce. Kryger et al[23] indicated that the criteria used to establish a clinical diagnosis might be different between the NUDATA study and the one reported by Marcus et al[26] (see Gerr et al[32]). In addition, it should be noted that physical examination might not have sufficient interobserver reliability[33] and that information on validity is largely unknown.[34]

On the basis of the limitations of physical examinations on the one hand, and the identical risk estimates for self-reported symptoms and clinically diagnosed disorders in the study by Marcus et al[26] on the other hand, self-reports of the degree of disability caused by symptoms might be preferred to grade the severity of symptoms in future epidemiological studies.

To estimate safe levels of the duration of computer use more precisely, more high-quality studies are needed. These studies should focus on measuring the duration of computer use in a more objective way, differentiating between total computer use, mouse use and keyboard use, attaining sufficient exposure contrast, and collecting data on disability caused by symptoms.

Sensitivity analysis

The levels of evidence proposed in this review might have been influenced by arbitrary decisions regarding the criteria used in the methodological quality assessment. The methodological quality score ranged between 45% and 73%, with seven of nine studies scoring between 45% and 55%. On the basis of this distribution, our a priori cut-off point of >50% might have influenced the levels of evidence and potentially the results of this review. Shifting the cut-off point from >50% to >40%, would have only changed the level of evidence for the combination of mouse use and hand–arm symptoms and disorders. Strong evidence, instead of moderate evidence,
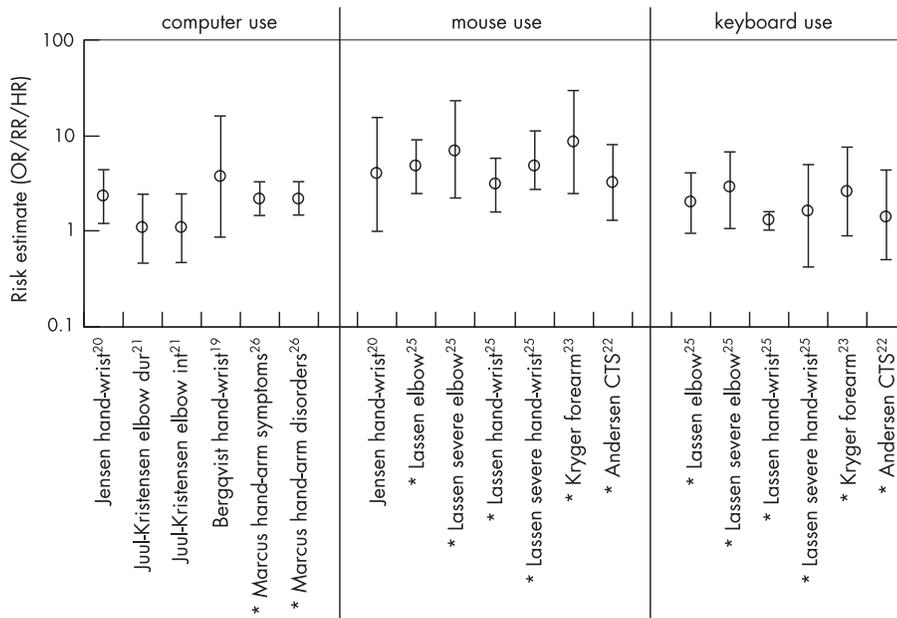
Figure 1 Risk estimates for the association between duration of computer use and hand–arm symptoms and disorders. See the italic numbers in the results columns of table 1 for exact values (*, high-quality study). CTS, carpal tunnel syndrome; HR, hazard ratio; OR, odds ratio; RR, rate ratio.

would have been concluded. By contrast, shifting the cut-off point to >60% would not have influenced our levels of evidence at all.

Variation of exposure contrasts between studies might also have influenced the levels of evidence via the consistency of results. Studies analysing limited exposure contrasts are less likely to find a positive association than studies analysing large exposure contrasts. Large variations in exposure contrast between studies were only available for the associations between the duration of total computer use and both hand–arm and neck–shoulder symptoms and disorders. However, variation in exposure contrast was not likely to influence the levels of evidence for these associations. For the association

between the duration of mouse use and neck–shoulder symptoms, a higher exposure contrast in the study by Jensen[20] might have led to a positive association. In that case, moderate evidence instead of insufficient evidence would have been concluded.

