Den Videnskabelige Komite

Dansk Selskab for Arbejds- og Miljømedicin

A critical review of evidence for a causal relationship between computer work and musculoskeletal disorders with physical findings of the neck and upper extremity

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Forord

Dansk Selskab for Arbejds- og Miljømedicin (DASAM) har i december 2004 etableret en videnskabelig komité, som har til opgave løbende at formidle udbud med henblik på udarbejdelse af opdateret videnskabelig dokumentation vedrørende arbejdsbetingede sygdomstilstande samt forestå redigeringsprocessen af det videnskabelige dokument.

Komiteens oprettelse var foranlediget af, at Arbejdsskadestyrelsen har ønsket en række referencedokumenter om det videnskabelige grundlag for at antage, at særlige arbejdsmæssige påvirkninger kan være årsag til bestemte sygdomme. Komiteen står til rådighed for andre rekvirenter af lignende referencedokumenter. Komité-medlemmer blev udpeget af DASAM efter indkaldelse af forslag ved offentligt opslag.

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Det foreliggende referencedokument er nummer 2 af de udbudte opgaver. Det vedrører spørgsmålet om det videnskabelige grundlag for at antage, at computerarbejde kan forårsage sygdomme i nakke, skuldre og arme (eksklusive karpaltunnelsyndrom). Opgavens indhold har været beskrevet af Arbejdsskadestyrelsen, der har finansieret udarbejdelsen af dokumentet.

Graden af evidens for en årsagsmæssig sammenhæng er rubriceret efter en standard, som DASAM's videnskabelig komite har udarbejdet på baggrund af internationale standarder. Den anvendte standard er vist i Appendix.

Opgaven er løst af overlæge, dr.med. Bo Veiersted, overlæge, dr.med. Morten Wærsted og videnskabelig assistent, fysioterapeut Therese Nordberg, Statens arbeidsmiljøinstitutt, Oslo. Opgaven har været uafhængigt bedømt af to særligt sagkyndige reviewere, professor dr.med. Mats Hagberg, Gøteborg Universitet og overlæge ph.d. Johan Hviid Andersen, Herning Sygehus, og der er herudover indhentet skriftlige bemærkninger fra komiteens medlemmer. Dokumentet er efterfølgende gennemgået og drøftet på et heldags-møde med reviewerne, komiteen og forfatterne. Sluttelig har forfatterne revideret referencedokumentet i forhold til de fremkomne bemærkninger.

Komiteen og reviewerne kan tiltræde dokumentets konklusioner og de præmisser, der ligger til grund herfor.

København januar 2006

Sigurd Mikkelsen
Formand for DASAM's Videnskabelige Komite.

Resumé på dansk

Dette systematiske kritiske litteraturstudie belyser tilgængelig videnskabelig dokumentation for en eventuel sammenhæng mellem computer-arbejde og sygdomme i nakke, skuldre og arme.

Litteraturgennemgangen er afgrænset til tilstande, hvor sygdomsdiagnosen er baseret på, at der foruden symptomer også er fundet tegn på sygdommen ved klinisk undersøgelse eller brug af andre objektive metoder. Sammenhængen mellem computerarbejde og symptomer uden objektive fund er ikke omfattet af litteraturgennemgangen. Det samme gælder sammenhængen mellem computerarbejde og karpaltunnelsyndrom, der er behandlet i et særskilt referencedokument. De anførte afgrænsninger er betinget af den opgave, der er stillet af opdragsgiveren.

Der blev gennemført en omfattende litteratursøgning i databaserne Medline, Cochrane, Embase, DisDoc, NIOSHtic2 og HSEline. Ud af ialt 13410 artikler, gennemgået ved læsning af titler eller abstracts, blev der identificeret 78 epidemiologiske artikler, der omhandlede computer-arbejde og bevægeapparatslidelser. En søgning i forfatternes egne arkiver og søgning i referencelisterne for de identificerede artikler gav yderligere 55 epidemiologiske artikler. Disse blev gennemlæst.

Følgende inklusionskriterier blev benyttet:

(i) studiet skulle undersøge en population som regelmæssigt brugte mus eller tastatur,

(ii) studiet skulle undersøge bevægeapparatslidelser i nakke, skuldre eller arme (med undtagelse af karpaltunnelsyndrom),

(iii) studiet skulle inkludere en relevant objektiv undersøgelse (fx. scanning, røntgen eller klinisk undersøgelse),

(iv) studiet skulle være gennemgået og accepteret til publikation af andre eksperter inden for området ('peer reviewed') og publiceret på engelsk eller et af de skandinaviske sprog, og

(v) studiet skulle give mulighed for at beregne risiko estimater for forskellige eksponeringer ved computer arbejde.

Ud af de ialt 133 artikler opfyldte 9 artikler disse kriterier. De 9 artikler stammede fra 5 forskellige undersøgelser. To af undersøgelserne havde et prospektivt studie design, to var tværsnitsundersøgelser og en var et case- kontrol studie (se nedenfor).

Undersøgelsernes kvalitet blev bedømt, dels ved en skematisk gennemgang af en række kvalitetsparametre, dels ved en kvalitativ vurdering med vægt på undersøgelsens styrke og validitet. Undersøgelsernes kvalitet blev gradueret som lav, moderat eller høj.

De forskellige undersøgelsers resultater for en bestemt sygdom blev herefter vurderet med hensyn til graden af evidens for, at der var tale om en årsagsmæssig sammenhæng mellem sygdommen og computerarbejde. Resultaterne af andre studier, der er relevante for problemstillingen, men som ikke er omfattet af selve litteraturgennemgangen, er inddraget som supplement.

Den samlede grad af evidens blev vurderet efter en standard, som DASAM's videnskabelige komite har udarbejdet (se Appendix 1). Graden af evidens er opdelt i 5 kategorier:

1. tilstrækkelig evidens for en årsagmæssig sammenheng (+++),
2. begrænset evidens for en årsagsmæssig sammenhæng, grad A (++),
3. begrænset evidens for en årsagsmæssig sammenhæng, grad B (+)
4. utilstrækkelig evidens for en årsagsmæssig sammenhæng (0)

5. evidensen tyder på, at der ikke er nogen årsagsmæssig sammenhæng (-).

Den begrænsede evidens er som anført delt i to grupper, Grad A og Grad B. Grad A betyder, at den begrænsede evidens ikke umiddelbart ser ud til at kunne forklares ved svagheder i studierne, dvs. en ret stærk evidens. Grad B betyder, at den begrænsede evidens meget vel kan forklares ved svagheder i studierne, altså en svagere grad af evidens.

De 5 studier kan kort beskrives som følger:

Bergqvist et al. (referencelistens nr. (1, 2)). Undersøgelsen er en tværsnitsundersøgelse fra 1987 af 322 computer arbejdere (mindst 5 timers computer arbejde dagligt) og en kontrolgruppe på 62 personer (under 5 timers computer arbejde dagligt). Computerarbejdet har formentlig bestået i arbejde med tastatur. Musearbejde er ikke nævnt. Der er foretaget ergonomiske observationer. Undersøgelsen omfatter klinisk undersøgelse og diagnoser for specifikke sygdomme i nakke-, skulder-, albue- og håndregionerne. I resultatopgørelsen er flere sygdomme i samme region slået sammen og sygdomme i albue- og håndregioner er slået sammen. Undersøgelsens kvalitet er vurderet som moderat.

Ferraz et al. (referencelistens nr.(3)). Undersøgelsen er en tværsnitsundersøgelse fra 1995 af 130 computer arbejdere og 138 personer med traditionelt kontorarbejde uden brug af computer. Computerarbejdet refereres som tastaturarbejde. Undersøgelsen omfatter klinisk undersøgelse og diagnoser for specifikke sygdomme i nakke-, skulder-, albue- og håndregionerne. Undersøgelsens kvalitet er vurderet som lav til moderat.

Gerr & Marcus (referencelistens nr.(4, 5)). Undersøgelsen er en opfølgnings-undersøgelse fra 2002 af 632 nyansatte med mere end 15 timers computerarbejde per uge, overvejende med tastatur. Deltagerne er fulgt med dagbøger om deres arbejde ved computer og symptomer i op til 38 måneder. Der er foretaget målinger og observationer af en række ergonomiske faktorer. Undersøgelsen omfatter klinisk undersøgelse og diagnoser for specifikke sygdomme i nakke-, skulder-, albue- og håndregionerne. I resultat-opgørelsen er de specifikke sygdomme i nakke- og skulderregionerne og i albue- og håndregionerne slået sammen. Undersøgelsen fokuserer på virkningen af ergonomiske forhold. Virkningen af tastaturtid er kort anført, mens effekten af musetid ikke nævnes. Undersøgelsens kvalitet er vurderet som moderat til høj.

NUDATA-undersøgelsen (referencelistens nr. (6-8)). Undersøgelsen er en opfølgnings-undersøgelse af tekniske assistenter og maskinteknikere med basisundersøgelse i 2000 og en 1-års opfølgningsundersøgelse i 2001 med henholdsvis 6943 og 5658 deltagere. Kontrolgruppen er intern og består af de personer, der arbejder mindst med mus eller tastatur. Computerarbejde er opdelt i musearbejde og tastaturarbejde . Der er selvrapporterede data om ergonomiske forhold. Undersøgelsen omfatter klinisk undersøgelse og diagnoser for specifikke sygdomme i nakke-, skulder-, albue- og håndregionerne. Undersøgelsens kvalitet er vurderet som moderat til høj.

Tornqvist et al. (referencelistens nr. (9)). Undersøgelsen er en case-kontrol undersøgelse af 392 cases og 1511 kontroller. Cases var personer i et givet optageområde som søgte professionel behandling for lidelser i nakke og skuldre. Oplysninger om computerarbejde blev opnået ved interview og opdelt i over eller under 4 timers dagligt computerarbejde. Undersøgelsen omfatter klinisk undersøgelse og diagnoser for specifikke sygdomme i nakke- og skulder-sygdomme. I resultatopgørelsen er alle diagnoser slået sammen. Undersøgelsens kvalitet er vurderet som moderat.

De sygdomme, der er belyst i litteraturgennemgangen er de sygdomme, der er anført i de pågældende undersøgelser. Som anført har flere undersøgelser slået specifikke sygdomsdiagnoser sammen i resultatopgørelserne vedr. deres sammenhæng med computerarbejde. Disse resultater indgår i litteraturgennemgangens vurdering af årsagssammenhænge med computerarbejde, hvis den samlede diagnosegruppe overvejende består af en enkelt specifik diagnose, og er så henført til denne diagnose, men evidensen vurderes så som svagere end hvis det havde været den specifikke diagnose alene.

Følgende diagnoser er gennemgået:

(i) Nakkesmerter med fysiske fund
(ii) Skulder-tendinitis
(iii) Epicondylit (tennis- og golf-albue)
(iv) Nerveafklemning i underarmen (pronator teres syndrom og supinator syndrom)
(v) Håndledstendinit

Diagnosen 'Nakkesmerter med fysiske fund' dækker forskellige ikke standardiserede diagnoser omfattende Tension Neck Syndrome (Bergqvist et al., Ferraz et al., NUDATA, Tornqvist et al.) og Somatic Pain Syndrome (Gerr & Marcus), hvor der ud over nakkesmerter er palpationsømhed og/eller bevægeindskrænkning i nakken. De øvrige diagnoser følger i højere grad standardiserede diagnostiske kriterier.

Konklusioner

Nakkesmerter med fysiske fund (se tabel I)
Der er begrænset evidens, grad B, for en årsagsmæssig sammenhæng mellem computer arbejde og musearbejde. Grad B betyder at den begrænsede evidens meget vel kan forklares ved svagheder i studierne. Der er utilstrækkelig evidens til at bedømme om der er en eventuel årsagssammenhæng med tastaturarbejde.

Skuldertendinit, epikondylit og nervekompression i underarmen (se tabel II, III og IV).
Der er utilstrækkelig evidens til at bedømme om der er en eventuel årsagssammenhæng med computer-, muse- eller tastaturarbejde.

Håndledstendinit (se tabel V)
Der er begrænset evidens, grad B, for en årsagsmæssig sammenhæng mellem computer-, muse og tastaturarbejde. Grad B betyder at den begrænsede evidens meget vel kan forklares ved svagheder i studierne.

Graden af evidens for en årsagsmæssig sammenhæng er vurderet som lidt stærkere for håndledstendinit end for nakkesmerter med fysiske fund.

Der er fundet få spredte effekter af *ergonomiske forhold* i forbindelse med computerarbejde. Der er utilstrækkelig evidens til at bedømme disse forholds betydning for udvikling af sygdomme i nakke, skuldre og arme.

Der er utilstrækkelig evidens til at vurdere om computerarbejde har en forskellig betydning for udvikling af sygdomme i nakke, skuldre og arme hos *kvinder sammenlignet med mænd*.

Forskningsbehov

Der er behov for, at fremtidig forskning i videst muligt omfang inddrager objektive mål for både eksponering og sygdom. Om dette er realistisk er tæt sammenhængende med hvilket design der skal anvendes til at finde de alt i alt relativt sjældne sygdomstilfælde. Området er kompliceret, og det er ikke muligt at fremkomme med specifikke anbefalinger inden for rammerne af det foreliggende arbejde.

Review

Contents

<u>Overview of figures and tables</u>

1 Introduction and aim

Musculoskeletal complaints in the neck and upper extremity and computer work are common in modern society and both show an increasing trend. Three to four year old data from Eurostat show that approximately 50% of the working population in Scandinavia and Finland and a slightly lesser percentage in Iceland use computers half the working day or more (http://www.dst.dk). The latest Norwegian survey in 2003 showed that almost 54% of the work force use computer at least half the working day (http://www.ssb.no). With a 26% average for the EU-15 countries, the Nordic countries have the highest prevalence of occupational computer use in Europe (http://www.dst.dk). The increased use of computers in the working population is reflected in the insurance data. Numbers from the United States show that computer mouse related cumulative trauma disorder claims (CTD claims) increased from 4 claims in 1989 to 219 in 1993. In the same time period general computer related CTD claims increased from 70 to 3593 claims. In total the cost for general and mouse computer related CTD claims was 15,502,787 US dollars in 1993 (10).

Computer work is defined in this review as work with video display units (VDU) or video display terminals (VDT) that involves the use of keyboard and/or mouse. Work that involve the use of a personal digital assistant (PDA), handheld computer, personal organizer device or other forms for mobile computers are not considered in this review. Many previous reviews of epidemiological literature have indicated a possible causal relationship between subjective complaints in the neck and arm and computer work (11-13). Typing on a keyboard is a typical aspect of computer work, but it is often difficult to separate keyboard activity from computer work per se (11, 14, 15).

