Health Council of the Netherlands

Computer use at work

2012/38E

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Gezondheidsraad
Health Council of the Netherlands

To the Minister of Social Affairs and Employment

Subject : presentation of advisory report *Computer use at work*
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Dear Minister,

Your predecessor requested advice on a number of working conditions-related risks by letter. I hereby present you with the advisory report on computer use at work. The advisory report was drafted by the Committee on the Identification of Workplace Risks.

Computer use results in a physical burden, and it therefore represents a health risk for Dutch employees, especially for upper extremity complaints. This advisory report answers the question of whether it is possible to determine health-based or safety-based occupational exposure limits for computer use at work. Although the Committee was unable to determine a limit below which shoulder and hand/arm complaints do not occur, it was able to identify the risks. These risks may be used as a starting point for further social debate regarding exposure limits.

The Committee used comments received on a public draft of this advisory report and assessments obtained from the Standing Committee on Health and the Environment.

I have also forwarded the advisory report to the Minister of Health, Welfare and Sport for informational purposes today.

Yours sincerely,
(signed)
Prof. dr. W.A. van Gool,
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Computer use at work

Committee on the Identification of Workplace Risks
A Health Council of the Netherlands Committee

to:

the Minister of Social Affairs and Employment

No. 2012/38E, The Hague, December 20, 2012

The Health Council of the Netherlands, established in 1902, is an independent scientific advisory body. Its remit is "to advise the government and Parliament on the current level of knowledge with respect to public health issues and health (services) research..." (Section 22, Health Act).

The Health Council receives most requests for advice from the Ministers of Health, Welfare & Sport, Infrastructure & the Environment, Social Affairs & Employment, Economic Affairs, and Education, Culture & Science. The Council can publish advisory reports on its own initiative. It usually does this in order to ask attention for developments or trends that are thought to be relevant to government policy.

Most Health Council reports are prepared by multidisciplinary committees of Dutch or, sometimes, foreign experts, appointed in a personal capacity. The reports are available to the public.

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INAHTA

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Executive summary

The request for advice

At the request of the Minister of Social Affairs and Employment, the Health Council of the Netherlands has investigated whether there are current or longer term options for deriving concrete health-based or safety-based occupational exposure limits for computer use. This advisory report is one of a series of advisory reports in which the Committee on the Identification of Workplace Risks examines various occupational risks covered by the Dutch Working Conditions Act and its associated regulations. To answer the Minister's questions, the Committee studied scientific data on the adverse health effects of computer use. The Committee's focus lay on results from longitudinal research, as these provide the most reliable picture.

Extent of computer use and related health complaints

In 2004, over three million workers indicated they regularly used a computer at work. On average, a Dutch worker spent 3.8 hours per day behind a computer monitor in 2010. Private computer use is also increasingly common.

Studies show that workers using a computer may develop health complaints. One in three Dutch people states to experience arm, wrist, hand, shoulder or neck complaints 'regularly' or 'persistently'. These complaints are described as pain, stiffness and tingling/numbness. It is known that a proportion of these people

may develop chronic complaints with clear adverse health effects. This may affect not only daily well-being, but also result in a loss of productivity at work and sick leave. Computer use does not only lead to physical complaints. Sleeping disorders, psychological complaints and eye complaints are also reported by workers. However, there are no suitable studies available that quantify these complaints.

Health risks due to computer use at work

The physical consequences of computer use at work have been studied extensively in the scientific literature. Many studies gather information about the degree of exposure and health complaints via self-reporting. The duration of exposure is mapped by asking workers how long they use a computer, keyboard or mouse while working. Only a limited number of studies objectively measured the amount of computer use (via automatic software registration). In these latter studies, however, no association was found between exposure and serious health complaints. Studies recording exposure via self-reporting did show a clear association with health complaints. According to the Committee, self-reported duration of computer use at work provides a better description for computer work in general.

The Committee is of the opinion that, based on available data, it is not possible to indicate a level of computer use without developing health complaints. There are various longitudinal studies available on the consequences of computer use, but the differences between the measures for exposure make comparisons difficult. Some studies found an elevated risk of complaints for minimal mouse use, from half an hour per day, particularly in arms and hands, while other studies found no significant risks associated with that exposure.

It is possible to gain information on the additional risk of health complaints due to computer use. To this end, the Committee combined the results of available longitudinal studies in a meta-analysis. If the degree of computer use is expressed as hours of mouse use per week, this provides the most conservative estimate of the additional risk. The table below summarises the additional risks of shoulder, neck and hand/arm complaints.

Incidence of complaints after computer use.[a]

Mouse use (hours / week)	Additional incidence of shoulder complaints (%)[b]	Additional incidence of neck complaints (%)[c]	Additional incidence of hand/arm complaints (%)[d]
None	0	0	0
5	1.7	1.3	2.2
10	3.7	2.6	4.6
15	5.7	3.9	7.4
20	8.0	5.4	10.5
30	12.9	8.1	17.4

[a] Computer use is expressed as the (selfreported) hours working with a mouse.
[b] (pooled) Incidence of shoulder complaints in the unexposed or low-exposed workers in several studies is 15.0%.
[c] (pooled) Incidence of neck complaints in the unexposed or low-exposed workers in several studies is 22.2%.
[d] (pooled) Incidence of hand/arm complaints in the unexposed or low-exposed workers in several studies is 13.6%.