Dose–response analysis

In general, the dose–response analysis for hand–arm symptoms showed an increase in point estimates over an increasing duration of mouse use. Jensen et al[20] presented an increased risk at a rather low duration of mouse use and again at a high duration of mouse use. It is possible that residual confounding was present in their study, because subjects who had a low
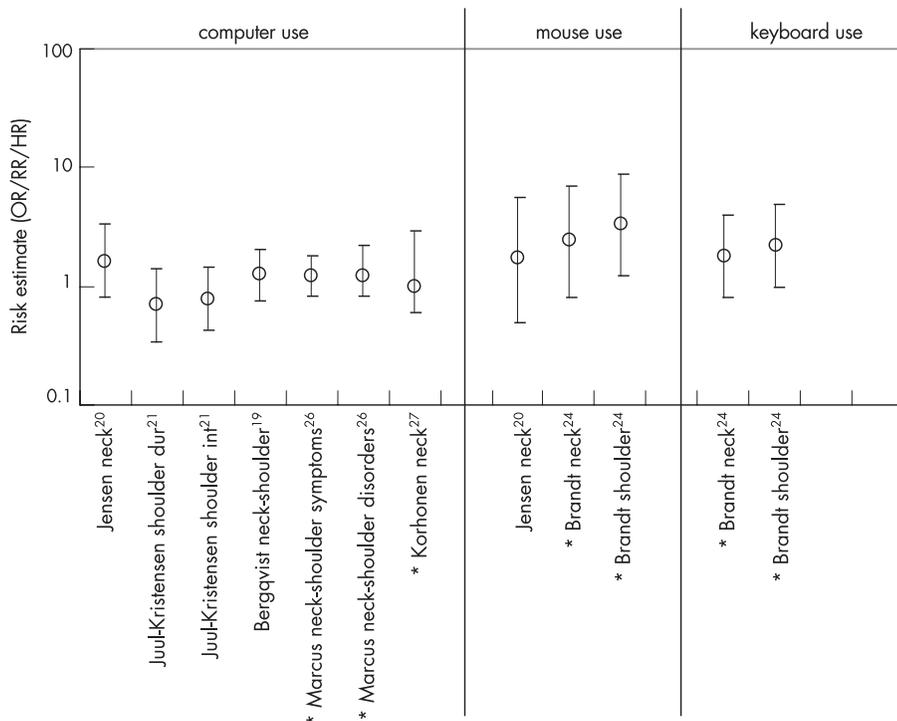

Figure 2 Risk estimates for the association between duration of computer use and neck–shoulder symptoms and disorders. See the italic numbers in the results columns of table 1 for exact values (*, high-quality study). HR, hazard ratio; OR, odds ratio; RR, rate ratio.
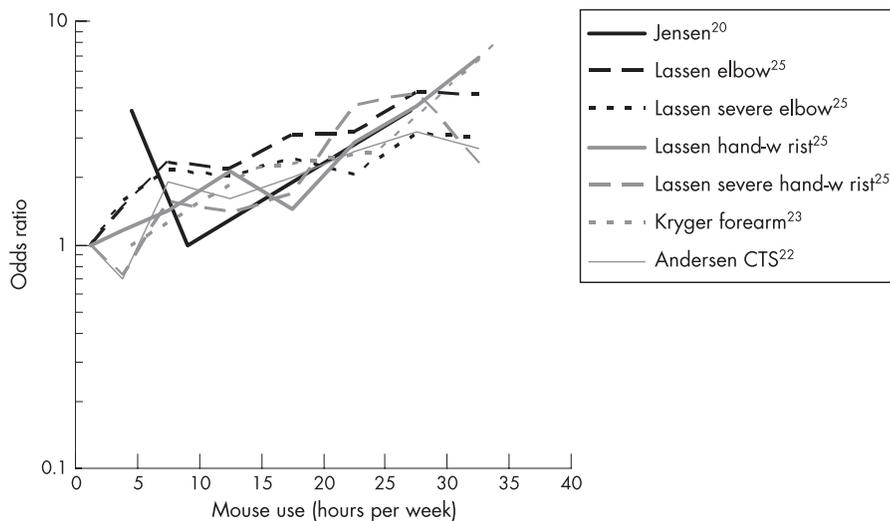

Main messages

- Longitudinal studies provide moderate evidence for an association between the duration of mouse use and the incidence of hand–arm symptoms among office workers.
- Future studies are needed to improve our understanding of safe levels of occupational computer use by dealing with the methodological limitations of the studies published so far.