A complex of various environmental work factors characterizes computer work, and there are several features that are relevant when discussing the development of musculoskeletal problems in this type of work. Physical factors, psychosocial and organisational factors as well as individual factors are all thought to affect the workers musculoskeletal health (16). Psychosocial factors have been investigated in relation to computer work and upper extremity and neck symptoms, and it is believed that factors like time pressure and high perceived work load interact in the development of the symptoms (17, 18). Some physical and psychosocial factors may be specific for computer work, while others can also be present in occupational groups with no computer use. An example of generic factors concerning computer work can be illustrated by prolonged sitting, postures in the neck and hand intensive work (19). Even though psychosocial factors can be of great importance when investigating disorders in computer users, this review will mainly focus on the specific physical factors relevant to computer work when evaluating a possible causal relationship with neck and upper extremity musculoskeletal disorders.

The use of a keyboard requires the depression of the keys, implying repetitive finger movements. The location, height and design of the keyboard affects the posture of the wrist, elbow and shoulder (11). Non-neutral position of the wrist like wrist extension or ulnar deviation have been reported as risk factors for arm, wrist and hand pain (13) (12). Physical factors as high typing speed and a lack of forearm support have been indicated as a risk factor for upper extremity symptoms (11) (20). Non-keyboard input devices, such as the computer mouse, can also be related to physical strain. Repetitive clicking in addition to the sustained low-level muscle activity when holding and moving the mouse may increase the sustained muscle activity and the tendon strain (11). Non-neutral position of the wrist and long daily mouse use have also been reported as risk factors for hand and/or wrist complaints (20, 21, 16).

The epidemiological studies concerning computer use and musculoskeletal health are mainly based on subjective measures of upper extremity musculoskeletal symptoms, and indications exist of an exposure-response relationship between typing time and risk of upper extremity symptoms (11, 20). It is also found that upper extremity symptoms are more frequent in the mouse operating hand compared to the other arm and hand (22). However, when evaluating a possible causal relationship between computer work and musculoskeletal disorders, such as when handling insurance claims, it is necessary with a more objective measure of sustained effect on the musculoskeletal system.

The aim of this study was to critically review the epidemiological evidence for a possible causal relationship between different aspects of computer work, including keyboard and mouse use, and neck and upper extremity musculoskeletal disorders with physical findings (except carpal tunnel syndrome (CTS)).

2 Material and methods

2.1 Search strategy

A computer based literature search was performed using Medline (1966 - April 2005), Cochrane (1993 – April 2005), Embase (1966 – April 2005), CisDoc, NIOSHtic2 and HSEline (1977 – April 2005) to identify relevant studies. A search profile for the computer-based search was discussed and developed in cooperation with the library personnel at the National Institute of Occupational Health. The following keywords were used: (disorder, musculoskeletal disorder*, diagnosis, discomfort OR pain) AND (upper extremit*, fingers, finger, hand*, wrist*, elbow*, shoulder* OR neck) AND (personal computer, laptop, visual display unit*, vdu*, keyboard*, computer* OR pc). In the search using Embase and the review search on Medline the keywords symptoms and risk factor* were used in addition to the terms previously mentioned.

To maximize the number of relevant studies retrieved, a search was also done in the authors personal archives/files in addition to screening the reference lists of all the included epidemiological studies and six selected reviews that were identified through the computer based search (11, 13, 14, 16, 23, 24).

2.2 Literature selection

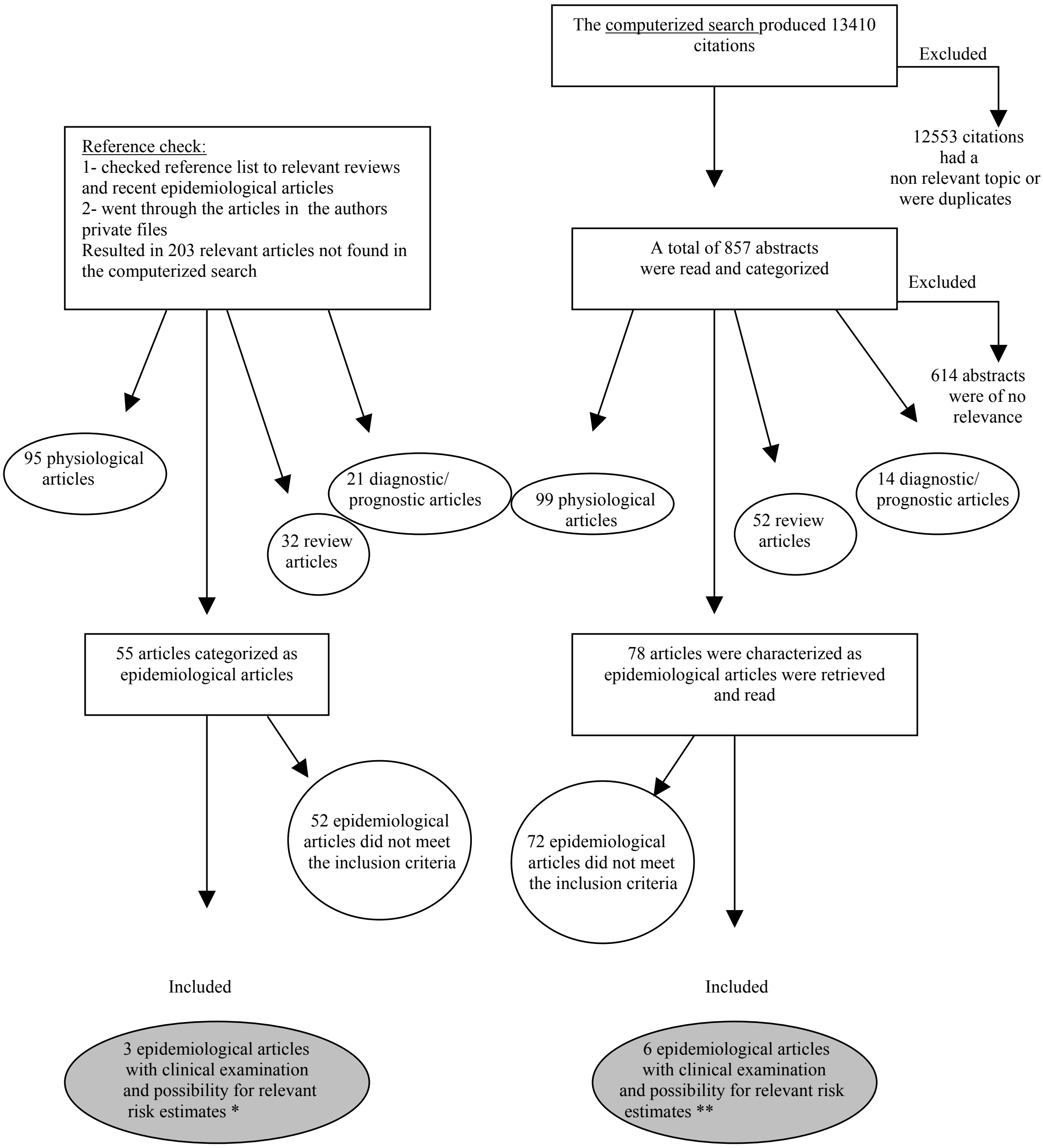
The titles of all articles from the computer-based search were screened for relevance to computer use and upper extremity pain or disorders. Two reviewers (KBV and TN) read the titles and decided if the title were related to the topic of the review. If it, based on the title, was unclear whether the article was of interest, the abstract was checked. Abstracts of all the selected titles were retrieved and read, and when the topic was relevant the full article was retrieved. In the cases where the abstracts were not available or when the abstract gave insufficient information, the full article was retrieved. All relevant articles were then classified into four categories: epidemiological articles, review articles, physiological articles and diagnostic articles. The epidemiological articles having data on computer use and musculoskeletal disorders in the neck and upper extremity were the primary targets for the present review. The reason for including the other categories was to use them as supplement to analyze, discuss and evaluate the different findings in the epidemiological articles. The review category included articles that critically analyzed the epidemiological and biological evidence for computer related upper extremity musculoskeletal disorders. The articles in the physiology category were used to evaluate the biological plausibility and discuss the mechanical load in relation to computer keyboard and mouse use. The articles categorized as diagnostic were articles concerning diagnostic definitions or prognostic factors of work-related upper extremity musculoskeletal disorders relevant for computer work. All the articles in the epidemiological category were read and the following five inclusion criteria were applied: (i) the study was peer reviewed and published in English or Scandinavian languages, (ii) the study had a population of working individuals, that used computer mouse and/or keyboard regularly, (iii) the study involved pain disorders in the neck and upper extremity, (iv) the study had to include a relevant objective examination (e.g. scanning, x-ray or a physical examination), and (v) the study design made it possible to perform risk estimates for diagnostic entities of pain disorders related to different exposures of computer work. Studies only focusing on the carpal tunnel syndrome were excluded (see separate review). Reports, abstracts and proceedings were also excluded from this review. The use of "diagnostic entities" in criterion (v) correspond mostly to the clinical criteria proposed by Harrington et al. in 1998 (25) (26) and Sluiter et al. in 2001 (27). Based on the International classification of disease, the disorders with physical findings were given the corresponding ICD-10 code (see table II). When needed the ICD10 code was supplemented with a code indicating site of musculoskeletal involvement (1 – shoulder region, 2 – upper arm, 3 – forearm/wrist, 4 – hand). In criterion (iv) the term "objective examination" needs clarification. In this review an objective examination is either understood as a physical examination or a laboratory test (e.g. MR and X-ray). The physical examination has to be carried out according to a protocol or schedule stated clearly in the article. Studies qualifying for criteria (i-iv) but not for criterion (v), were included when appropriate as contributing evidence. See Figure 1 for flow-chart of the selection process.

2.3 Quality assessment

The included studies were assessed with respect to their methodological strength. The first part of this assessment was conducted using a quality assessment list, which is based on existing quality criteria used in recent reviews (28-30). The list consisted of 23 items which were grouped in 5 categories; study purpose, study population, exposure measurements, outcome measurements, and analysis and data presentation (see Table I). Each of the items were scored either; positive (1), negative (0), unclear (?) or not applicable. The number of items that were applied differed slightly between articles depending on the study design. This schematic assessment was carried out by two of the authors (KBV and MW), which independently considered each of the articles. The final assessment for each article was decided in a consensus meeting with all three authors (TN, KBV and MW).

The simple schematic method for quality assessment used here, however, does only give a limited insight into the quality of the considered papers (see i.e. Higgins JPT, Green S, editors. approaches to summarising the validity of studies. Cochrane Handbook for Systematic Reviews of Interventions 4.2.5 [updated May 2005]; Section 6.7. http://www.cochrane.org/resources/handbook/hbook.htm (accessed 30th September 2005)). It was therefore decided to subject the articles to a more "qualitative" quality assessment based on the guidelines given, among others, in the Cochrane Handbook. First it was decided whether the study in question gave possibility to assess risk estimates for the possible association between computer work and the musculoskeletal disorders of interest for the present review. The studies that fulfilled this criterion were then quality assessed for precision (lack of random error) and validity (lack of systematic error) (31). The precision of the studies was assessed mainly by the sample size and the width of the confidence intervals. The reliability of the physical examinations (sensitivity, specificity and predictive value) was not presented in the included studies. The internal validity of the studies was mainly evaluated with respect to the possibility of selection bias, information bias and confounding (31). Selection bias concerns for example different interest to participate in a study for exposed compared to unexposed subjects and the "healthy-worker effect".

Figure 1. Flow-chart to illustrate the selection procedure when accepting and rejecting papers in the review



* (1, 6, 9)
** (2-5, 7, 8)

Information bias may on one hand cause differential misclassification where a classification of exposure or effect depends on other variables (e.g recall bias) and may on the other hand cause non-differential misclassification. A relation between exposed and unexposed may be "confounded because the difference in disease frequency between the exposed and unexposed results from a mixture of several effects, including (but not limited to) any exposure effect " (31). We included under external validity (applicability or generalisability) the appropriateness of the research questions posed in the study and the choice of scientific methods (study design, subjects studied, and relevance of exposure and outcome measures). On the basis of this qualitative approach it was concluded if the study had a low, moderate or high quality.

2.4 Level of evidence

To evaluate the evidence of causality in this review, the criteria from the NIOSH review in 1997 (19) is used as the basis. These are in turn built upon the criteria of causality suggested by Hill (32). We used the following four evaluation criteria:

1. Consistency: an association that is repeated in multiple independent studies support the plausibility of a causal relationship. The causal relationship is weakening when similar studies show different results.
2. Temporality: exposure always precedes the response in time. This is ensured in prospective cohort designs.
3. Exposure-effect relationship: an association between the occurrence of a disease and the intensity, duration or frequency of the exposure, will support a causal relationship.
4. Coherence of evidence: a consistence of the associations and the natural history and biology/physiology of the disorder (biological plausibility) will support a causal relationship.

Findings that met all of the causality criteria were emphasised more than findings that met few of the criteria. On the basis of this assessment the degree of evidence was decided.

On the basis of IARC`s classification system the strength of evidence from the selected epidemiological articles was classified into 5 categories, according to the categories suggested by The Scientific Committee of the Danish Society of Occupational and Environmental Medicine, 2005. The following categories were used:

+++	Sufficient evidence of a causal association
++	Limited evidence, grade A (bias and confounding are not a likely explanation of associations(<50%))
+	Limited evidence, grade B (bias and confounding are not an unlikely explanation of associations(>50%))
0	Insufficient evidence of a causal association
-	Evidence suggesting lack of a causal association

See Appendix I for further definitions of categories.

2.5 Data extraction

Information on design, case definition, study population, sample size, response rate, exposure assessment, and results was extracted from each article (see Table IX). The associations between computer work per se, keyboard and mouse use and musculoskeletal disorders in the neck and upper extremity, was presented. Positive findings were defined as statistically significant associations and/or relative risks (RR), hazard ratios (HR) or odds ratios (OR) >2.0 or <0.5. The 95% confidence interval is presented with the RR, HR or OR when stated in the article.

2.6 Definition of neck and upper extremity disorders with physical findings and clinical diagnoses.

The relevant disorders are selected on the basis of findings in the epidemiological studies of interest in this review. The demands on precision of the diagnostic tests are lower for the epidemiological studies compared to what is needed in clinical practice (33, 34). However, it is problematic that the different studies on computer work and upper extremity and neck disorders use different case definitions. It is on the other hand important that the studies have used diagnostic tests with high sensitivity and specificity for certain diagnostic entities (27). Since there is no scientific consensus for the ICD-10 musculoskeletal diagnoses, the case definitions proposed by Harrington et al. in 1998 (25) and in the criteria document by Sluiter et al. (27) are considered in this review. Table VIII gives an overview of definitions of the diagnoses used by the included studies.