Possibilities for occupational exposure limits

A safe threshold value below which no (physical) health effects occur due to computer use cannot be given. However, the Committee does believe it is possible to set occupational exposure limits based on risk calculations. This means a debate is required to determine what degree of risk is acceptable. This requires definition of a normative framework. An important choice here involves deciding what additional risk of a given adverse health effect is deemed acceptable, taking into account aspects such as the prevalence and incidence of neck, shoulder, arm and hand complaints in the general population. However, policy and social considerations will also play a role in the ultimate decision.

Conclusion

Many studies into the physical effects due to computer use relate to traditional computer workplaces (with a PC, keyboard and mouse). However, working environments are changing. There are changes in both hardware (different equipment use, such as tablets and smartphones) and working patterns. The Committee does not know to what degree the results of this advisory report also apply to modern (or future) working environments. However, the Committee did not find any data in the available literature to indicate these changes will result in different health risks. Studies among students, who likely use computers more irregular, show similar health complaints as studies among workers. Information on this topic is

limited, however. The Committee is therefore of the opinion that more research is required into the consequences of greater computer use diversity for health.

Chapter 1

Introduction

Compared to fellow European employees, Dutch employees spend the most time behind a computer monitor; 3.8 hours per day in 2010. Computer use – i.e. use of a computer, mouse and/or keyboard – is particularly common in office jobs. There are indications that this kind of work leads to complaints and conditions of the neck and upper limbs (shoulder, arm and hand). Considering the growing computer use both at work and in private, the health risks that develop as a result are expected to increase. The consequences for society in terms of rehabilitation, absenteeism and work disability may be costly. In this advisory report, the Committee on the Identification of Workplace Risks of the Health Council of the Netherlands examined the possibilities for defining health-based occupational exposure limits for computer use at work.

1.1 Computer use: definition

Computer use may be defined as performing tasks using an alphanumeric or graphic display in a computer environment.[1,2] The traditional computer environment is understood to mean a workplace with a keyboard*, mouse, desk

* The keyboard is the primary input device for computers. In the Netherlands, the most commonly used keyboards have a QWERTY layout (named based on the first six letters), which come in a variety of ergonomic shapes, for example splitting the right and left halves of the keyboard (split keyboards) or with keys recessed compared to the wrist support (recessed keyboards).

or work surface, a chair, peripherals such as a telephone, modem or printer, and optional accessories, or facilities that allow for data entry.[2] Computer use may also simply be viewed as 'typing, clicking and watching', meaning an employee is using the keyboard and mouse and/or watching the screen.[1] Computers are generally used in a seated position.

The current computer environment is undergoing changes. The use of touch screens, laptops, e-readers, netbooks (small, lightweight laptops), PDAs (personal digital assistants), etc. is on the rise.[3] Available research on the health effects of computer use, however, is primarily focused on traditional workplaces.

1.2 Extent of computer use in the Netherlands

Since the introduction of the computer in the 1960s and 1970s, the number of employees worldwide working with a computer has grown: work and activities that involve computers have expanded significantly. Computers are no longer only used for data entry and 'traditional' typing, but also for a very large proportion of other activities such as archiving, mailing and correspondence, collecting, storing and accessing data, and for gaining access to all manner of internet-based applications.

In 1991, there were 80 million computers in use in the United States; by 2000, the number had grown to over 100 million. Over 77 million employees worked with computers in 2003.[4] In Europe, 88 million employees work behind a computer monitor. 50 million Europeans indicate they use a computer for at least half of their working day.[5]

Relative to their fellow European employees, Dutch employees spend the most time behind a computer monitor: on average, computer users hit a key 5,000 times per working day, with peaks of up to 30,000 keystrokes per day.[6] In 2000, 60% of the working population in the Netherlands spent over a quarter of their working hours working with a computer, and 33% even worked with a computer almost exclusively.[7,8] In 2004, 48% of women and 46% of men indicated they regularly performed work using a computer. That same year, over 3 million employees indicated they were regular computer users.[7,8] In 2010, Dutch employees on average spent 3.8 hours per day working behind a computer monitor.[7,8]

However, the computer is not only a workplace tool, but has gained an important position in people's private lives as well. The possibilities are likely to continue

to grow, and new technological developments are sure to present themselves. Wireless communications is one such technology that has significantly expanded the computer's potential in recent years. In addition to exposure to computer use at work, the exposure at home is also increasing significantly, a unique aspect of computer use as an occupational hazard.