---

exposure to mouse use might have had a high exposure to keyboard use, leading to a long duration of total computer use and thus an increased risk.

Lassen *et al*[25] showed a decreased risk for developing severe hand–wrist pain at their highest exposure category (ie, >30 h per week). A possible explanation is a saturation of biological pathways, or the presence of less susceptible workers at the highest exposure category due to selection in the past.[35]

To be able to explore a dose–response relationship, we assumed that the relationship between the point estimates of increasing exposure categories was linear. In addition, we had to estimate the average exposure within an exposure category. Both these factors might have biased our findings. However, these assumptions did not influence our general conclusion that the risk of developing hand–arm symptoms is higher at longer self-reported durations of mouse use.

Biological plausibility

The studies in this review that investigated the effects of the same exposure contrast on both the hand–arm and the neck–shoulder region, generally showed stronger risk estimates for the hand–arm region than for the neck–shoulder region. Studies on muscle activity during computer use are in line with these findings, since they indicate a higher loading of the hand–arm region (extensors of the wrist) than of the neck–shoulder region (trapezius muscle).[36–38] In addition, Laursen *et al*[39] found fewer electromyographic gaps in the extensor muscles of the wrist than in the trapezius muscle during computer use, potentially indicating longer periods of continuous activation of local muscle fibres belonging to the same motor unit. The findings from both lines of research are supported by a hypothesis that attributes a central role to the overuse of muscles and the physiological consequences of this overuse in the pathophysiological mechanism underlying hand, arm, shoulder and neck symptoms and disorders.[40]

Stronger risk estimates were found for mouse use than for keyboard use and total computer use. This difference can also be interpreted using the muscle overuse mechanism described above. Less variation in working postures during mouse use has been observed in comparison with keyboard work,[36 41] potentially leading to a longer duration of continuous muscle loading.[42]

On the basis of the above, it seems that evidence for a pathophysiological mechanism is available. However, caution is advised. The central role of muscles in the pathophysiological mechanism has been criticised.[43] In addition, it should be borne in mind that the evidence found in this review for and against associations was based on a limited number of studies. In addition, data for the effects of mouse and keyboard use are for the larger part derived from the NUDATA cohort. The possibility that a long duration of keyboard use can be a risk factor for developing hand, arm, shoulder or neck symptoms and disorders cannot be excluded, since only a limited range of exposures to keyboard use was available in the NUDATA cohort.

Limitations of this review

The conclusions of this review are based on a rather low number of cohort studies. Therefore, it is possible that the conclusions might change when new studies become available in the future.

A second limitation is that we compared studies with different case definitions. This might have influenced the results. Future research might indicate whether the associations between the duration of computer use and hand–arm or neck–shoulder symptoms are sensitive to these differences in case definition.

In addition, our review focused on only one contributing factor to the incidence of hand–arm and neck–shoulder symptoms and disorders among computer users (ie, duration of computer use). This does not represent the general concept of a multifactorial origin of musculoskeletal disorders.[6 9] Moreover, it might be possible that other factors related to computer use (such as working postures or mental demands) act as effect modifiers of the association between the duration of computer use and hand–arm and neck–shoulder symptoms. A combination of, for example, high mental demands and long duration of computer use might lead to a higher incidence than a long duration of computer use in itself. This might explain the

observed variation between study populations of the effect of a longer daily duration of computer use.

CONCLUSION

This review showed moderate evidence for an association between the duration of mouse use and the incidence of hand–arm symptoms. Indications for a dose–response were found. In addition, the neck–shoulder region seemed less susceptible to exposure to computer use than the hand–arm region. Both findings are supported by a pathophysiological mechanism based on the overuse of muscles during computer use. The low number of high-quality studies prevents drawing a firm conclusion. More research is needed to confirm our findings.

. . . .