2.6.1 Neck pain with physical findings (M54.2)

Non-radiating pain in the neck is often called tension neck syndrome, also referred to as trapezius myalgia in recent reviews (35, 36). It is often assumed not to be a specific disorder, and may be defined as a complex of non-specific disorders (27). In a review by Waris et al. on occupational neck and upper limb disorders they suggest the subjective symptoms for tension neck syndrome to be: neck pain, feeling of fatigue or stiffness in the neck. The objective signs were: muscle tightness, palpable hardenings, tender spots in muscle and straightening of the cervical spine (37). Tension neck syndrome was used to designate this entity in the NUDATA-study (7) and in the studies by Bergquist et al. (1, 2), Tornqvist et al. (9) and Ferraz et al. (3). Gerr et al. used somatic pain syndrome as a diagnostic entity (4). In this review the non-specific neck disorder will be called “neck pain with physical findings” and which may correspond to Cervicalgia (M54.2) in the ICD-10. The entity “radiating neck pain” used by Sluiter et al. was not used in any of the included studies (27) and Harrington et al. did not describe an entity of neck pain with physical findings (25).

2.6.2 Cervical syndrome (M54.1)

According to Waris et al. cervical syndrome is a well-defined diagnostic entity compared to tension neck syndrome. The criteria required for a cervical syndrome diagnosis in the presented studies were not equal to the criteria proposed by Waris et al. (37). Positive neck compression test (Spurling`s test) was the only objective criteria that the study by Marcus et al. had for cervical syndrome or radicular pain syndrome (5). The cervical syndrome in this review corresponds to the radiculopathy (M54.1) in the ICD-10 classification. Neither Sluiter et al. nor Harrington et al. defined the cervical syndrome (25, 27).

2.6.3 Shoulder tendonitis (M75.1, M75.2, M75.4)

In the study by Marcus et al. (5) the criteria for shoulder tendonitis is quite similar to that of Harrington et al. (25). Rotator cuff tendonitis require a history of pain in the deltoid region and pain on one or more resisted active movements (see below) and biceps tendonitis require a history of anterior shoulder pain and pain on resisted active flexion of elbow or supination of forearm. In Sluiter et al. (27) the subjective symptoms for a case definition required; intermittent pain in the shoulder region without paresthesias and worsened pain with active elevation, present at examination or for at least four days the previous week. The objective signs were stated as; pain with resisted shoulder abduction, external/internal rotation, resisted elbow flexion or painful arc on active upper arm elevation. Rotator cuff syndrome is shoulder tendonitis involving the tendons of the rotator cuff, it may also include supraspinatus tendonitis. In Mani et al. the diagnostic criteria was defined as a positive arc-of-motion and/or positive Hawkin`s impingement sign (35). In the NUDATA-study, Brandt et al. rotator cuff syndrome was defined as positive impingement test and pain at resisted shoulder abduction, external or internal rotation (7). The shoulder tendonitis syndrome corresponds in this review to the rotator cuff syndrome (M75.1), the bicipital tendonitis (M75.2), and the impingement syndrome of shoulder (M75.4) in the ICD-10. Shoulder myalgia was defined as substantial palpation tenderness of the levator scapula, the supraspinous or the infraspinous muscles in the Brandt et al. study (7).

2.6.4 Epicondylitis, lateral (M77.1) and medial (M77.0)

The articles that have defined lateral and/or medial epicondylitis in their case definitions have all included palpation tenderness in the relevant region (3, 5, 6, 8). Harrington et al. (25) require lateral epicondylar pain and epicondylar tenderness and pain on resisted extension of the wrist. However, palpation of tenderness when diagnosing epicondylitis was found by Viikari-Juntura et al. to have low reliability and comparability (38), and it is therefore not a diagnostic criteria in the Sluiter criteria document (27). In Sluiter et al. the criteria for an epicondylitis diagnosis requires at least intermittent, activity-dependent pain corresponding to the lateral or medial epicondyle, and that it is present at examination or for at least four days during the previous week. The objective measurement must find signs of local pain on resisted wrist extension (lateral) or flexion (medial). The epicondylitis corresponds in this review to the lateral epicondylitis (M77.1) and the medial epicondylitis (M77.0) in the ICD-10.

2.6.5 Supinator syndrome and pronator teres syndrome (G56.3)

Supinator syndrome and pronator teres syndrome are both conditions caused by radial nerve compression. Entrapment of the radial nerve in the forearm can produce a variety of signs and symptoms depending on the compression location, and the symptoms can in some cases be similar to those of epicondylitis or wrist tenosynovitis (27). One of the included articles investigated supinator syndrome (6). The clinical case definition was similar to the one presented in Sluiter et al. as radial nerve compression (27). The case definition required tenderness in the supinator area on palpation and either positive resisted forearm supination or resisted middle finger extension. The time frame was stated as pain present at examination or for at least four days the previous week (27). The radial nerve compression corresponds in this review to mononeuropathy of the radial nerve (G56.3) in the ICD-10.

Kryger et al. was the only one of the included articles that investigated pronator teres syndrome, which is not defined in the criteria document by Sluiter et al. The clinical criteria were based on Rayan et al. (39) and defined as substantial pressure palpation tenderness on the volar side of the proximal forearm. In addition to pain in the pronator area when testing resisted pronation of the forearm and/or paresthesias in 1-3 finger when resisted flexion of middle finger (6). The pronator teres syndrome corresponds in this review to mononeuropathy of the radial nerve (G56.3) in the ICD-10.

2.6.6 Wrist tendonitis (M65.8(3))

In the study by Marcus et al. the objective sign for flexor or extensor tendonitis was defined as pain at resisted wrist flexion or extensor movements and either palpation tenderness, swelling, crepitation or local warmth/redness (5). This definition is identical to the case definition proposed in other articles evaluating upper extremity disorders, except that these definitions do not include the sign of local warmth and redness (27, 40). The criteria formulated by Sluiter et al. requires additionally symptoms of intermittent pain-ache in ventral or dorsal forearm or wrist region that is present on the day of examination or on at least four days the last week (27). Harrington et al. (25) require pain on movement localised to the affected tendon sheaths in the wrist and reproduction of pain by resisted active movement of the affected tendons with the forearm stabilised. In this review the case definitions that is classified as wrist tendonitis may correspond to the diagnosis other synovitis and tenosynovitis (forearm region) (M65.8(3)) in the ICD-10.

2.6.7 De Quervain`s disease (M65.4)

The extensor tendon in the first dorsal compartment is the most commonly affected to chronic injury and is therefore presented separately from the other extensor tendons of the wrist (40). Harrington et al. (25) require pain which is centred over the radial styloid and tender swelling of the first extensor compartment and either pain reproduced by resisted thumb extension or a positive Finkelstein's test. Only two of the 9 included articles investigated computer use and the risk of developing De Quervain`s disease (4, 8). Their objective sign requirement for diagnosis was almost similar to the Harrington criteria; radial wrist pain, point tenderness located to the first dorsal compartment and a positive Finkelstein's test (8). Sluiter et al. (27) follows the Harrington criteria, but in addition the subjective symptoms of intermittent pain or tenderness over the radial side of the wrist must be present at examination or on at least four days the last week. The De Quervain's syndrome correspond to the Radial styloid tenynovitis [de Quervain] (M65.4) in the ICD-10.

In conclusion, the case definitions of the neck pain disorders in the included studies, are not comparable with the criteria document by Sluiter et al. (27), however, the other case definitions for the upper extremity are to a great extent comparable. The Harrington et al. criteria (25) do not include neck pain and nerve compression disorders, but do otherwise correspond fairly well to the case definitions of the included studies.

2.7 Prognosis of the neck and upper extremity disorders with physical findings

This section gives data on the prognosis of the musculoskeletal disorders included. The emphasis is on prognosis for these specified diagnoses with regard to work related factors and/or in relation to prospects for return to work. Generally the literature gives little information on the prognosis of work-related musculoskeletal disorders relevant from this point of view, especially when looking at specific diagnostic entities.
We have not found specific information on the prognosis for neck pain with physical findings or cervical syndrome with respect to return to work.

In a Danish study 113 industrial and service workers with shoulder tendonitis were followed with yearly re-examination up to three times (41). Some 50% of the workers recovered within 10 months. Higher age was strongly related to slow recovery, while physical work demands were not. The perception of the psychosocial work conditions before becoming a shoulder tendonitis case did

not predict recovery time (studied in the incident cases identified during the follow-up period) (41).
The lateral epicondylitis (tennis elbow) is the more common and have thus received most attention in the literature compared to the medial epicondylitis. In most cases this is a self-limiting condition that will generally resolve within 1 year on conservative treatment (42) and in a general population study the remission rate improved with increasing age (43).

With conservative treatment 50% of patients with pronator syndrome have been reported to recover in 4 months (44). We have not found specific information on the prognosis for pronator teres syndrome with respect to return to work.
In an outpatient hand rehabilitation clinic Barthel and co-workers (45) performed a case study on 24 patients with complaints related to repetitive use participating in a multidisciplinary rehabilitation program. Bilateral hand and forearm pain were the main symptoms and most cases (83%) were related to computer keyboard use. A unique physical finding was diffuse tendon tenderness and tightness of the long flexor and extensor muscles of the forearm (carpal tunnel syndrome was only found in one patient). The rehabilitation program consisted of medical management with pharmacologic interventions, occupational therapy with workplace simulation and job-site evaluations, and psychological treatment with pain management and biofeedback training. Twenty-five percent of patients achieved resolution of most symptoms, although on a modified and often reduced activity level; and 54% had moderate improvement. Of the patients receiving medical disability compensation, 58% returned to their previous jobs (45).
Two out the 24 cases in the case study of an outpatient hand clinic cited above under wrist tendonitis/tenosynovitis (45), were diagnosed with De Quervain’s tendonitis. Both patients showed improvement following treatment and could continue work at ergonomically modified workplaces.

3 Results

The results of the computer-based search gave a total of 13410 citations. After titles and abstracts were reviewed for their relevance, 78 epidemiological articles were read, of which 13 articles were included on basis of the first four inclusion criteria (i-iv). The reference list and personal archive search resulted in 203 relevant articles, and 55 of them were epidemiological articles. After applying the inclusion criteria (i-iv) four more articles were accepted from personal archives, resulting in a total of 17 articles.

The fifth inclusion criterion was used to extract documentation for risk estimates of specific diagnoses, which resulted in a final inclusion of nine studies. The eight studies (46-53) excluded due to criterion (v) will be cited as contributing evidence when appropriate. The MEPS (Musculoskeletal, Eyestrain, Psychosocial and Stress) research collaboration made interventions on optometric corrections and ergonomic adjustments and training but they did not use diagnostic entities (only described physical findings) and were furthermore not designed to calculate risk estimates (46-48). Only one study in MEPS used a control group but the groups were rather small and no risk estimate was presented (46). The study by Hales et al. (49) focus on organizational and psychosocial aspects in a study of computer users exposed at least 6 hours per day. They did not analyse possible effects of contrasts in exposure between groups. Brisson et al. (50) performed an intervention study on the effect of ergonomic training on musculoskeletal disorders in university employees using computer 5 hours per week or more. The possibility of using a contrast within a rather large sample was not used, only an effect of the intervention was analysed. Relevant diagnoses were investigated but due to lack of statistical force they were merged into ill-defined diagnostic entities. Ferreira et al. (53) investigated the effect of an organisational intervention for call center operators on musculoskeletal diagnoses. However, these were ill-defined in the article and no contrast of exposure effect was analysed. The studies by Hünting et al. (51) and Onishi et al. (52) performed in the early 1980-ies only use physical findings and no specific diagnostic entities. Both used a control group but none of them made risk estimates. In addition, both studies were published very early after the introduction of computers in working life, assumingly resulting in a description of computer work that is “out of date”.

A total of nine scientific articles were identified and fulfilled the criteria for inclusion (i-v), but several articles were based on the same study. Three articles came from the NUDATA study (6-8). Bergqvist et al. wrote two articles on the same data in 1995 (1, 2), Gerr et al. and Marcus et al. wrote two articles on their data in 2002 (5, 54) and two studies were published as single articles in 1995 (3) and 2001 (9). Of these five included studies, two were longitudinal, two cross-sectional and one study had a case-control design. (More details on the rejection and acceptance of articles are shown in the flow diagram, Figure 1).

3.1 Schematic quality assessment of preliminary included articles

The overall agreement was 76% between the two reviewers who performed the schematic evaluation of methodological quality of the included articles. The range for the agreement on each article was 56% to 94%. There was more disagreement on quality item 12,16 and 23 compared to the other items. Table VII presents the final assessment of the “schematic” methodological quality for each individual article that was decided on at a consensus meeting between the authors.

3.2 Quality assessment and main findings of the included studies

The relations between computer use and neck or shoulder disorders with physical findings were studied by eight of the included articles, but only two (5, 7) of them looked at computer keyboard and mouse use in particular.
Elbow diagnoses in relation to computer work per se was presented in two studies (1-3), and in relation to the use of computer keyboard and mouse in two studies (4, 5, 8). Diagnoses of forearm, wrist and hand (mainly wrist tendonitis) were studied in relation to computer use per se in two studies (1-3), and to computer keyboard and mouse use in four studies (1-6, 8).

Bergqvist et al. (1, 2) describes a study of 322 VDT users examined in 1987, but selected from an original study population from 1981 consisting of 395 exposed and 141 controls, the latter not working with VDT, and rather evenly distributed in a) an insurance company, b) an airline/post office and c) three daily newspapers (55). The exposed in the 1987 study should work with VDT at least 5 hours per week (h/w) (N=260), and subjects working less than 5 h/w with VDT were also included in a control group (N=62). One of the articles included in this review (2) only use the 260 current VDT users for analyses. The precision of the study seems sufficient, since many confidence intervals for OR's are small, e.g. the largest of results of interest was 0.6-3.0. The cross-sectional design of the study reduces the possibility to detect an effect of temporality. Longitudinal approach was only performed on subjective symptoms (56, 57). It may exist selection bias both at entry into the study (choice of work and department) and as a "healthy-worker effect", especially for hand problems as suggested by the authors (1). However, the authors analysed the drop-outs and concluded with low risk for this kind of selection bias (57). The response rate was high. The exposure was classified according self-reported working hours with VDT use, which may be viewed differently in the different work places mentioned above. This possible reason for exposure misclassification is not discussed in the article. The persons performing the physical examinations were blinded for subject status and results from a questionnaire. Adjustment was performed for age, gender, organizational and ergonomic factors. Overall, we evaluate the precision and the internal validity as acceptable. The study was designed to evaluate VDT work as such and includes interactive and data entry computer work, but (of course) it does not evaluate computer mouse use, as all users only used keyboard. The low number of subjects in the control group may be a matter of concern for this study, however, the risk estimates seems robust. Overall, we evaluate the external validity as sufficient. The overall assessment concluded with a study of *moderate quality*.