1.3 The request for advice

This advisory report is one in a series of reports on possible limits for various occupational risks. On 10 July 2007, the Minister of Social Affairs and Employment asked the Health Council of the Netherlands to:

- periodically report whether there are *currently* new (international) scientific insights regarding concrete occupational health-based or safety-based exposure limits
- periodically report whether any new (international) scientific insights regarding concrete occupational health-based and/or safety-based exposure limits are *expected*
- additionally, the Minister requested *existing* scientific insights be considered.

The full request for advice has been included as Annex A to this advisory report.

On 14 March 2008, the Committee on the Identification of Workplace Risks was appointed for this task. The Committee is composed of experts in the fields of working conditions, health, safety and occupational disease. The chairman and members of the Committee and its working group are listed in Annex B.

1.4 The Committee's methods

Existing health-based or safety-based occupational exposure limits, both in the Netherlands and internationally, are used as a starting point for the advisory report by the Committee. If limits and/or legal frameworks are present, the Committee first examines whether these have a health-based or safety-based foundation.

Subsequently, the Committee explores the scientific literature using review publications. This allows the Committee to gain insight in the health-based and safety-based issues resulting from computer use at work. This initial phase is a starting point for the second phase, in which the Committee performs a systematic literature review, and collects primary scientific publications on the potential adverse effects of computer use at work on health and/or safety.

Once the Committee reaches a consensus on content, a draft of the advisory report is published for commentary by third parties. Received comments are integrated in the finalisation of the advisory report (Annex C).

1.5 Reading guide

In the second chapter, the Committee provides an overview of applicable national and international laws and guidelines governing computer use at work. In the third chapter, the Committee describes the results of the systematic literature review into the health effects of computer use at work. Chapter four outlines the possibilities for limits based on available data. The results of several meta-analyses are presented in Chapter five. In Chapter six, the Committee translates the results of the meta-analyses to the Dutchoccupational context and describes the risks of complaints due to computer use at work. Finally, Chapter seven contains a number of recommendations regarding computer use at work.

Chapter 2

Laws and guidelines

This chapter provides an overview of legislation and regulations relating to computer use at work. The Dutch Working Conditions Act and Decree contain rules for employers and employees designed to protect and promote the health, safety and welfare of employees and independent entrepreneurs.[9] Additionally, there are a number of guidelines.

2.1 Legal rules

The updated Working Conditions Act (enacted on 1 January 2007) contains requirements for computer use. These requirements are consistent with both the International Organization for Standardization and the European directives.[10,11] The Working Conditions Decree contains the following sections that apply to computer use:

- Section 5.7 on definitions
- Section 5.8 on applicability
- Section 5.9 on risk identification and assessment
- Section 5.10 on daily scheduling of labour
- Section 5.11 on measures relating to the protection of the eyes and eyesight of employees
- Section 5.12 on the requirements for the layout of computer workstations.

The Working Conditions Decree links computer use to a working environment, via the monitor and the computer workstation. These are defined in Section 5.7:

a Monitor: an alphanumeric or graphic display, regardless of the display technology used;
b Computer workstation: the monitor and the entirety of associated monitor equipment used by an employee, including the immediate working environment.

Section 5.10 of the Working Conditions Decree on the scheduling of labour states the following regarding computer use:

Work using a monitor is organised such that this work is always interrupted by other types of activities or a resting period after at most two consecutive hours, so as to relieve the burden of working behind a computer monitor.

The Working Conditions Provisions elaborate further on the Decree. In addition to the six sections of the Decree listed above, Sections 5.1, 5.2 and 5.3 of the Working Conditions Provisions address computer use. Section 5.1 pertains to equipment and furnishings, Section 5.2 to the layout of the computer workstation, and Section 5.3 to the software.

The maximum duration of 2 hours of consecutive labour referred to in the Working Conditions Decree for work behind a computer monitor is considered a legal limit for computer use. If, for jobs consisting entirely of computer use, the duration of labour is limited to 5 to 6 hours per day, the rule that an employee may not work at a computer for longer than 2 consecutive hours remains applicable. If work behind a computer is alternated with breaks, it is recommended these breaks (depending on the intensity of work performed) last at least 10 minutes. In principle, the additional breaks required to alleviate the burden of computer use at work are considered to be part of the working hours.

2.2 Other recommendations and guidelines

Occupational diseases in the Netherlands must be registered and reported via the national reporting and registration system of the Netherlands Center for Occupational Diseases (NCvB). The NCvB promotes the quality of prevention, (early) diagnosis, treatment and support for occupational diseases and work-related conditions. In order to promote and standardise the registration of occupational diseases, the NCvB has created registration guidelines for many conditions. These guidelines provide information on the causal link between

conditions and exposure (at work) to occupational factors.[12] These registration guidelines were developed based on recent scientific literature. The scientific literature has not always been collected in a systematic manner.