Authors' affiliations

S IJmker, A J van der Beek, W van Mechelen, Department of Public and Occupational Health, Institute for Research in Extramural Medicine (EMGO), VU University Medical Centre, Amsterdam, The Netherlands
B M Blatter, P M Bongers, TNO Quality of Life, Hoofddorp, The Netherlands
M A Huysmans, Institute for Fundamental and Clinical Human Movement Sciences (IFKB), Faculty of Human Movement Sciences, Vrije Universiteit, Amsterdam, The Netherlands

REFERENCES

1 **Freeman RB**. The labour market in the new information economy. *Oxford Rev Econ Policy* 2002;**18**:288–305.
2 **Andries F**, Smulders PGW, Dhondt S. The use of computers among the workers in the European Union and its impact on the quality of work. *Behav Inf Technol* 2002;**21**:441–7.
3 **Hall W**, Morrow L. 'Repetition strain injury': an Australian epidemic of upper limb pain. *Soc Sci Med* 1988;**27**:645–9.
4 **Bammer G**, Martin B. The arguments about RSI: an examination. *Community Health Stud* 1988;**12**:348–58.
5 **Szabo RM**, King KJ. Repetitive stress injury: diagnosis or self-fulfilling prophecy? [Review]. *J Bone Joint Surg Am* 2000;**82**:1314–22.
6 **Punnett L**, Bergqvist U. Visual display unit work and upper extremity nusculoskeletal disorders: a review of epidemiological findings [review]. *Arbete och Hälsa* 1997;**16**:1–161.
7 **Tittiranonda P**, Burastero S, Rempel D. Risk factors for musculoskeletal disorders among computer users [review]. *Occup Med* 1999;**14**:17–38.
8 **Gerr F**, Marcus M, Monteilh C. Epidemiology of musculoskeletal disorders among computer users: lesson learned from the role of posture and keyboard use [review]. *J Electromyogr Kinesiol* 2004;**14**:25–31.
9 **Wahlström J**. Ergonomics, musculoskeletal disorders and computer work [review]. *Occup Med* 2005;**55**:168–76.
10 **Rothman KJ**, Greenland S. Causation and causal inference. Causation and causal inference. In: Rothman KJ, Greenland S, eds. *Modern epidemiology*, 5th edn. Philadelphia, PA: Lippincott-Raven, 1998:7–28.
11 **Hoogendoorn WE**, van Poppel MN, Bongers PM, *et al.* Physical load during work and leisure time as risk factors for back pain [review]. *Scand J Work Environ Health* 1999;**25**:387–403.
12 **Ariens GA**, van Mechelen W, Bongers PM, *et al.* Physical risk factors for neck pain [review]. *Scand J Work Environ Health* 2000;**26**:7–19.
13 **Van der Windt DA**, Thomas E, Pope DP, *et al.* Occupational risk factors for shoulder pain: a systematic review [review]. *Occup Environ Med* 2000;**57**:433–42.
14 **Hooftman WE**, van Poppel MN, van der Beek AJ, *et al.* Gender differences in the relations between work-related physical and psychosocial risk factors and musculoskeletal complaints [review]. *Scand J Work Environ Health* 2004;**30**:261–78.
15 **Kuorinka I**, Jonsson B, Kilbom A, *et al.* Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl Ergon* 1987;**18**:233–7.
16 **Baron S**, Hales T, Hurrell J. Evaluation of symptom surveys for occupational musculoskeletal disorders. *Am J Ind Med* 1996;**29**:609–17.
17 **Palmer K**, Smith G, Kellingray S, *et al.* Repeatability and validity of an upper limb and neck discomfort questionnaire: the utility of the standardized Nordic questionnaire. *Occup Med (Lond)* 1999;**49**:171–5.
18 **Lindström K**, Leino T, Seitsamo J, *et al.* A longitudinal study of work characteristics and health complaints among insurance employees in VDT Work. *Int J Hum Comput Interact* 1997;**9**:343–68.
19 **Bergqvist U**, Knave B, Voss M, *et al.* A longitudinal study of VDT work and health. *Int J Hum Comput Interact* 1992;**4**:197–219.
20 **Jensen C**. Development of neck and hand-wrist symptoms in relation to duration of computer use at work. *Scand J Work Environ Health* 2003;**29**:197–205.
21 **Juul Kristensen B**, Sogaard K, Stroyer J, *et al.* Computer users' risk factors for developing shoulder, elbow and back symptoms. *Scand J Work Environ Health* 2004;**30**:390–8.