The prevalence of neck or shoulder disorders in the study population of current VDT users was found to be 21.8% for tension neck syndrome (TNS), 23.4% for cervical diagnoses (e.g. cervical syndrome) and 11.9% for shoulder diagnoses (e.g. tendonitis) (2). The authors found that VDT users did not have higher risk for TNS and cervical diagnoses compared to non-VDT (or low-level) users. TNS and cervical diagnoses were however associated with VDT work for 20 hours or more per week when combined with use of progressive glasses and presence of spectral glare respectively (1). TNS was associated to a too highly placed keyboard and cervical diagnosis to static posture (2). Almost nine per cent (8.7%) of current VDT-users had an arm/hand diagnosis (1, 2). The authors found that working with computers 20 hours or more per week was associated with increased level of hand/arm diagnoses *only* in combination with limited rest opportunity and non use of arm support (1). Hand/arm diagnosis was associated to no use of lower armrest (2).

Ferraz et al. (3) performed a cross-sectional study on keyboard operators and traditional office workers. The precision of the study was not optimal with rather few cases in the comparison groups, especially concerning tension neck syndrome (TNS) also shown in wide confidence intervals. The risk for selection bias is evaluated as low since all keyboard operators and a randomized sample of office workers were selected and examined. It seems from the article that no adjustment was performed for individual and psychosocial factors, however, the authors compared the groups on these issues and found comparable conditions. The exposed subjects were described as keyboard operators, but may have performed "computer work per se". A non-differential misclassification may occur since the exposure of the control group was badly described (they had little to no keyboard work). However, the internal validity is evaluated as sufficient. The research question was appropriate but choice of method (cross-sectional study) limits possible conclusions on causal relationships. Furthermore, the use of statistical methods do not control efficiently for confounders. The exposure contrast was well defined and described but perhaps this kind of strictly keyboard work is outdated, especially limiting the interpretation for "developed countries". The overall assessment concluded with a study of *low to moderate quality*.

Of the 130 keyboard users in the study they found 7,7% with TNS compared to 1.4% of the traditional office workers with no/little keyboard work. Three point eight per cent of the keyboard users had supraspinous tendonitis while no diagnosis was found among non-keyboard users (3). Punnett et al. (11) used the data by Ferraz et al. to calculate the prevalence ratio of TNS (PR=5.3; 1.2-23.8) and any upper extremity disorder (PR=4.4; 2.5-7.9). Of the 130 keyboard users in the study by Ferraz and colleagues, they found 1,5% with epicondylitis compared to 1.4% of workers with no or little keyboard use (3). The prevalence of hand and wrist tenosynovitis/tendonitis (wrist tendonitis) in the study by Ferraz et al. was 17.7% in keyboard users, compared to 3.6% in the traditional office workers (3). Punnett et al. (11) used the data by Ferraz et al. to calculate the prevalence ratio of wrist tendonitis (PR=4.9; 1.9-12.5). Ferraz et al. also showed that men were less likely to get upper extremity disorders in general, but not specifically for forearm, hand or wrist disorders (3).

Gerr et al. (4) and Marcus et al. (5) performed a prospective study of computer users with no control group, making it difficult to assess the risk of computer work per se. Internal contrasts concerning keyboard hours and work postures were focused upon. The precision of the study is sufficient, indicated by HR with small confidence intervals. This study includes all new employees with more than 15 h/w of computer use, the subjects were followed closely with especially symptoms and if positive, a follow up by physical examination was performed. Selection bias was well controlled. It was not described if the examiner was blinded. The internal validity was assessed as sufficient. Hours of keying per week was analyzed, otherwise analyses included control for age, sex and psychosocial factors. The study was designed to evaluate the effect of work postures in computer users, however keyboard time was evaluated. The overall assessment concluded with a study of *moderate to high quality*.

Ten per cent of a cohort of 632 newly hired computer users reported neck/shoulder symptoms and 5.9% met the criteria for neck/shoulder disorders of whom most were diagnosed with the somatic pain syndrome (5.8%) (4). Marcus et al. found no association between hours keying and neck-shoulder disorders (5). However, they found that the presence of a telephone shoulder rest was a risk factor for neck-shoulder disorders, while an inner elbow angle above 121° was associated to a lower risk of neck-shoulder disorders (5). Gerr et al. reported that 2.2% were diagnosed with an arm/hand disorder, which was approximately 50% of those reporting arm/hand symptoms (4). Marcus et al. showed that more than 5° of wrist ulnar deviation was related to a greater risk for arm/hand disorders. Keyboard height with the "J" key over 3,5 cm above table surface was a risk factor while keyboard placed with the "J" key more than 12 cm from the table edge was associated to a reduced risk for arm/hand disorders (5). None of the other workstation characteristics from the Marcus et al. study showed any association with elbow disorders (5). (See table IX for more information on specific workstation characteristics). Females were more likely to get hand/arm disorders compared to men (4).

<u>The NUDATA-study</u> was presented in several articles (6-8), and is a prospective study that is the largest of the included studies (6943 subjects). Despite the size of the study rather few clinical cases were found that met the criteria for tension neck syndrome (TNS), right shoulder myalgia and epicondylitis and even fewer that met the criteria of rotator cuff syndrome or clinical forearm cases. Only symptom cases with pain the last seven days were invited for a physical examination leading to an examination rate between 4 and 24 %, depending on symptom location. An analysis of the drop-outs found no signs of a healthy-worker effect (selection bias) (8). The exposure estimates were based on subjectively assessed time of different computer related tasks. This may cause an information bias, and result in differential misclassification of exposure if pain symptoms make subjects aware of longer working hours with computer use. Independent of these sources of bias, this study performs a detailed assessment of exposure and outcome and is sufficiently large to take into account the effect of possible confounders. Overall, we evaluate the precision and the internal validity as sufficient. The design of the study made it possible to find large groups with considerable internal contrasts in time using keyboard or mouse and working postures. The risk estimates were adjusted for physical, psychosocial and personal characterstics, why a possibility for overadjustment exists after adjustment for especially psychosocial workplace factors. The study group consisted of technical assistants and machine technicians, but their exposure of computer use was quantified making it possible to generalize to other occupations with this exposure. The overall assessment concluded with a study of *moderate to high quality*.

In the NUDATA-study 10.6% reported neck pain at baseline, while 1.4% was diagnosed with TNS (7). The risk of TNS increased four-fold in the baseline data when the weekly hours spent with computer mouse exceeded 25 hours a week compared to no/minor mouse use. A similar increase was not found for keyboard use (7). No association was found between position of screen, mouse or keyboard, arm support and TNS at baseline or at 1-year follow-up (7). For shoulder disorders no association were found with use of neither keyboard nor mouse use (7).

Twenty-four per cent reported elbow or hand/wrist pain at baseline, 0.42% were diagnosed with lateral epicondylitis, 0.03% with medial epicondylitis (8) and 0.23% as "clinical forearm cases" (palpation tenderness in the proximal aspect of the arm)(6). An association was found between computer mouse use for over 30 hours per week and clinical forearm cases (6), but not for wrist tendonitis or De Quervain's syndrome (8). However, a significant trend was found at baseline between mouse time and wrist tendonitis of the extensor side described in a thesis based on the NUDATA-data (58). No other ergonomic factor was associated with epicondylitis, clinical forearm cases or other specific diagnoses of the distal arm (6).

The precision of the Tornqvist et al. (9) case-control study was estimated as good with 392 cases and three times as many controls. The confidence intervals of the study were mostly rather small, however PC work in male cases was rare resulting in a low power for these results. The indicated participation rate of 69 % among controls should have been further evaluated, despite this it was evaluated to be a low risk of selection bias (control for age and previous symptoms). Recall bias, on the other hand, could be a matter of concern as a common problem for case-control studies. The exposure estimate was based on interview data and dichotomized with 4 h/day of VDU work as the cutpoint. It is not known from the article if the researchers were blinded for case or control status. The internal validity was difficult to assess but is presumably sufficient. The research questions, study design and effect assessment were appropriate and the sample from the general population makes the results generalisable. This exposure estimate of VDU work was crude and made it impossible to make exposure-response relationships. The overall assessment concluded with a study of *moderate quality*.

Thirty-eight per cent of the male and 53% of the female cases, which sought care or treatment for neck or shoulder disorders, were diagnosed with tension neck syndrome in the study by Tornqvist et al. (9). Cervical brachialgia and shoulder tendonitis constituted 10% of the cases for both male and female. Both cases and controls were offered a clinical examination and 58% of male and 71% of female cases got a confirmed diagnosis, while 21% of the male controls and 27% of female controls were diagnosed with one or several of the neck/shoulder disorders mentioned above (9). Adjusted relative risk (RR) for having a confirmed diagnosis of a neck or shoulder disorder was 0.8 (95%CI, 0.2-2.6) for men and 1.9 (95%CI, 1.0-3.4) for women when working more than 4 hours per day with VDU.

3.3 Musculoskeletal disorders and gender difference among computer users

Earlier reviews on visual display unit work and gender difference concerning musculoskeletal disorders have summarized that female gender appears to be related to a higher occurrence of reporting upper extremity symptoms (11, 24). In this review two of the studies show no gender difference in self-reported neck pain. However, after clinical examination female gender was associated with the diagnosis of tension neck syndrome (2, 7). In the case of right shoulder pain and right shoulder myalgia, results from the NUDATA-study showed an increased risk for female computer users (7). Bergqvist et al. 1995, compared men and women with high degree of similar computer work, and found no difference in shoulder pain reports, but increased risk for shoulder diagnosis among women (2). Marcus et al. (5), on the other hand, found no increased risk among women to have either neck/shoulder symptoms or disorders. In the same study they found increased risk for arm/hand diagnosis among women but no difference in self reported arm/hand symptoms. Ferraz et al. (3) showed that men were less likely to have any upper extremity disorders.

The gender differences found in the included studies are somewhat irregular when it comes to both musculoskeletal symptoms and diagnosis. However it appears that women have a higher prevalence of neck and upper extremity diagnoses than men. There is scarce data on the cause of the possible gender difference in the included studies and on the interaction between computer work and gender. Earlier studies have suggested that the female gender probably is a confounder for non-work related factors and not an independent risk factor for upper extremity musculoskeletal disorders (20, 59). One of the proposed explanations for the difference in musculoskeletal symptoms and disorders is that they are exposed to different risk factors outside the work place (surrogate confounder), in addition to a possible job gender segregation that contribute to a difference in occupational exposure to risk factors (59).

4 Discussion

The following paragraphs will first discuss methodological aspects of the present review. The discussion of a possible causal relationship between computer work and neck and upper extremity disorders with physical findings is then divided into diagnoses. For each diagnosis we will first present studies focusing on *computer work per se*, then the documentation related to use of *keyboard and mouse* and at last, if relevant in regard to the epidemiological findings, a description of other possible evidence that focus on pathophysiology, experimental and other studies that may illustrate a biological plausibility. Tables that summarize possible associations between computer use and specific diagnoses are also presented (Table I-VI).

4.1 Methodological considerations

A critical systematic review to disclose existing high quality documentation of causal relationships will have both weak and strong properties depending on inclusion criteria and the quality assessment approach. On one hand, high quality epidemiological papers may have been excluded as sources of knowledge for this review, because they did not include physical examination of the subjects. These studies may use case definitions that are good substitutes for diagnoses, and have high quality exposure measures, but did not meet the inclusion criteria and were thereby excluded. On the other hand, the present review only relies on sources of high and relevant quality that ensures relevance in regard to diagnosis as the "objective" outcome. Even if a high correlation have been documented between symptoms and diagnoses (60), and the reliability of the clinical examination has been questioned (61), we limited this review to the documentation on clinical diagnoses with respect to the main aim of the study.

Despite the broad computerized search done in this review, selection bias may influence the results. Studies could have been missed if the key terms attached to them in the database did not include the key terms listed in our search. The search gave 13410 citations and even though two reviewers read and decided if the title of the article were relevant there could have been articles that were overlooked and therefore constitute a possible bias. In addition publication bias is also a source that affects the results. Studies with positive associations are much easier published than studies with no or negative association. However, this bias may increase the possibility of finding the evidence for a causal relationship if it exists.

When investigating the workers ergonomic conditions, two of the five included studies obtained information by observation or measurements (5) (2). This was partly done also in a third study (keystroke performance) (3). Two studies used self-reported exposure estimation (7) (9). Both the observational data and the self reported data gives a possibility of misclassification. The observation might not reflect the constant posture or ergonomic conditions that the worker has over time, and the self-report exposure (e.g. time spent at VDT) may be exaggerated for cases compared to controls. Faucett et al. (62) showed that subjects often reported longer working duration than was observed. The same tendency to overestimate keyboard times were found in the recent study by Homan et al. (63). On the other hand, it has also been found that subjective reports very accurately reflects the observed ergonomic exposure, but that the classification errors that occurred was due to some workers overestimating the repetitiousness of their jobs (64).

In the included studies the diagnostic criteria of different neck and upper extremity musculoskeletal disorders vary (see Table VIII). A lack of conformity in case definitions between the studies may reduce the external validity of the individual studies. However, the studies with precise diagnostic criteria were compared to the criteria document by Sluiter et al. (27), and the diagnostic consensus from a delta study by Harrington et al. (25). The case definitions of these documents were to a sufficient degree comparable to the definitions used in the included studies with regard to neck and upper extremity disorders. One exception was the definition of neck pain with physical findings that differed both within the included studies and between these and the documents defining diagnostic entities (25, 27).
Most of the included articles controlled potential confounding by age, gender and psychosocial factors. One article (3) was unclear on the statistical analysis and on whether they potential confounding variables were controlled for. This study is consequently not emphasized to the same degree as the high quality studies in the discussion below.

4.2 Neck pain with physical findings

Neck pain with physical findings is a common term for e.g. tension neck syndrome (TNS) and somatic pain syndrome of the neck that were common diagnoses for the included studies. The case definition included mostly pain and neck muscle tenderness due to palpation (3, 7) and/or movement of the neck (1, 2), but was not described in one of the studies (9). Two studies did not separate between neck and shoulder disorders (5, 9) and an analysis of these "mixed outcome studies" showed that neck pain with physical findings was by far the most common diagnosis, from 71% (9) to 97%(4, 5). The evidence from the included studies is summarized in Table I.

Cervical syndrome was only evaluated in one study (4), and this diagnosis constituted only one of the 37 neck/shoulder disorders diagnosed in the study. Thus the data for evaluation cervical syndrome was too sparse.

4.2.1 Computer work per se.
There is no clear tendency in studies including risk estimates for an association between computer work per se and neck pain with physical findings (1, 2). Tornqvist et al. (9) found a significant association with VDT work ≥ 4 hours/day, but only for women. One study of low to moderate quality (3) found a greater risk for TNS in keyboard operators compared to controls.