The registration guideline on occupational conditions of the upper extremity [*Registratierichtlijn Werkgerelateerde aandoeningen aan het bewegingsapparaat in de bovenste extremiteit (RSI)]*, the NCvB notes that besides repetitive labour, computer use is the most important occupational burden. This guideline indicates available evidence for an association between certain physical factors (such as posture, force, motion and vibration) and occupational musculoskeletal conditions of the upper extremities. The guideline indicates that frequent repetition (2-4 times per minute, or cycles shorter than 30 seconds) of movements for more than 4 hours per day is likely to result in a work-related association with incident shoulder, neck, elbow and forearm complaints.

Chapter 3

Health effects due to computer use at work

The Committee performed a literature review, using the following two main questions: 1) what health and safety problems develop due computer use at work? 2) to what degree is exposure (in terms of duration, frequency and/or intensity) to this occupational risk related to these problems? This chapter describes the specific and non-specific health effects of computer use at work.

3.1 Broad literature exploration

A broad literature exploration identified a number of scientific literature reviews on the development of health-related and safety-related problems due to computer use at work (see Annex D). Working behind a computer monitor is related to an increased risk of health complaints.[13-22] Computer and mouse use have been associated with neck and upper limb complaints (shoulders, arms, wrists and hands), as well as with eye complaints. Keyboard use appears to lead primarily to hand/arm complaints.

3.2 Systematic literature review

After the broad literature exploration, the Committee performed a systematic literature review. The emphasis was on neck and upper limb complaints, particularly shoulders, arms, elbows, wrists and hands. As the majority of

reviews were published recently, the Committee decided to use January 2005 as the starting date for the systematic literature review. Annex E describes the search strategy and how studies were selected. All selected publications were subsequently described for quality.

The Committee decided only to consider longitudinal studies. In longitudinal research, exposure is determined prior to the health effect. This lowers the risk of confounding when examining associations between exposure and effect, providing the most reliable picture. Therefore, the Committee values the results obtained in longitudinal studies over data from case-control or cross-sectional studies, as long as the study quality is sufficient.

In its literature review, the Committee also specifically sought out studies performed among students, as: 1) in these cases there is long-term and frequent exposure to computer use, and 2) computer workstations at educational institutions are subject to working conditions legislation. By mapping the complaints in this group of computer users, the Committee also expected to gain greater insight into the consequences of different exposure patterns; peak use, laptop use and a greater diversity of computer workstations.

The selected studies recorded the degree of computer use as the duration (often expressed as hours per week) of computer, keyboard and/or mouse use. This information was usually obtained via self-report. The health effects were also primarily self-reported by the employees using questionnaires. Most studies were conducted in traditional workplace environments. The following sections provide an overview of the health effects associates with workplace computer use.

3.3 Effects on neck and shoulders

The systematic literature review identified nine studies examining the association between computer use and non-specific complaints in the neck and/or shoulders. Of these nine studies, eight were prospective cohort studies, and one was a cross-sectional study.[23-31] All studies are summarised in Annex F. In six of the eight cohort studies, both exposure to computer use and health outcomes (neck and/or shoulder complaints) were self-reported by employees. In one study, computer use was recorded via both self-report and automatic registration, and one study only used automatic registration.

In 2004, Brandt et al. conducted a prospective, one-year study into the effects of mouse and keyboard use on neck and shoulder complaints among over 5,000

Danish technicians*.[24] The cohort was 63% female, and the average age was 41 years. Participants were asked about their computer use and neck or right shoulder pain lasting at least seven consecutive days at two time points - the beginning of the study and after one year. Participants with complaints were invited to undergo physical examination. At the start of the study, 10.6% of employees had neck complaints, and 7.6% had right shoulder complaints (prevalence). After a one-year period, 1.5% of employees who were initially symptom-free had developed neck complaints (incidence); this figure was 1.9% for right shoulder complaints. These complaints persisted for at least seven consecutive days, and were described by the employees as moderately severe and inconvenient during work. This study expressed computer use as the hours per week employees estimated they used a mouse or keyboard. Employees who used a mouse for thirty hours per week or longer had a significantly elevated risk of developing right shoulder complaints (RR = 3.3; 95% confidence interval CI 1.2-8.9). With twenty to thirty hours of mouse use per week, the association with new shoulder complaints was not statistically significant (RR = 1.9; 95% CI 1.0-3.5). Likewise, no statistically significant association was found between thirty hours of mouse use or more per week and new neck complaints (RR = 2.4; 95% CI 0.8-6.8). The relationship between the development of complaints and computer use was less clear: no statistically significant association was found with complaints; even for fifteen hours of keyboard use per week or more, the association with the right shoulder complaints was not significant (RR = 2.2; 95% CI 1.0-4.9).

Andersen et al. (2008) examined part of the same cohort of technicians. They did not measure exposure via self-report, but they recorded weekly computer use for 52 weeks in over 2,000 individuals, using the so-called workpace recorder.[23] Participants were also asked about neck and shoulder pain on a weekly basis. Nine hours or more per week spent using a mouse led to a statistically significantly increased risk of shoulder complaints (OR = 1.10; 95%CI 1.05-1.16), but there was no statistically significant association with neck complaints (OR = 1.04; 95% CI 1.00-1.09). The examined relationships between computer use and neck and shoulder complaints did not reveal any statistically significant associations (OR_{neck} = 1.01; 95% CI 0.98-1.03; $OR_{shoulder}$ = 1.01; 95% CI 0.98-1.04). Andersen et al. (2008) found no statistically significant associations between computer use and chronic complaints (lasting longer than thirty days) of the right shoulder and neck (insofar as this was experienced as a burden).