22 **Andersen JH**, Thomsen JF, Overgaard E, *et al.* Computer use and carpal tunnel syndrome. A 1-year follow-up study. *JAMA* 2003;**289**:2963–9.
23 **Kryger AI**, Andersen JH, Lassen CF, *et al.* Does computer use pose an occupational hazard for forearm pain; from the NUDATA Study. *Occup Environ Med* 2003;**60**:e14.
24 **Brandt LP**, Andersen JH, Lassen CF, *et al.* Neck and shoulder symptoms and disorders among Danish computer workers. *Scand J Work Environ Health* 2004;**30**:399–409.
25 **Lassen CF**, Mikkelsen S, Kryger AI, *et al.* Elbow and wrist/hand symptoms among 6,943 computer operators: a 1-year follow-up study (the NUDATA Study). *Am J Ind Med* 2004;**46**:521–33.
26 **Marcus M**, Gerr F, Monteilh C, *et al.* A prospective study on computer users: II. Postural risk factors for musculoskeletal symptoms and disorders. *Am J Ind Med* 2002;**41**:236–49.
27 **Korhonen T**, Ketola R, Toivonen R, *et al.* Work related and individual predictors for incident neck pain among office employees working with video display units. *Occup Environ Med* 2003;**60**:475–82.
28 **Heinrich J**, Blatter BM, Bongers PM. A comparison of methods for the assessment of postural load and duration of computer use. *Occup Environ Med* 2004;**61**:1027–31.
29 **Lassen CF**, Mikkelsen S, Kryger AI, *et al.* Risk factors for persistent elbow, forearm and hand pain among computer workers. *Scand J Work Environ Health* 2005;**31**:122–31.
30 **Armstrong BG**. Effect of measurement error on epidemiological studies of environmental and occupational exposures [review]. *Occup Environ Med* 1998;**55**:651–6.
31 **Blangsted AK**, Hansen K, Jensen C. Validation of a commercial software package for quantification of computer use. *Int J Ind Ergon* 2004;**34**:237–41.
32 **Gerr F**, Marcus M, Ensor C, *et al.* A prospective study of computer users: I. Study design and incidence of musculoskeletal symptoms and disorders. *Am J Ind Med* 2002;**41**:221–35.
33 **Salerno DF**, Franzblau A, Werner RA, *et al.* Reliability of physical examination of the upper extremity among keyboard operators. *Am J Ind Med* 2000;**37**:423–30.
34 **Marx RG**, Bombardier C, Wright JG. What do we know about the reliability and validity of physical examination tests used to examine the upper extremity? [Review]. *J Hand Surg [Am]* 1999;**24**:185–93.
35 **Steenland K**, Deddens JA. A practical guide to dose-response analyses and risk assessment in occupational epidemiology [review]. *Epidemiology* 2004;**15**:63–70.
36 **Bystrom JU**, Hansson GA, Rylander L, *et al.* Physical workload on neck and upper limb using two CAD applications. *Appl Ergon* 2002;**33**:63–74.
37 **Jensen C**, Borg V, Finsen L, *et al.* Job demands, muscle activity and musculoskeletal symptoms in relation to work with the computer mouse. *Scand J Work Environ Health* 1998;**24**:418–24.
38 **Fernstrom E**, Ericson MO. Computer mouse or Trackpoint—effects on muscular load and operator experience. *Appl Ergon* 1997;**28**:347–54.
39 **Laursen B**, Jensen BR, Garde AH, *et al.* Effect of mental and physical demands on muscular activity during the use of a computer mouse and a keyboard. *Scand J Work Environ Health* 2002;**28**:215–21.
40 **Visser B**, van Dieën JH. Pathophysiology of upper extremity muscle disorders. *J Electromyogr Kinesiol* 2006;**16**:1–16.
41 **Karlqvist L**, Hagberg M, Selin K. Variation in upper limb posture and movement during word processing with and without mouse use. *Ergonomics* 1994;**37**:1261–7.
42 **Jensen C**, Finsen L, Hansen K, *et al.* Upper trapezius muscle activity patterns during repetitive manual material handling and work with a computer mouse. *J Electromyogr Kinesiol* 1999;**9**:317–25.
43 **Knardahl S**. Psychophysiological mechanisms of pain in computer work: the blood vessel-nociceptor interaction hypothesis. *Work Stress* 2002;**16**:179–89.