4.2.2 Keyboard and mouse use.
In the NUDATA-study over 4,000 female and 2,500 male technical assistants and machine technicians were asked about active time at the computer (8). The women used mouse 15 h/w and the men 13 h/w; corresponding figures for keyboard use were 9 and 8 h/w, respectively. Brandt et al. (7) found in the baseline data an increased risk for TNS, including an exposure-effect relationship, for work with mouse in the right hand for more than 25 h/w. No similar findings were found for keyboard use. The one-year incident cases were too few for reliable analyses.
A comprehensive study of ergonomics of computer work was performed in the study by Gerr et al. (4) and Marcus et al. (5). For somatic pain syndrome they found a "protective" effect of inner elbow angle above 121° while using the keyboard, but this effect was attenuated with increasing hours of keying per week. They found a

tendency for increased risk with shoulder flexion above 35° while using the mouse. An increased keyboard position in relation to elbow level has been shown as a risk factor (1, 2).

4.2.3 Possible contributing evidence. Previous critical reviews conclude mostly with a causal relationship between computer work per se (or computer work in general) and neck pain, e.g.(11, 13, 14, 16).

The results of the NUDATA-study on TNS, were supported by baseline data for neck and shoulder pain symptoms; neck symptoms showed a weaker but still significant exposure-effect relationship to mouse use but not to keyboard use. Some indications were presented that the incident of new neck pain symptoms was associated to mouse use more than 30 h/w and almost significant to keyboard use for more than 15 h/w (7).
In the MEPS-study (46-48), female data entry operators had more pain during sideways movements of the neck and a higher number of trigger points in the neck region compared to the female data dialogue operators (46).

Several cross-sectional studies have shown an association between neck and shoulder pain symptoms and working with computer from 2 h/day (65), via 6/7 h/day (66, 67), to almost the whole working day (especially for females) (68). However, a number of high quality prospective studies have also been performed, that relate symptoms to exposure assessed in advance. These do not confirm the positive findings mentioned above (57, 69-71).

Work related load of the neck is also influenced by individual working technique and use of specific devices in computer work (individual aspects). A "protective" effect on neck pain with physical findings by arm rest or forearm support have been reported (5, 51, 72), and also for neck symptoms (71, 73, 74), but not confirmed in other studies (7). "Non-optimal position of a non-keyboard input device" have shown an increased risk for neck/shoulder symptoms in both men and women (65), and neck flexion above 20° for more than 2/3 of the time in repetitive work resulted in a double to triple increase in risk of neck/shoulder pain with pressure tenderness (75). Aarås et al. (76) showed in an elegant intervention study with prospective parallel group design, that introduction of a mouse design with neutral wrist position (vertical Anir mouse) reduced neck pain significantly, compared to use of the traditional mouse that resulted in more pronated wrist position. Sillanpää et al. (77) investigated neck, shoulder, elbows or forearm/wrist symptoms of 298 office workers, 238 custom service workers and 247 designers and related them to computer/mouse use. Work with computer over 4 h/day or mouse use over 4 h/day did not increase the risk for neither of the symptoms. However, subjective grading of poor ergonomics in general, bad keyboard or mouse placement all showed increased risk in relation to all symptoms.

Jensen et al. (78) found a lower number of EMG-gaps and a more repetitive activity on the mouse side compared to opposite side, indicating a more harmful muscle activity pattern on the mouse side. However, increased activity in the trapezius muscle have been reported also after exposure of psychological stress (79-81) and high precision demands (82). The population at risk is perhaps more prone to a high level of perceived muscular tension (80, 83, 84), which has been found even when adjusting for high physical exposure, high job strain and age (85).
Several studies document an interaction between mechanical work load at computer work and psychosocial risk factors (17, 69).

The conclusion in Table I is supported by many cross-sectional studies but not by a number of high quality prospective studies. Data entry operators may be at greater risk than dialog operators. Many studies support the effect of individual aspects, especially increased perceived muscular tension, increased risk in computer work per se and non-optimal ergonomic conditions of mouse use. Plausible hypothesis on pathophysiological mechanisms for injury is presented.

Table I. Overview over possible associations between computer work and neck pain with physical findings

	Computer work per se	Mouse time	Keyboard time	Other findings and comments
Bergqvist et al. (Tension neck syndrome)	No association	-	-	Positive association when working with too highly placed keyboard or limited rest breaks and for working ≥ 20 h/week with computer in combination with the use of bifocal/progressive glasses.
Ferraz et al. (Tension neck syndrome)	Sign. association to keyboard use	-	Sign. association to keyboard use	Keyboard use is here seen as equal to computer use
Gerr & Marcus et al. (Somatic pain syndrome)	-	-	No association	Inner elbow angle of >121° and armrests have protective effect (disappears with long keying time).
NUDATA-study: Brandt et al. (Tension neck syndrome)	-	Increasing risk from 25 h/week	No association	No association was found for the ergonomic variables; arm support and abnormal mouse or keyboard position.
Tornqvist et al. (Neck and shoulder disorders – mainly TNS)	Sign. association with VDT work ≥4h/day only for women	-	-	Association with repetitive finger movements and constrained sitting (≥4h/day). Association with the combination of computer work and job strain only for women.
Conclusion	**Limited evidence**	**Limited evidence**	**Insufficient evidence**	

"–" designates that the topic was not examined.
"sign." designates statistical significance.

4.2.4 Evidence of causal relationship for neck pain with physical findings?

One study of low to moderate quality suggests an association between computer work per se (mostly with keyboard use) and neck pain with physical findings and one study of moderate quality especially for women. One study of moderate quality found no association, and the two studies of high quality did not examine this topic. The contributing evidence is not unambiguous, several high quality prospective studies of symptoms do not support an association. One high quality study documents a clear association between mouse use and neck pain with physical findings.

We conclude that there is limited evidence grade B for a causal relationship for computer work per se and mouse time, but insufficient evidence for keyboard time

However, indications are found of the importance of individual working. technique in causality of neck pain with physical findings. These include lack of forearm support, non-neutral position of forearm and neck flexion.

4.3 Shoulder tendonitis and shoulder myalgia

Many studies do not separate between neck and shoulder disorders, as mentioned in section 4.2, making it difficult with a conclusion on shoulder disorders in specific. The evidence from the included studies is summarized in Table II.

4.3.1 Computer work per se.

Shoulder tendonitis was one of four in the “shoulder diagnosis group” in the Bergqvist study (1, 2, 86) and presumably the most common. Data entry operators showed no increased risk for shoulder diagnoses in that study, and not for working hours above 20 h/w, neither for data entry nor interactive operators (1). Limited rest break opportunity was a risk factor for shoulder diagnoses for all computer workers (2).
Supraspinous tendonitis was more common among keyboard users than controls (3).

Table II. Overview over possible associations between computer work and shoulder tendonitis and shoulder myalgia

	Computer work per se	Mouse time	Keyboard time	Other findings and comments
Bergqvist et al. (Combined – see text)	No association	-	-	No association for data entry or interactive (dialog) work ≥20 h/week.
Ferraz et al. (supraspinous tendonitis)	Sign. association to keyboard use	-	Sign. association to keyboard use	Keyboard use is here seen as equal to computer use
Gerr et al. & Marcus et al. (Rotator cuff syndrome and biceps tendonitis)	-	-	Insufficient prevalence and incidence rate to conclude	
NUDATA-study: Brandt et al. 1) shoulder tendonitis, and 2) right should. pain	-	Insufficient prevalence and incidence rate to conclude	Insufficient prevalence and incidence rate to conclude	
Tornqvist et al. (Neck/shoulder disorders – low prevalence of shoulder tendon.)	Sign. association with VDT work ≥4h/day (only women)	-	-	Association with repetitive finger movements and constrained sitting (≥4h/day). Association with the combination of computer work and job strain only for women.
Conclusion	**Insufficient evidence***	**Insufficient evidence**	**Insufficient evidence**	

“–“ designates that the topic was not examined.
“sign.“ designates statistical significance.
* *Insufficient evidence* is chosen here, because Tornqvist et al. had only approximately 6% shoulder disorders in this combined neck-shoulder disorder group.

4.3.2 Keyboard and mouse use.
Rotator cuff syndrome and shoulder myalgia were diagnosed in the Brandt et al. study (7). They found no exposure-response relationship or otherwise increased risk for right shoulder myalgia of keyboard or mouse use. The definition of this disorder overlap extensively with TNS, that reduces its specificity as a shoulder disorder.

4.3.3 Possible contributing evidence.
As mentioned under neck pain, previous critical reviews conclude mostly with a causal relationship between computer work per se (or computer work in general) and neck and shoulder pain, e.g.(11, 13, 14, 16). Repetitive movements of the upper extremity in general (19) and fixed keyboard height (29) seems to be risk factors for shoulder pain, otherwise are the documentation sparse.

An exposure-response relationship was found for right shoulder symptoms and mouse use (especially significant above 15 h/w), a tendency also for keyboard use but no effect of arm support (7). Cross-sectional studies have indicated an increased risk for shoulder pain symptoms after daily four hours of mouse use (68), and four hours of keyboard use (87).

4.3.4 Evidence of causal relationship for shoulder tendonitis?
One study of low to moderate quality found an association between computer work per se and supraspinous tendonitis, and one study of moderate quality found no association. Three studies analyzed the relation but all had insufficient data. This concerned also mouse and keyboard time. *We conclude that there is insufficient evidence for a causal relationship for computer work per se, keyboard and mouse time.*

4.4 Epicondylitis

The evidence from the included studies is summarized in Table III.

4.4.1 Computer work per se.
The study by Bergqvist et al. (1, 2) showed no significant association to epicondylitis (lateral/medial). Similarly these diagonses were not associated to keyboard operators compared to non-keyboard operators in the study by Ferraz et al. (3). However, only two cases were found in each exposure group, making the study inconclusive.

4.4.2 Keyboard and mouse use.
Epicondylitis (lateral/medial) was investigated in the NUDATA-study and no association was found between exposure and clinical diagnoses (8). Thirty-one cases of epicondylitis (including 2 medial) were found among 1888 with right elbow pain symptoms in a population of 6865 participants at baseline. One year later 7 new cases of lateral epicondylitis were found among 562 new elbow symptoms in the same cohort.

4.4.3 Possible contributing evidence.
Existing reviews diverge concerning conclusions on the evidence for a causal relationship between computer work and elbow pain/ epicondylitis (11, 19). Karlqvist et al. (65) showed among 498 male and 785 female computer users an increased risk of elbow/forearm/hand symptoms over 3 days the last month with computer work over 2 h/day (OR Male: 2.0; 1.2-3.4/ Female: 1.3; 1.0-1.8). Severe elbow pain last year may be closest to a clinical epicondylitis case and NUDATA-data from the baseline investigation will be used as an example instead of incident severe pain because of less "data force" in the latter. A 25 % increased odds ratio for severe elbow pain was found already above 5 h/w of mouse use and showed a clear exposure-response relationship, but with no threshold effect. Mouse speed, keyboard use or micropauses were not

associated to pain (58). Keyboard use did not show the same pattern. Arm/wrist support did not reduce the risk for severe elbow pain in mouse use, but some beneficial effect was found in keyboard use (8). The odds ratio for severe elbow pain was increased for continuous mouse time of 10 h/w, but not for continuous keyboard time.

Table III. Overview over possible associations between computer work and epicondylitis

	Computer work per se	Mouse time	Keyboard time	Other findings and comments
Bergqvist et al. (Combined – epicondylitis and hand/finger tendonitis)	No association	-	-	Effect of computer work ≥20 h/week combined with non-use of lower arm support and limited rest opportunity. Inconclusive for epicondylit.
Ferraz et al. (lat. and med. epicondylitis)	No association	-	No association	Keyboard use is here seen as equal to computer use
Gerr et al. & Marcus et al. (combined – see text)	-	-	Insufficient prevalence and incidence rate to conclude	
NUDATA-study: Lassen et al. (lat. and med. epicondylitis)	-	No association	No association	Only conclusion on baseline data (too few incidence cases)
Tornqvist et al.	-	-	-	
Conclusion	**Insufficient evidence**	**Insufficient evidence**	**Insufficient evidence**	

"–" designates that the topic was not examined.

4.4.4 Evidence of causal relationship for epicondylitis?

None of the included studies found association between computer work characterstics and diagnosed epicondylitis, however, only one study had conclusive results.

We conclude that there is insufficient evidence for a causal relationship for computer work per se, keyboard and mouse time.

4.5 Forearm pain, supinator syndrome and pronator teres syndrome

The evidence from the included studies is summarized in Table IV.

4.5.1 Computer work per se

No data has been found related to computer work per se.

4.5.2 Keyboard and mouse use.

The NUDATA-study (6) found 16 forearm pain cases, nine cases with supinator syndrome and three with pronator teres syndrome by blinded examination of 296 right-sided symptom cases in a population of 6943 computer users. The odds ratio of belonging to these 16 forearm pain cases was eightfold higher if the subject worked more than 30 h/w with a mouse device (6). Six new cases of forearm pain and no cases of nerve entrapment were found in the follow-up. Due to this low number of diagnoses, it was difficult to perform more sophisticated analyses.

4.5.3 Possible contributing evidence.
The study done by Karlqvist et al. (88) showed that computer assisted design operators, had a 2-4 times greater risk for arm symptoms, when using computer mouse for >5.6 h/w a week compared to less than 5.6 h/w. Operators with the mouse located outside an "optimal" area on the table reported more symptoms from many regions in the upper extremity. A position of the mouse for right-handed just right for the screen with forearm support was the best perceived and showed the lowest muscle activity in the neck, shoulder and arm muscles (89).

Table IV. Overview over possible associations between computer work and pronator teres syndrome or supinator syndrome

	Computer work per se	Mouse time	Keyboard time	Other findings and comments
Bergqvist et al.	-	-	-	-
Ferraz et al.	-	-	-	-
Gerr et al. & Marcus et al.	-	-	-	-
NUDATA-study: Kryger et al. Supinator syndrome, pronator teres syndrome	-	No association	No association	≥ 30h/week of mouse use was associated with moderate/severe palpation tenderness in the proximal aspect of the forearm
Tornqvist et al.	-	-	-	-
Conclusion	**Not possible to evaluate**	**Insufficient evidence**	**Insufficient evidence**	

"–" designates that the topic was not examined.

4.5.4 Evidence of causal relationship for forearm pain, supinator syndrome and pronator teres syndrome?
One high quality study documented an association between the risk for being a forearm pain case and mouse use more than 30 h/w, but this was the only study that investigated this diagnostic entity. It was found insufficient prevalence and incidence rate to conclude for radial nerve compression and pronator teres syndrome.