* Technicians who are members of the Danish Association of Professional Technicians.

Hagberg et al. (2007) and Tornqvist et al. (2009) conducted a ten-month study in a Swedish cohort of over 1,000 computer users in various professions*, a little over half of whom were women, with an average age of 44 years.[25,30] The participants self-reported their computer use and musculoskeletal complaints on a monthly basis. The study by Hagberg et al. focused on self-reported decreased work productivity or absenteeism due to musculoskeletal complaints. They found a statistically significant reduction in productivity due to shoulder complaints if a mouse was used for between thirty minutes to three hours per day (HR = 3.4; 90% CI 1.40-8.17). For three hours of mouse use per day or more, the association with shoulder complaints was of the same order of magnitude, but not statistically significant (HR = 3.0; 90% CI 0.97-9.52). Other investigated (self-reported) exposure measures, such as the number of hours of computer use, data entry or continuous uninterrupted computer use, were not associated with shoulder complaints. Decreased productivity due to neck complaints was not observed for any of these exposure measures. Tornqvist et al. (2009) investigated the same exposure measures in relation to (self-reported) pain in the neck or shoulder (for at least three days in the past month).[30] The investigators calculated the incidence ratio per 100 person-years was 67 cases for neck complaints and 41 cases for shoulder complaints. Only (self-reported) mouse use for thirty minutes to three hours per day resulted in a statistically significantly increased risk of shoulder complaints (RR = 1.62; 95% CI 1.12-2.34); the risk was not statistically significantly elevated in the event of more the three hours per day of mouse use (RR = 1.30; 95% CI 0.77-2.19). No associations with the investigated risk measures were found for neck complaints.

IJmker et al. studied almost 2,000 office workers in the Netherlands for a two-year period, with exposure to computer use and neck/shoulder complaints reported every three months.[26] The cohort was about 50% male and the average age was 41 years. The incidence of serious neck and shoulder complaints reported during the last three months varied between 3.9 and 8.8%. Mouse use for four hours or more per day (self-reported) resulted in a statistically significantly increased risk of neck and shoulder complaints (RR= 1.5; 95% CI 1.1-2.0). The association was not seen for self-reported computer use. In addition to self-reported exposure, investigators also recorded computer use with a workpace recorder for three months. The recorded duration of computer, mouse and keyboard use was not associated with a statistically significantly elevated risk of neck and shoulder complaints.

* Professions including: management and administration, graphic design, ICT support, medical back office, technical support.

Three previous longitudinal studies by Marcus et al. (2002), Korhonen et al. (2003) and Juul-Kristensen et al. (2004) yielded no statistically significant associations between neck and/or shoulder complaints and computer or keyboard use.[27-29]

In a cross-sectional study among over 450 office workers, Rahman and Abdul (2004) found twice as many upper limb complaints, including neck and shoulder complaints (OR = 2.0; 95% CI 1.1-3.4), with computer use for more than two hours per day.[31] Among employees who used the computer for five hours per day or more, the number of complaints was seven times higher (OR = 7.5; 95% CI 2.3-24.2).

3.4 Effects on arms, elbows, wrists and hands

In addition to neck and/or shoulder complaints due to computer use, effects on arms, elbows, wrists and/or hands have also been observed. The systematic literature review identified nine studies, including seven prospective cohort studies and two cross-sectional studies.[25-27,29,30,32-34] These studies are summarised in Annex F. Six of the seven cohort studies used self-reported information on both exposure to computer use and health outcomes (arm, elbow, wrist and/or hand complaints). In one study, computer use was recorded using both self-reporting and independent registration.

The previously described Danish longitudinal study among over 5,000 technicians also investigated pain complaints of the forearm, elbow, and wrist/hand.[32] Kryger et al. (2002) described that mouse use (with the right hand) during five to nine hours per week increased the risk of moderate pain complaints in the right forearm (OR = 2.7; 95% CI 1.3-5.6). An increase in the number of hours of mouse use also led to an increased risk of complaints; over thirty hours per week of mouse use resulted in a risk of complaints seven times higher than for no or minimal mouse use (OR = 7.3; 95% CI 3.1-1.17). The investigators found that use of a keyboard for twenty hours per week or more also resulted in a statistically significantly increased risk of moderate forearm pain complaints (OR = 2.9; 95% CI 1.2-7.1). At the beginning of the study, 4.3% of employees had right forearm complaints and 1% had left forearm complaints. After one year, the incidence of new right forearm complaints was 1.3%, and the incidence of left forearm complaints was 0.4%. The physical examination found none of these new cases was due to nerve impingement.