We conclude that there is insufficient evidence for a causal relationship for computer work per se, keyboard and mouse time. Forearm pain is not a commonly accepted diagnosis and therefore not included in the final conclusion (Table VI).

4.6 Wrist tendonitis

Extensor, flexor tendonopathy and De Quervains syndrome is merged into the diagnostic entity "wrist tendonitis" in this paragraph. The evidence from the included studies is summarized in Table V.

4.6.1 Computer work per se.
Marcus et al. (5) used hand/arm disorders as a category, including epicondylitis, carpal tunnel syndrome and forearm extensor/flexor tendonitis, but the forearm tendonitis diagnoses constituted approximately 85% of all diagnoses in that category (4). They found a small but significant 4 % increase in risk (hazard ratio) for every hour of keying performed per week.

Ferraz et al. (3) found a higher prevalence of tendovaginitis/tendonitis in the wrist/hand of keyboard users compared to controls. Arm/hand diagnoses are merged as one outcome category in the Bergqvist et al. study (1, 2, 86). This category includes any diagnosis of epicondylitis, carpal tunnel syndrome and tendonitis / degenerative joint disorders in the hand (86). The distribution of these diagnoses was not presented in the Bergqvist papers and it is therefore difficult to extract the risk for wrist tendonitis specifically. The amount of computer work per se was not positively associated to arm/hand diagnoses. A relation was found only when combining computer work more than 20 h/w with limited rest opportunities and non-use of lower arm support (1, 2).

4.6.2 Keyboard and mouse use
Bergqvist et al. (1) found an exposure-response relationship between risk for arm/hand diagnoses and lowering of the keyboard in relation to elbow level. Wrist tendonitis was also investigated in the NUDATA-study (8). Seventeen cases of flexor, 20 cases of extensor tendonitis and 9 cases of De Quervain's syndrome were found among 3.169 with right wrist/hand pain symptoms in a population of 6.866 participants at baseline. After one year 6 new cases of flexor and 2 of extensor tendonitis and 3 cases of De Quervain's syndrome were found among 617 new wrist/hand pain symptoms in the same cohort. No association was found between keyboard time categories and clinical diagnoses, but a significant trend was found at baseline between mouse time and wrist tendonitis of the extensor side described in a thesis based on the NUDATA-data (58).

Marcus et al. (5) found that a horizontal location of the "J" key more than 12 cm from the edge of the desk was associated with a lower risk of hand/arm disorders (and symptoms). This may be another way of describing forearm support. An elevated position of the keyboard ("J" key more than 3.5 cm above table surface) and a radial deviation for more than 5° while using a mouse were risk factors for hand/arm disorders. Another interesting finding of this study was a doubled risk of hand/arm disorders when using a keyboard wrist rest (5).

4.6.3 Possible contributing evidence.
The critical reviews that focused on computer work all concluded with a causal relationship between computer work per se and upper extremity complaints and disorders (11-13) , however, reviews on generic factors did not support this conclusion (19, 90).

Severe wrist/hand pain last year may be closest to a clinical tendonitis case and data from the baseline investigation in the NUDATA-study will also be used here as an example instead of incident severe pain because of less power in the latter. An increased odds ratio for severe wrist/hand pain was found above 5 h/w of mouse use and showed a clear exposure-response relationship, but with no threshold effect. This study found a 21-25 % increase in forearm and hand pain per 5 hours increase in mouse use per week (58). As for epicondylitis described above, keyboard use did not show the same pattern. Several cross-sectional studies have shown an association between computer work and wrist/hand pain (67, 68, 87, 91). This is also supported in prospective studies for computer use (57, 69) or typing (92).

Despite that NUDATA did not find that arm/wrist support reduced the risk for severe wrist/hand pain, neither during keyboard nor mouse use (8), individual working technique may even be of greater importance for forearm and wrist diagnoses or pain symptoms compared to neck disorders. An ulnar deviation (abduction) of the wrist for more than 20° increases risk of clinical findings in the forearm, wrist or hand (51). Forearm support seem also to reduce ulnar deviation in keyboard use (74). The study done by

Karlqvist et al. (88) showed that computer greater risk for arm symptoms, when using computer mouse for >5.6 h/w a week compared to less than 5.6 h/w. Operators with the mouse located outside an "optimal" area on the table reported more symptoms from many regions in the upper extremity. A position of the mouse for right-handed just right for the screen with forearm support was the best perceived and showed the lowest muscle activity in the neck, shoulder and arm muscles (89). The introduction of the Anir mouse (see above under the neck) resulted in decreased wrist/hand pain and also reduced clinical signs, e.g. 9 subjects had signs of tenosynovitis of forearm extensor muscles before intervention, none after intervention (93). Decreased muscle activity has been found in the hand extensors when working in a neutral hand position compared to the pronated hand posture in ordinary mouse use (94, 95).

The intensity and basic characteristics of computer work may be related to pathomechanisms by different findings. The muscle activity of forearm flexor muscles has been found to be significantly higher for CAD operators than data entry operators (96). A repetitive ulnar deviation task with 20-25 repetitions per minute performed in the laboratory showed low-frequency fatigue (decrease of muscle force in response to 1-20 Hz stimulation) during a working day without noticeable discomfort (97). This has also been found after 10 minutes of static wrist extensions at 10 % of maximal voluntary contraction, and with a continued effect after 150 minutes of recovery (98). Time pressure and verbal provocation (stress situation) during computer mouse use resulted in assisted design operators, had a 2-4 times increased heart rate, blood pressure and muscle activity in neck, forearm and hand muscles and also peak forces applied to the mouse button (99).

The contributing evidence is a clear support to the conclusions in Table V by several cross-sectional and prospective epidemiological studies for a causal relationship between several aspects of computer work and wrist tendonitis. Plausible hypothesis on pathophysiological mechanisms for injury is presented.

4.6.4 Evidence of causal relationship for wrist tendonitis?

One high quality study showed a positive trend between mouse time and risk for wrist extensor tendonitis, and another high quality study showed an exposure-effect relationship for keying time. One study of moderate quality showed no association with computer work per se, but this study was inconclusive for this specific diagnostic entity. Several pathophysiological and experimental studies give biological plausibility to this conclusion.

We conclude that there is a limited evidence grade B for a causal relationship for computer work per se, mouse and keyboard time.

Indications exist of a reduced risk for wrist tendonitis of forearm support, a low keyboard and vertical mouse. An increased risk may be caused by wrist support during keyboarding and ulnar deviation of the wrist.

Table V. Overview over possible associations between computer work and wrist tendonitis

	Computer work per se	Mouse time	Keyboard time	Other findings and comments
Bergqvist et al. (Combined – epicondylitis and hand/finger tendonitis)	No association	-	-	Effect of computer work ≥20 h/week combined with non-use of lower arm support and limited rest opportunity. Inconclusive for wrist tendonitis.
Gerr et al. & Marcus et al. (combined – see text)	-	-	Sign. association	Wrist tendonitis constituted 85% of combined diagnoses. Above 5° wrist radial deviation when using mouse was an ergonomic risk factors.
Ferraz et al. (Wrist tendosyn-ovitis/tendonitis)	Sign. association to keyboard use	-	Sign. association to keyboard use	Keyboard use is here seen as equal to computer use
NUDATA-study: Lassen et al. (Wrist ext. and flex. tendonitis, De Quervain`s syndrome)	-	Sign. association (see other findings)	No association	A significant positive trend was found between mouse time and wrist extensor tendonitis.
Tornqvist et al.	-	-	-	
Conclusion	**Limited evidence***	**Limited evidence**	**Limited evidence**	

"–" designates that the topic was not examined. "sign." designates statistical significance.
* *Limited evidence* is chosen here, despite only Ferraz et al. found a significant association, but because the Bergqvist study was inconclusive for wrist tendonitis specifically, and the other studies indicated associations for mouse and keyboard time.

4.7 Conclusions

The aim of this systematic critical literature review was to evaluate a possible causal relationship between computer, keyboard and mouse use and musculoskeletal disorders with physical findings in the neck and upper extremities compatible with clinical diagnoses such as tendonitis and epicondylitis. Carpal tunnel syndrome and pain disorders without physical findings were not part of the review. These delimitations were decided in the task description made by the funding agency, the Danish National Board of Industrial Injuries.

The main results based on available documentation are summarized in Table VI. No evidence at or above limited evidence grade A (with bias and confounding not likely to explain associations) was found for computer work causally related to the musculoskeletal disorders of the neck and upper extremity included in this review. Limited evidence grade B (with bias and confounding not unlikely to explain associations) was found for a causal relationship between computer work per se and mouse time related to neck pain with physical findings, but not for keyboard time. Limited evidence grade B was also found for a causal relationship between computer work per se, mouse and keyboard time related to wrist tendonitis.

The association between different aspects of computer work for wrist tendonitis was stronger than for neck pain with physical findings. Insufficient evidence was found for a causal relationship between shoulder tendonitis, epicondylitis and entrapment syndromes related to any aspect of computer work. The included studies indicated that women have a higher prevalence of neck and upper extremity diagnoses than men, but the studies give no/little data on the cause of the possible gender difference and on the interaction between computer work and gender.

We will underline that these conclusions are based on few included studies of computer work and diagnostic entities. The report does not assess the possibility of a causal relationship between this kind of exposure and pain symptoms.

Most people in modern working life use computer to a large and increasing extent. Many report musculoskeletal pain, but since the prevalence of work related musculoskeletal diagnoses are low, we need to develop more efficient study designs that may unravel questions concerning causality. More research on epidemiological associations is needed, as well as studies on mechanisms and clinical aspects that focus on a possible effect of computer work on the musculoskeletal system; this includes the possible multifactorial causality of these disorders.

Table VI. Level of evidence for a causal relationship

+++ Strong evidence
++ Limited evidence, grade A
+ Limited evidence, grade B
0 Insufficient evidence
- Evidence suggesting a lack of causal relation

Diagnosis*	Risk factor		
	Computer use per se	Computer mouse time	Computer keyboard time
Neck pain with physical findings	+	+	**0**
Shoulder tendonitis	**0**	**0**	**0**
Epicondylitis (medial or lateral)	**0**	**0**	**0**
Nerve entrapments (pronator teres and supinator syndrome)	**0**	**0**	**0**
Wrist tendonitis	+	+	+

* All diagnoses require specific physical findings, see Table VIII.

5 Summary

This report gives the results of a systematic critical literature review on the relationship between computer work and musculoskeletal disorders in the neck and upper extremities verified by a physical examination. Carpal tunnel syndrome (CTS) is discussed in a separate report and not included here. The documentation in the scientific literature is sparse. A comprehensive search in several databases gave only five studies (nine articles) fulfilling the inclusion criteria, two having a prospective study design (five articles), two having a cross-sectional design (three articles) and one case-control study. A schematic scoring of the scientific quality of the included articles showed that the articles to a varying degree satisfied the items of the quality assessment list. A qualitative detailed quality assessment was then performed in order to conclude the studies as having low, moderate or high quality. The conclusions of this report are mainly based on the latter studies of moderate to high quality. However, some attention was also given to relevant findings in studies lacking the clinical examination of the cases, and in studies of possible pathophysiological mechanisms. Limited evidence grade B was found for a causal relationship between computer work per se and mouse time related to neck pain with physical findings, but not for keyboard time. Limited evidence grade B (with bias and confounding not unlikely to explain associations) was also found for a causal relationship between computer work per se, mouse and keyboard time related to a diagnosis of wrist tendonitis. The association between different aspects of computer work was stronger for wrist tendonitis than neck pain with physical findings. Insufficient evidence was found for a causal relationship between diagnoses of shoulder tendonitis, epicondylitis and entrapment syndromes related to any aspect of computer work.

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Table VII. Assessment of schematic methodological quality of included articles.

Design (a) Pr	Cr	Ca	Quality assessment item list	Bergqvist(a,b	Brandt	Ferraz	Gerr/ Marcus	Kryger	Lassen	Tornqvist
			Study purpose:							
√	√	√	1 Positive if a specific, clearly stated purpose was described	1	1	1	1	1	1	1
			Study population:							
√	√	√	2 Positive if the main feature (description of sampling frame, distribution by age and gender) of the study population were stated	1	1	1	1	1	1	1
√	√	√	3 Positive if the participation rate at the beginning of the study was at least 80%	1	0	1	0	0	0	1
√			4 Positive if the response after 1-year of follow-up was at least 80% or if the nonresponse was not selective		1		1	1	1	
		√	5 Positive if the cases and referents were drawn from the same population and a clear definition of the cases and referents was stated, and if people with chronic upper limb pain (>90 days) are excluded from the controls							1
			Exposure measurements:							
√	√	√	6 Positive if data on physical load at work were collected and used in the analysis.	1	1	1	1	1	1	1
√	√	√	7 Positive if data on physical load at work were collected using standardized methods of acceptable quality (b)	0	0	0	0	0	0	1
√	√	√	8 Positive if data on the psychosocial factors at work were collected and used in the analysis (c)	1	1	0	1	1	1	1
√	√	√	9 Positive if data on psychosocial factors at work were collected using standardized methods of acceptable quality (b)	0	1	0	1	1	1	1
√	√	√	10 Positive if data on physical and psychosocial load during leisure time were collected and used in the analysis	0	1	1	1	1	1	0
√	√	√	11 Positive if data on historical exposure at work were collected and used in the analysis	1	0	1	1	0	0	0
√	√	√	12 Positive if data on history of upper limb disorders, age and gender were collected and used in the analysis	1	0	0	1	0	0	0
	√	√	13 Positive if exposure assessment was blinded with respect to disease status (d)	1		1				0
		√	14 Positive if exposure was measured in an identical way among the cases and referents							1
		√	15 Positive if exposure was assessed at a time prior to the occurrence of the outcome							0
			Outcome measurement:							
√	√	√	16 Positive if data on outcome were collected using standardized methods of acceptable quality (b) (e)	1	0	1	0	0	0	1
		√	17 Positive if incident cases were used (prospective enrolment)							0
√			18 Positive if data on outcome were collected for at least 1 year		1		1	1	1	
√			19 Positive if data on outcome were collected at least every 3 months		0		1	0	0	
			Analysis and data presentation:							
√	√	√	20 Positive if the statistical model used were appropriate for the outcome studied and the measurement of the association estimated with this model were presented (including confidence intervals)	1	1	0	1	1	1	1
√	√	√	21 Positive if the study controlled for confounding	1	1	0	1	1	1	1
√	√	√	22 Positive if the number of cases in the multivariate analysis was at least 10 times the number of independent variables in the analysis	1	1	0	1	1	1	1
√	√	√	23 Positive if the study discusses the findings in relation with relevant clinical diagnostic criteria	0	1	0	1	1	1	1

(a) This column shows whether the item was used in the quality list for prospective (Pr), case control (Ca) or cross-sectional (Cr) studies.
(b) This item was scored positive if the quality of the methods used was tested and documented by the authors or the authors used (and made reference to) well established and documented methods in the literature.
(c) Data on working hours and on pauses from work were assessed as physiological exposure.
(d) If more than one exposure were assessed in the study, it was sufficient that one exposure assessment was blinded to have a positive score on this item.
(e) This item was scored for the data on outcome of the clinical examination.

Table VIII

Criteria for case definitions used in the included epidemiological studies when classifying different musculoskeletal disorders.
The prevalence (and when possible one-year incidence) of the investigated disorders and the corresponding ICD-10 diagnoses.

Ref.	Clinical criteria (signs or diagnosis)	Prevalence	ICD-10
Bergqvist et al. (1995) (a,b)* (1, 2)	Clinical criteria as described in Wolgast (86): Neck: - 'TNS diagnosis' (tension neck syndrome – ache/pain in the neck, tiredness and stiffness in the neck, possible headache, pain during movements, muscular tenderness) - 'Cervical diagnoses' (cervical syndrome (CD), cervical degenerative disease, thoracic outlet syndrome) (ache/pain in neck/arm, headache, decreased mobility during isometric contraction due to pain, numbness). Shoulder: (frozen shoulder, tendonitis, degenerative joint disease) - Shoulder tendonitis, ache/pain in the shoulder, decreased range of motion, resisted muscle test pain Arm/hand: (tendosynovitis/tendonitis, degenerative joint disease) - Epicondylitis, ach, pain in the elbow, palpation pain at medial or lateral epicondyle and resisted muscle test pain. - Hand/finger tendonitis/tenosynovitis, ach, pain in hand, activity induced pain, resisted muscle test pain, swelling, muscle weakness and painful tendon palpation	Neck TNS: 21.8% (55/247) CD: 23.4% (59/247) Shoulder: Shoulder D: 11.9% (30/247) Arm/hand: Arm/hand D: 8.7% (22/247)	Neck M54.2 Cervicalgia M 54.1 Radiculopathy Shoulder: M 75.1,Rotator cuff syndrome M 75.2, Bicipital tendonitis Arm/hand: M77.1, Lateral epicondylitis M 77.0, Medial epicondylitis M 65.8.3 Other specific synovitis and tedonsynovitis of the wrist/hand
Brandt et al. (2004)** (7)	Neck: - Tension neck syndrome (TNS) defined as pain and stiffness in the neck with palpation tenderness in the trapezius muscle. Shoulder: - Right sided rotator cuff syndrome (RCS) was defined as pain in the deltoid region of the upper arm on interviews and a positive impingement test, pain on resisted abduction, external- or internal rotation. - Right shoulder myalgia was defines as substantial palpation tenderness in the levator scapula, the supraspinous or the infraspinous muscles.	Neck TNS: 1.4% (100/6943) 1-y inc TNS: 0.18% (10/5658) Shoulder: RCS: 0.5% (10/6943) 1-y inc RCS: 0.07% (4/5658) Right shoulder myalgia: 0.01% (35/6943) 1-y inc right shoulder myalgia: 0.21% (12/5658)	Neck M54.2 Cervicalgia Shoulder: M 75.1, Rotator cuff syndrome
Ferraz et al. (1995)** (3)	Neck: - TNS (tension neck syndrome) – feeling of fatigue/stiffness, headache neck pain, at least 2 tender spots, hardenings or muscle tightness. Shoulder: - Bicipital tendonitis – localized shoulder pain with tenderness over the supraspinous tendon - Supraspinous tendonitis –localized shoulder pain with tenderness over the bicipital tendon Elbow: - Epicondylitis – localized elbow pain with tenderness on the lateral or medial epicondyle Wrist/hand - Wrist tendosynovitis/tendonitis –localized tenderness and/or swelling of the tendon and sheat of the flexor carpi radialis or the extensor carpi. - Myalgia – pain in the muscle and joints respectively was reported in the absence of physical findings.	Neck TNS: 7.7% (10/130) Shoulder: Supra. tend: 3.8% (5/130) Bicip. tend: 1.5% (2/130) Elbow: Epicond: 1.5% (2/130) Hand/wrist H/W tend: 17.7% (23/130) Myalgia: 2.3% (3/130) Any UMSD diagnosed: 38.5%	Neck M54.2 Cervicalgia Shoulder: M 75.1,Rotator cuff syndrome M 75.2, Bicipital tendonitis Elbow: M77.1Lateral epicondylitis M 77.0, Medial epicondylitis Hand/wrist M 65.8.3 Other specific synovitis and tedonsynovitis of the wrist/hand

Table VIII (Continued)

Ref.	Clinical criteria (signs or diagnosis)	Prevalence	ICD-10
Gerr et al. (2002) and Marcus et al (2002)** (4, 5)	Neck: - Radicular pain syndrome, requires positive neck compression test (Spurling`s test) - Somatic pain syndrome, positive if pain on palpation of either sternomasteoid muscle or trapezius muscle (unilat. or bilat.) and abnormal cervical range of motion Shoulder: - Rotator cuff syndrome,RCS tendonitis, positive if detecting supraspinatus point tenderness AND either positive supraspinatus muscle test or painful arc motion test - Bicipital tendonitis, point tenderness on palpation of the long head of the biceps AND either positive Speed`s test or positive Yergason`s test Elbow: - Medial epicondylitis, positive Reverse Cozen`s test AND either a positive medial epicondyle point tenderness or positive medial (flexor) muscle mass point tenderness - Lateral epicondylitis, positive Cozen`s test OR positive Mill`s manoeuvre AND positive lateral epicondyle point tenderness or positive lateral (extensor) muscle mass tenderness. Forearm/wrist/hand: -Flexor carpi radialis tendonitis, positive if pain at the volar radial side of the wrist with resisted radial deviation AND wrist flexion AND one of following symptoms: point tenderness, local warmth, swelling, redness or crepitance. - Flexor carpi ulnaris tendonitis, positive if pain at the volar ulnar side of the wrist with resisted ulnar deviation AND wrist flexion with resistance AND one or more of the symptoms as mention above - Digital flexor tendonitis, positive if pain at the palmar wrist with resisted wrist and digit flexion AND one ore more of the symptoms mention above. - Extensor tendonitis (dorsal compartment 1), positive Finkelsteins test or pain on resisted thumb MCP extension. - Extensor tendonitis (dorsal compartment 2-6),pain of the hand with resisted muscle pain and tenderness, local swelling, local warmth, redness or crepitation. (some variation for the different compartments, see (4) -Ulnar neuritis, paresthesias in the distribution of the ulnar nerve and prolonged sensory latency of the ulnar nerve. - Intersection syndrome, either point tenderness located on the dorsolateral side of the wrist proximal to the extensor retinaculum, localized swelling or crepitance - Trigger finger, pain in flexor tendon sheat at the A1 pulley and either crepitance in the flexor tendon sheat at the A1 pulley or decreased ROM of digit due to locking in either flexion or extension.	Neck SPS: 5.8% (36/622) Rad pain synd: 0.2% (1/622) Shoulder: RCS: 0.5% (3/622) Bicipital tendonitis; 0.2% (1/622) Any neck/shoulder disorders: 5.9% (37/622) Hand/arm disorders: 2.2% (24/632)	Neck M 54.2, Cervicalgia M 54.1, Radiculopathy Shoulder: M 75.1,Rotator cuff syndrome M 75.2, Bicipital tendonitis Hand/wrist M 65.8.3, Other specific synovitis and tedonsynovitis of the wrist/hand M 65.4, Radial styloid tenosynovitis
Kryger et al (2005)** (6)	Forearm: - Clinical forearm case: moderate/severe palpation tenderness in proximal aspect of the forearm - Supinator syndrome: Substantial pressure palpation tenderness over the fibrous arch at the origin of the supinator muscle. In addition to pain in the same area when testing resisted supination of forearm, and/or resisted extension of the middle finger - Pronator teres syndrome: substantial pressure palpation tenderness on the volar side of the proximal forearm. In addition to pain in the pronator area when testing resisted pronation of the forearm, and/or paresthesias in dig 1-3 when testing resistance of flexion of middle finger.	Forearm: Right forearm disorder: 0.23% (16/6943) Supinator syndrome: 0.13% (9/6943) Pronator teres syndrome: 0.04% (3/6943)	Forearm: G 56.3, Mononeurapathy of radial nerve
Lassen et al (2004)** (8)	Elbow: - Lateral epicondylitis was defined as pain located at the lateral epicondyle or the neighbouring soft tissue. The pain caused at least "quite a lot of trouble" during the last year and a indication of palpation tenderness in addition to tenderness when examining resisted dorsal flexion of the wrist (elbow extended and forearm pronated) - Medial epicondylitis was defined as pain located at the medial epicondyle or the neighbouring soft tissue. The pain caused at least "quite a lot of trouble" during the last year and a indication of palpation tenderness in addition to tenderness when examining resisted volar flexion of the wrist (elbow extended and forearm pronated) . Hand/wrist: - Wrist tendonopathy required wrist/hand pain to be located to the extensor or flexor tendons combined with either tendon point tenderness or swelling or crepitation - De Quervain's syndrome required radial wrist pain, point tenderness located to the first dorsal compartment and pain in the same area when doing passive ulnar deviation of the wrist with the thumb fixed.	Elbow: Lateral epicondylitis: 0.42% (29/6943) Medial epicondylitis: 0.03% (2/6943)	Elbow: M77.1, Lateral epicondylitis M 77.0, Medial epicondylitis

Table VIII (Continued)

Ref.	Clinical criteria (signs or diagnosis)	Prevalence	ICD-10
Tornqvist et al (2000) (9)	Diagnosis: (The diagnoses are stated in the article, but no definition is given) <u>Neck:</u> - Tension neck syndrome - Cervical brachialgia <u>Shoulder</u> - Shoulder tendonitis	<u>Neck</u> (not possible to evaluate prevalence in case-control study). TNS (38% of male and 53% of female cases) Cervical brachialgia and shoulder tendintis (10% of the male and female cases)	<u>Neck:</u> M 54.2, Cervicalgia M 54.1, Radiculopathy <u>Shoulder:</u> M 75, Shoulder tendonitis

TNS-(Tension neck syndrome), CD (Cervical diagnoses), RCS (Rotator Cuff Syndrome), Supra. tend (supraspinous tendonitis), Bicip. tend (Bicipital tendonitis), Epicond. (Epicondylitis), H/W tend (Hand/wrist tendinosynivitis/tendonitis), "1-y inc" = one-year incidence.

* Studies that performed physical examination on all participants

** Studies that only performed physical examination on the symptom cases

Table IX Presentation of the articles design and results (only regarding physical examination).
Confidence limits are 95% unless other specified

Reference Design category	Case definition (outcome)	Study design / purpose Study population Sample size	Exposure assessment	Results from the physical examination (Positive results presented when statistically significant or OR/RR >2.0 or <0.5)	Comments
Bergqvist et al. (1995) (a,b) (1, 2) Cross-sectional study	Physical examination by a physiotherapist defined clinical cases in four categories (for diagnostic criteria see Table VIII): - TNS (tension neck syndrome) - cervical diagnoses (cervical syndrome, cervical degenerative disease, thoracic outlet syndrome) - shoulder diagnoses (frozen shoulder, tendonitis, degenerative joint disease) - arm/hand diagnoses (tendosynovitis/tendonitis, degenerative joint disease) In addition symptom cases (separate for neck/shoulder and arm/hand): were defined according to subjective reporting on the Nordic questionnaire.	Cross-sectional study in 1987 of a sample of office workers previously studied in a cross-sectional study in 1981 (55). The prospective 1981-87 data was reported in a separate article (57). Assessed the impact of VDT use in general, not specific on keyboard or mouse use. Office workers in seven Stockholm companies; 52% interactive, 29% data entry and 19% non VDT users were compared. Response rate: 92% questionnaire (322/353) (91% physical examination)	Observed ergonomic factors: Static work posture, non-use of lower arm support, hand in non-neutral position, insufficient leg space at table, repeated movements with risk of tiredness, height difference keyboard elbow, high visual angle to VDT and spectral glare present on VDT. Self-reported VDT use in general. Historical exposure estimated from questionnaires in 1981 and 1987. Not specific on the use of keyboard and/or mouse. Self-reported data (questionnaire) on individual, organizational and ergonomic factors.	<u>Neck</u> VDT use in general was not statistically associated with cervical diagnoses (OR=1.3 (0.6-2.6)) or a TNS diagnosis (OR=1.0 (0.5-1.9) or neck/shoulder discomfort (OR=1.4 (0.8-2.4)) compared to non VDT users. Working ≥ 20 h/week at VDT was associated with: - a TNS diagnosis for workers with bifocal/progressive glasses (OR =6.9 (1.1-42.1)) - cervical diagnoses for workers who had spectral glare at their workplace (OR= 2.2 (0.9-5.3)) Keyboard too highly placed was associated with a TNS diagnosis (OR=4.4 (1.1-17.6)). Limited rest breaks were associated with a TNS diagnosis (OR=7.4 (3.1-17.4)). Static posture was associated with cervical diagnoses (OR=5.1 (0.6-42.5)). <u>Shoulder</u> VDT use in general was not statistically associated with shoulder diagnoses (OR=0.6 (0.3-1.5)). Shoulder diagnoses were associated with limited rest break opportunities (OR=3.3 (1.4-7.9)), low task flexibility (OR=3.2 (1.2-8.5)), and also the female gender (OR=7.1 (1.6-32.2)). Shoulder diagnoses were not associated with working hours with a VDT (for interactive work ≥20h/w OR=0.5 (0.2-1.4), for data entry ≥20h/w OR=0.9 (0.3-2.2)). <u>Elbow / forearm / wrist / hand</u> Arm/hand diagnoses were associated with: - working ≥ 20 h/week with VDT when combined with limited rest opportunity and non-use of lower arm support (OR=4.6 (1.2-17.9)). - a combination of no use of lower arm support and limited opportunities for rest breaks (OR=10.1 (2.4-43.2)). - non use of lower arm support (OR=2.7 (0.9-8.3)). - being a woman with children (OR=5.2 (1.2-22.8)). - age>40 (OR=2.4 (0.6-10.3)).	535 workers were investigated in 1981, 353 subjects remained at the workplace in 1987 (34% dropout), possible "healthy worker effect" Physical examiners and ergonomic investigator were blinded to the participants reporting in the questionnaires Univariate associations were adjusted for individual (age, gender etc), organizational and ergonomic factors. Factors still showing an association after adjustment were included in the multivariate logistic regression models.