Two years later, Lassen et al. published results relating to pain complaints in the elbow and wrist/hand.[33] Use of a mouse from five hours per week increased the risk of wrist/hand complaints (OR = 2.16; 95% CI 1.46-3.22) and elbow complaints (OR = 2.35; 95% CI 1.51-3.70). All of these examined pain complaints increased with the number of hours of mouse use per week. For thirty hours or more per week, the risks of wrist/hand and elbow complains were three to four times higher than for no or minimal mouse use (OR_{wrist} = 3.05; 95% CI 1.63-5.67; OR_{el} = 4.74; 95% CI 2.51-8.95). The associations between keyboard use and elbow or wrist/hand pain complaints were less clear than those for mouse use. With twenty hours or more of keyboard use, there was only a statistically significant association with wrist/hand complaints (OR = 1.61; 95% CI 1.13-2.28). At the start of the study, 27.5% of employees reported right elbow pain (5.5% severe), and 46.2% had complaints in the right wrist/hand (8.1% severe). After one year, 14.1% of participants had developed right elbow complaints (2.7% severe); this figure was 21% for the right wrist/hand (4.0% severe).

Comparable effects due to mouse use were found in the previously described prospective cohort study among Swedish computer users.[25] Hagberg et al. (2007) found that with thirty minutes to three hours of mouse use per day, the risk of decreased productivity due to forearm and hand complaints increased significantly (HR = 2.1; 90% CI 1.12-4.08). With mouse use for more than three hours per day, this risk was not significantly elevated, however (HR = 1.4; 90% CI 0.52-3.63). No associations were found between the number of hours of computer use, data entry per day, or continuous computer use without interruption and decreased productivity due to forearm/hand complaints. Tornqvist et al. (2009) examined the incidence of arm/hand symptoms in the same cohort.[30] Employees who used a mouse for at least thirty minutes per day were about one and a half times more likely to develop arm/hand complaints (OR = 1.44; 95% CI 1.01-2.05) than employees who spent less than thirty minutes per day using a mouse. With three or more hours of mouse use per day, complaints increased further (OR = 1.70; 95% CI 1.07-2.70). The incidence ratio of arm/hand complaints was 47 cases per 100 person-years. This study also found no associations between arm/hand complaints and the number of hours of computer use, data entry or continuous computer use without interruption.

In the two-year prospective cohort study by IJmker et al. (see Section 3.3), employees who reported four hours or more of computer use per day were almost twice as likely to develop arm/wrist/hand complaints (RR =1.9; 95% CI 1.1-3.1) than employees who were exposed for fewer than four hours per day.[26] The investigators found no association between arm/wrist/hand complaints and self-reported mouse use or registered computer, mouse or keyboard use. The

incidence of serious arm/wrist/hand complaints per three months varied between 2.8 and 4.6%.

Marcus et al. (2002) investigated risk factors for musculoskeletal disorders in a prospective cohort study among about 600 computer users.[29] Participants reported the hours spent using a keyboard and hand/arm complaints weekly. Employees with hand/arm complaints were examined clinically. The investigators found an elevated risk of hand/arm symptoms and conditions per hour of keyboard use per week (HR=1.04; 95% CI 1.02-1.06).

In a prospective cohort study among almost 2,000 office workers in 2004, 60% of whom were women, Juul-Kristensen et al. examined the effect of computer use on the frequency and intensity of elbow complaints.[27] This study showed that working with the computer for almost the entire day did not result in an increased risk of elbow complaints (OR = 1.08; 95% CI 0.60-1.93).

Two cross-sectional studies into computer use and wrist/hand complaints support the longitudinal data. In a study among 84 computer programmers, Shuval (2005) found that employees who reported working with a computer for more than seven hours per day had four times as many wrist/hand complaints (OR = 4.39; 95% CI 1.27-15.17) as employees who were exposed for fewer than seven hours per day.[35] With more than nine hours of computer use per day, there was no significant association with the number of wrist complaints (OR = 1.73; 95% CI 0.39-7.56).

The cross-sectional study by Walker-Bone et al. (2006) among over 4,000 patients from two general practices found that the incidence of non-specific wrist complaints was not statistically significantly increased for one hour or more of keyboard use per day (OR = 1.3; 95% CI 0.8-2.1).[34] *Tenosynovitis* of the wrist, however, was three times as common among these employees (OR = 3.1; 95% CI 1.3-7.8).

3.5 Carpal tunnel syndrome

In a cross-sectional study among over 2,000 participants (ages 25-65 years), as part of a larger study, Atroshi et al. (2007) examined the development of carpal tunnel syndrome (CTS) due to keyboard use at work.[36] CTS is the incidence of tingling or numbness in one of the hands due to reduced nerve conduction. The amount of keyboard use at work was measured using a questionnaire, while CTS was recorded using a questionnaire, physical examination and measurement of nerve conduction. No association was found between CTS and the number of hours of keyboard use (less than one hour, one to four hours, or more than four

hours per day). The prevalence ratios for the exposure groups were 0.93 (95% CI 0.52-1.7), 0.55 (95% CI 0.26-1.2) and 0.52 (95% CI 0.23-1.2), respectively.

In 2003, Andersen et al. found similar results.[37] In a prospective cohort study among over 5,000 employees, they found no association between keyboard use and CTS symptoms following a one-year follow-up period. However, mouse use of 20 hours per week or more was association with a statistically significantly increased risk of CTS symptoms in the right hand (OR = 2.6; 95% CI 1.2-5.5). After one year, 5.5% of studied employees had developed CTS symptoms or had reported worsening of their complaints; only 1.2% of this percentage had median nerve symptoms.

3.6 Neck, shoulder and arm complaints among students

The systematic literature review identified seven studies into the health effects of exposure to computer use in students, including three prospective cohort studies and four cross-sectional studies.[38-44] All studies are summarised in Annex G.

Two of the three longitudinal studies found an increased risk of pain complaints in arms, neck, shoulders or upper back due to computer use.[39,40] Chang et al. (2007) found that of the 13 male students, those who spent 2.5 hours or more using a computer had almost twice the risk of musculoskeletal complaints (OR = 1.96; 95% CI 1.12-3.42) compared to male students who spent less time using a computer. No significantly increased risk of these complaints was found for female students (n=14). The follow-up period for this study was three weeks. The prevalence of moderate or severe complaints among participating students was 48%.

Grimby-Ekman et al. (2009) examined the occurrence of neck/upper back complaints due to computer use in a prospective cohort study of 1,200 students with a two-year follow-up. More than two periods of four hours of computer use per week was associated with an increased risk of neck/upper back complaints (OR =1.4; 95% CI 1.11-1.71). The prevalence of complaints among participating students was 23%.[40]

In a six-month study among 93 school children (average age 16 years), Brink et al. (2009) found no significant association between computer use and the development of arm, neck or shoulder pain (≥ 1 hour and 45 minutes per day: OR = 1.7; 95% CI 0.7-4.2; ≥6 hours per week: OR = 1.6; 95% CI 0.7-3.8).[38]

In addition to the longitudinal studies, a number of cross-sectional studies were also found.[41-44] These studies among students also found that computer use resulted in more arm, neck and shoulder complaints.

In 2004, Schlossberg performed a questionnaire study among 200 students in order to evaluate the association between computer use and upper limb and neck complaints.[43] Four groups were created based on self-reported duration of computer use: a reference group (less than twenty hours per week) and three exposure groups (20 to 29 hours, 30 to 39 hours, and >40 hours per week). Students who had used a computer for 20 to 29 or 30 to 39 hours per week had more arm, shoulder and neck complaints than the reference group (20 to 29 hours per week OR = 4.3; 95% CI 1.2-14.4; 30 to 39 hours per week OR = 6.5; 95% CI 1.8-22.7). In 2007, Palm conducted a study among almost 3,000 students using questionnaires.[42] The female students who spent 14 hours per week or more using a computer reported significantly more forearm pain (PR = 1.56; 95% CI 1.17-2.06) and with more than 56 hours of computer use per week, they reported significantly more neck and shoulder complaints (PR = 1.33; 95% CI 1.08-1.64). In a study among 30 students, Menendez (2008) found that computer use was associated with significantly more upper limb complaints (OR = 1.1; 95% CI 1.1-1.2).[41] Smith et al. (2008) found significantly more neck complaints (OR = 1.7; 95% CI 1.2-2.3) in over 1,000 students if they spent more than 8.5 hours per week using a computer.[44]

3.7 Other effects

In addition to effects on the neck, shoulders, arms, elbows, wrists and hands presented in the previous sections, the systematic literature review revealed studies examining other effects of computer use. This section describes a number of health effects that have also been associated with computer use, such as eye complaints, psychological conditions and sleeping disorders.

3.7.1 Effects on the eyes

The literature review identified six cross-sectional studies that examined the relationship between computer use and various kinds of eye complaints.[45-49] In 2008, Uchino et al. examined the incidence of dry eyes in a group of over 1,000 office workers who used a computer.[46] In this study, both exposure to computer use and the health outcome were measured using questionnaires. Compared to a group with minimal exposure (N=1013; less than two hours per day), employees were found to suffer more from dry eyes if they spent between two and four

hours per day (OR = 1.28; 95% CI 1.04-1.56) or more than four hours per day (OR = 1.83; 95% CI 1.46-2.29) behind a computer monitor.

Vision complaints and eye damage (glaucoma) due to computer use were examined by Tatemichi et al. (2004).[45] In this study, conducted among about 250 employees, exposure to computer use was evaluated using a questionnaire, and health effects were determined via ophthalmological examination. Employees with a moderate (at least one hour per day for at least five years; OR = 1.27; 95% CI 1.04-1.56) or high (over four hours per day for at least ten years; OR = 1.58; 95% CI 1.21-2.05) level of computer monitor use had more vision complaints than less exposed employees. Employees with high exposure to computer monitor use also had more eye damage (glaucoma) (OR = 2.11; 95% CI 1.34-3.31) than less exposed employees.