Table IX (Continued)

Reference Design category	Case definition (outcome)	Study design / purpose Study population Sample size	Exposure assessment	Results from the physical examination (Positive results presented when statistically significant or OR/RR >2.0 or <0.5)	Comments
Brandt et al (2004) (7) (NUDATA-study) Prospective study	Clinical cases were defined as those receiving one of the following diagnoses (for diagnostic criteria see Table VIII) in an examination by a physician: - TNS (tension neck syndrome). - Right sided rotator cuff syndrome. - Right shoulder myalgia. At base-line only symptom cases and at follow-up only incident cases were invited to the physical examination (symptom case and incident case were defined by subjective reporting of pain in a questionnaire)	A prospective study on the effect of computer mouse and keyboard use on neck and shoulder pain and disorders. Technical assistants and machine technicians (identified through union files) working in 3527 public and private Danish companies were asked to fill in a questionnaire at baseline and at one year follow-up. Participants defined as symptom cases at baseline or incident symptom cases at follow-up were invited to a clinical examination. Baseline response rates: Questionnaire 73% (6943/9480) Clinical examination - neck: 82% (530/645) - shoulder: 85% (395/467) Follow-up response rates: Questionnaire 82% (5658/6943) Clinical examination - neck 74% (46/62) - shoulder 80% (63/79)	Self report (questionnaire) of workload, ergonomic factors and demographic data at baseline and of workload also at follow-up. Workload items included: - hours pr week the last 4 weeks working with computer (e.g. computer-assisted design, text editing and data entry) and without computer (e.g. worksite visits and meetings). 29% of total work hours was computer aided design work, 35% other computer work, and 36% non-computer work. - time of active use of mouse and keyboard. Ergonomic factors included e.g. position of screen, arm support, mouse or keyboard position and adjustments of table and chair.	<u>Neck</u> Association between TNS and weekly mouse use (at baseline) increased from RR=3.5 (1.0-12) to RR= 4.7 (1.2-18), when weekly mouse use increased from 25-29 hours to >30 hours. TNS associated with female gender (RR= 2.7 (1.5-4.9)). No association between ergonomic factors and outcome at neither baseline nor the 1-year follow-up. No association between TNS and: - keyboard use ≥20h/w (RR=1.3 (0.4-4.9)). - abnormal mouse position (RR=0.2 (0.02-1.1)). - abnormal keyboard position (RR=0.9 (0.5-1.8)). - arm support (when using mouse) ≥ 50% of worktime (RR=0.6 (0.3-1.2)). - arm support (when using keyboard) ≥ 50% of worktime (RR=1.0 (0.6-1.7)). <u>Shoulder</u> No association between right shoulder myalgia and weekly mouse or keyboard use (mouse use ≥ 30h/w RR=1.3 (0.1-11.6), keyboard use ≥ 20h/w RR=1.3 (0.2-11.2)). The clinical cases with the diagnosis 'right sided rotator cuff tendonitis' were to few both at baseline and follow-up to make any conclusions with respect to associations with keyboard and mouse use (prevalence 0.14%, incidence 0.07%). Right shoulder myalgia was associated with female gender (RR=7.2 (1.7-30.3)).	RR is adjusted for physical, psychosocial workplace factors and personal characteristics. The baseline and follow up clinical case numbers were relatively small witch can make the associations statistically unstable or non conclusive. The study gives no data on possible clinical findings in symptom-free participants.
Ferraz et al. (1995) (3) Cross-sectional study	A physical examination by a rheumatologist defined clinical cases (for diagnostic criteria see Table VIII): - TNS (tension neck syndrome). - bicipital tendonitis - supraspinous tendonitis - epicondylitis (lateral or medial) - wrist tendosynovitis/tendonitis - myalgia. In addition symptom cases were defined by subjective reporting of pain in a questionnaire.	Cross-sectional study comparing prevalence of upper-extremity musculo-skeletal disorders in keyboard operators and other office workers. All subjects had a brief physical examination by a physiotherapist. Subjects classified as symptom cases (from questionnaire data) or showed signs in the physiotherapist examination received a clinical evaluation by a rheumatologist. Study population: All keyboard operators (165, 71% females) and the same number of traditional office workers (with little or no keyboard work, 56% females) from two firms in São Paulo, Brazil. Response rate = 81% (268/330)	Data on each operators mean keystroke performance the preceding month was provided by the companies. A questionnaire gave data on break time (less then 30 min per day was considered inadequate), demographic data, work history, stress at work, ergonomic factors, satisfaction with the workstation, amount of leisure time physical activity and data on general health.	<u>Neck</u> TNS was associated with keyboard use (p=0.01). <u>Shoulder</u> Supraspinous tendonitis was associated with keyboard use (p=0.02). <u>Elbow</u> Epicondylitis was not associated with keyboard use (1.5% prevalence among keyboard users compared to 1.4% prevalence in other office workers). <u>Forearm / wrist / hand</u> Wrist tendosynovitis/tendonitis was associated with keyboard use (p<0.001). Analysis with all upper extremity musculoskeletal disorders grouped together showed increased risk for keyboard operators, and an association to length of employment and insufficient rest breaks. No association observed with number of keystrokes per minute.	Unclear if (and how) the results were adjusted for age, gender and psychosocial factors.

Table IX (Continued)

Reference Design category	Case definition (outcome)	Study design / purpose Study population Sample size	Exposure assessment	Results from the physical examination (Positive results presented when statistically significant or OR/RR >2.0 or <0.5)	Comments
Gerr et al. & Marcus et al. (2002) (4, 5) Prospective	Examination by an occupational therapist gave the following cases of musculoskeletal disorders (for diagnostic criteria see Table VIII): - radicular pain syndrome - somatic pain syndrome (criteria resembles tension neck syndrome) - rotator cuff tendonitis - bicipital tendonitis - medial epicondylitis - lateral epicondylitis - flexor carpi radialis tendonitis - flexor carpi ulnaris tendonitis - digital flexor tendonitis - extensor tendonitis (dorsal compartment 1-6) - intersection syndrome - distal flexor tenosynovitis (trigger finger) - ulnar neuritis Only symptom cases identified at baseline or during follow-up (assessed by a questionnaire filled in at enrolment and weekly during follow-up) were offered the standard physical examination, and only the symptomatic body region and the same area on the contralateral side were examined.	Prospective study of newly hired workers having ≥15 hours/week of computer work to determine the occurrence of and evaluate risk factors for neck-shoulder and hand-arm musculoskeletal symptoms and disorders. The workers were followed until they developed examination-confirmed disorders or for a maximum of 38 months. The study did not include for comparison workers having <15 hours/week with computer work. Participation rate: 66% (632/956)	Measurements of workstation characteristics, including keyboard/mouse characteristics and worker posture were performed at enrolment. Following items were included regarding keyboard (k.): - k. to elbow height differnce - k. inner elbow angle - k. shoulder abduction angle - k. shoulder flexion angle - k. wrist extension angle - k. wrist ulnar deviation angle - distance from table edge to 'J'key - distance from table surface to 'J'key - average key activation force Following items were included regarding mouse (m.): - m. inner elbow angle - m. shoulder abduction angle - m. shoulder flexion angle - m. wrist extension angle - m. wrist ulnar deviation angle Other items included: - monitor head tilt angle - monitor head rotation angle - presence of chair armrest - presence of wrist rest - presence of telephone shoulder rest - presence of sharp leading edge on table surface Self-administrated daily diary documented number of hours worked at computer and experience of musculoskeletal symptoms. 4 weeks after enrolment the participants completed a questionnaire on occupational psychosocial stress. Data on previous computer use, demographic data, personal health history, and tobacco use were collected by questionnaire at enrolment.	<u>Neck / shoulder</u> Subjects with an inner elbow angle of >121° had a reduced risk of neck-shoulder disorders (adjusted HR=0.11 (0.02-0.66)). This protective effect diminished with increasing keying hours. The presence of a telephone shoulder rest increased the risk of neck-shoulder disorders (adjusted HR=2.71 (1.40-5.23)). No other of the workstation characteristics were associated to neck-shoulder disorders in the finale adjusted model. When estimating relative risks the females were more at risk for neck-shoulder disorders (RR=1.9 (1.1-3.1)), but this effect was not significant in the adjusted hazard model (adjusted HR=1.37 (0.77-2.44)). Increasing age (age 30-39, and age 40 and older, compared with age<30) was a risk factor for neck-shoulder disorders (RR(30-39)=1.8 (1.1-2.9), RR(40+)=1.9 (1.1-3.5)). Similarly in the hazard model age of 30 and older (compared to age<30) had increased risk for neck-shoulder disorders (adjusted HR=1.75 (1.04-2.93)). Having a previous history of neck-shoulder pain was a risk factor for neck-shoulder disorders (RR=3.6 (2.1-6.0)). Hours keying per week were not associated with neck-shoulder disorders (adjusted HR=1.01 (0.99-1.04)). <u>Elbow / forearm / wrist / hand</u> Presence of a keyboard wrist rest increased the risk of hand-arm disorders (adjusted HR=1.96 (1.05-3.65)). >5° of wrist radial deviation when using a computer mouse gave a greater risk of hand-arm disorders (adjusted HR=1.82 (1.03-3.22)). Keyboard "J" key >12 cm from the tables edge reduced the risk of hand/arm disorders (adjusted HR=0.38 (0.20-0.71)). No other of the workstation characteristics were associated to hand-arm disorders in the finale adjusted model. Females were more at risk for hand-arm disorders (adjusted HR=2.18 (1.09-4.34)). Increasing age was not a significant risk factor for hand-arm disorders. Having a previous history of hand-arm pain was a risk factor for hand-arm symptoms (RR=2.7 (1.5-4.8)).	Hazard risk (HR) was adjusted for age, gender, psychosocial factors, and hours of keying pr. week

Table IX (Continued)

Reference Design category	Case definition (outcome)	Study design / purpose Study population Sample size	Exposure assessment	Results from the physical examination (Positive results presented when statistically significant or OR/RR >2.0 or <0.5)	Comments
Kryger et al (2005) (6) (NUDATA-study) Prospective	Clinical cases were defined as in Brandt el al (see above) for the following diagnoses: - clinical forearm case - supinator syndrome - pronator teres case (for diagnostic criteria see Table VIII) Only symptom cases and incident cases were invited to the physical examination (see Brandt el al above).	Equal to Brandt et al. (see above) except for response rate at clinical examination: At baseline: 85% (235/275) At follow-up: 82% (49/60)	See Brandt et al, above.	Forearm Using computer mouse ≥30 hours pr. week gave an OR of 8.2 (1.5-43.5) for being a clinical forearm case	Comments as for Brandt et al. (above)
Lassen et al (2004) (8) (NUDATA-study) Prospective	Clinical cases were defined as in Brandt el al (see above) for the following diagnoses: - lateral epicondylitis - medial epicondylitis - wrist tendonopathy - De Quervain's syndrome Only symptom cases and incident cases were invited to the physical examination (see Brandt el al above).	Equal to Brandt et al. (above) except for response rate at clinical examination, which were given combined for elbow and hand/wrist: At baseline: 82% (?/1666) At follow-up: 75% (?/436)	See Brandt et al, above	Elbow No significant findings Wrist / hand No significant findings	Comments as for Brandt et al. (above).
Tornqvist et al (2000) (9) Case-control	Both cases and controls were offered a physical examination and where grouped as follows: 1- without any objective sign of tension neck syndrome, cervical brachialgia or shoulder tendonitis 2- with tension neck syndrome 3- with cervical brachialgia 4- with shoulder tendonitis. The examination protocol is not further specified. A case was defined as a person from the study base seeking care/treatment because of neck or shoulder disorders by any caregiver in the region.	A case-control study assessing the influence of work-related physical and psychosocial factors on seeking care for neck or shoulder disorders. The cases were all subjects from the study base who sought care or treatment for neck or shoulder disorders. The study base was all men and women (20-59 years) living and working in the municipality of Norrtälje, north of Stockholm, who were gainfully employed, worked >17 hours pr. week and had worked at least 2 months during the last year. Participation rate cases 88% (392/444) Participation rate controls 60% (1511/2520) 262 of 392 "cases" got confirmed diagnoses and 1144 of 1511 "controls" was confirmed without a diagnosis.	Physical exposure was assessed by questionnaire and task oriented interview, identifying, e.g.: - work with hands above shoulder level ≥30 minutes per day - repetitive hand/finger movements many times per minute ≥2 days a week - constrained sitting ≥4 hours per day - VDT work ≥4 hours per day Psychosocial exposure was assessed by questionnaire and interview, e.g.: - job strain (job demands and decision latitude), - mental work demands, - balance demands and available resources and own competence, - social support - time pressure, - solitary work, - non-fixed salary, - temporary employment - night work, - long working hours	Neck and shoulder Among women repetitive finger movements (RR=1.6 (1.2-2.2)) and constrained sitting ≥4 hours/day (RR=1.6 (0.9-2.8)) were the strongest risk indicators for neck and shoulder disorders The combination of VDU work and job strain among women was associated with increased risk of neck and shoulder disorders (RR= 4.2 (1.5-11)). Among the confirmed cases and controls a RR for neck or shoulder disorder was for men 0.8 (0.2-2.6) and for women 1.9 (1.0-3.4).	Analysis adjusted for age, earlier neck/ shoulder symptoms lasting >3 months and for seeking care for neck/shoulder disorders The study had data on VDT work in general and was not specific on keyboard or mouse work.

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Appendix

Scientific Committee of the Danish Society of Occupational and Environmental Medicine.

<u>Degree of evidence of a causal association</u>

The following categories are used.

+++	sufficient evidence of a causal association
++	limited evidence, grade A (bias and confounding are not a likely explanation of associations(<50%))
+	limited evidence, grade B (bias and confounding are not an unlikely explanation of associations(>50%))
0	insufficient evidence of a causal association
-	evidence suggesting lack of a causal association

Description of categories:

Sufficient evidence of a causal association (+++):

A causal relationship is very likely between an exposure to a specific risk factor and a specific outcome.
A positive relationship has been observed between exposure to the risk factor and the outcome in at least several studies in which chance, bias, and confounding could be ruled out with reasonable confidence.

Limited evidence, grade A, (++):

Some convincing epidemiological evidence exists for a causal relationship between an exposure to a specific risk factor and a specific outcome.
A positive relationship has been observed between exposure to the risk factor and the outcome in studies in which chance, bias, and confounding are not the likely explanation.

Limited evidence, grade B, (+):

Some convincing epidemiological evidence exists for a causal relationship between an exposure to a specific risk factor and a specific outcome.
A positive relationship has been observed between exposure to the risk factor and the outcome, but it is not unlikely that this relationship could be explained by chance, bias, or confounding.

Insufficient evidence of a causal association (0):

The available studies are of insufficient quality, consistency, or statistical power to permit a conclusion regarding the presence or absence of a causal association.

Evidence suggesting lack of a causal association (-):

Several studies of sufficient quality, consistently and statistical power indicate that the specific risk factor is not causally related to the specific outcome.