Woods (2005) had over 300 participants complete a questionnaire, and found that employees with a high level of exposure to computer use (10,000 keystrokes per hour) had between two and a half (OR = 2.4; 95% CI 1.3-4.6) and seven and a half (OR = 7.7; 95% CI 2.3-25.9) more eye complaints (fatigue, dryness) than employees with lower exposure to computer use.[47] These findings were confirmed by Ye et al. (2007)[48]: compared to a group of unexposed people, employees who spent less than five hours per day (OR = 3.1; 95% CI 2.3-4.3) or more than five hours per day (OR = 5.4; 95% CI 3.8-7.5) using a computer monitor, had more eye complaints.

In a cross-sectional study among almost 2,000 school children, Khader (2006) found that school children who used computers had more myopia (OR = 1.16; 95% CI 1.06-1.26).[49]

3.7.2 Psychological conditions

The literature review identified one cross-sectional study by Ye et al. (2007) that examined the relationship between computer use and psychological conditions.[48] About 750 office workers participated in this study, in which both exposure and health outcome* were measured using a questionnaire. This study found that employees who spent five or more hours per day using a computer monitor had more psychological conditions (OR = 1.42; 95% CI 1.13-1.78) than employees who used a computer monitor for less than five hours per day.

* The 12 questions on the questionnaire on psychological conditions examined: lost sleep, feeling of being under strain, inability to concentrate, feeling unable to play a useful role, inability to face problems, inability to make decisions, inability to overcome difficulties, feeling unhappy, lack of enjoyment in day-to-day activities, feeling depressed, lack of confidence and feeling of worthlessness.

3.7.3 *Sleeping disorders*

The literature review identified one cross-sectional study by Yoshioka et al. (2008) that examined the relationship between computer use and sleeping disorders. Both exposure to computer use and the health outcome were measured using a questionnaire.[50] In this study, statistically significant risk measures were only found for high exposure to computer use: employees who used a computer for six hours or more per day had 60% more sleeping disorders than employees who used a computer for less than two hours per day (OR = 1.62; 95% CI 1.18-2.27).

3.8 Areas for attention in epidemiological research

In the evaluation of the epidemiological literature, the Committee was hindered by differences in study design and exposure measures.

3.8.1 *Importance of study design*

Longitudinal studies in which exposure is determined prior to the health effect have the lowest risk of confounding in relation to the association between exposure and effect. Such studies provide the most reliable picture. In case-control studies, minimal confounding is to be expected if exposure is determined blinded from patient status. Case-control studies in which exposure is based on questionnaires or interviews have problems similar to those present with cross-sectional research, in which self-reported exposure may have been affected by health status.

Therefore, the Committee places a greater value on the results of longitudinal studies. If unavailable, it then turns to case-control studies, as long as exposure has not been self-reported. The Committee only views cross-sectional research as indicative of an association.

3.8.2 *Self-reported exposure and complaints*

In all epidemiological studies, exposure was reported by the study subjects, via questionnaires or interviews. Only two longitudinal studies independently recorded the duration of computer use.[23,26] The study by IJmker et al. (2011), in which computer use was recorded via both self-reporting and registration, showed that self-report overestimated the number of use hours. Various studies

show that exposure recorded through self-report is less reliable than measured exposure.[51-53] Van der Beek and Frings-Dresen noted that self-report provides limited information about tasks and activities and that "Further information can be obtained from observations, which can best be combined with direct measurements of exposure to posture, movement, and exerted forces to achieve exposure profiles by occupational task". Heinrich noted that computer users generally overestimate their total computer use by more than one and a half hours.[51,52]

Self-reported duration of computer use does risk overestimation of exposure, but clear relationships with health complaints have been found. The Committee therefore cannot rule out that, as computer use is concerned, self-report may, in part, also be a measure of the experienced physical burden, which is not the case for independent registration. The Committee assumes that self-reported computer use may be a measure for the amount of time spent with computer-related activities. It therefore considers self-reported duration of computer use as an acceptable method.

The health effects were also primarily self-reported, particularly where local (pain) complaints were concerned. Physical examinations were also performed in a number of longitudinal studies. In the opinion of the Committee, local non-specific (pain) complaints can only be inventoried via self-report, and it considers this method sufficiently reliable.

3.8.3 *Potential confounding factors*

The Committee notes that a number of potential confounding factors must be considered when interpreting the data. For example, the longitudinal studies also show relationships between personal, psychosocial and work-related factors and upper limb complaints. High BMI (body mass index) and smoking were found to almost double the risk of shoulder complaints.[25] Dissatisfaction with the ergonomic layout of the computer workstation, high demands and limited possibilities for exerting control increased the risk of neck, shoulder and arm/hand complaints.[24,25,30,33] There are a variety of theories regarding the relationship between psychosocial factors and musculoskeletal conditions.[54] The Committee cannot determine the degree to which these factors contribute to the relationships between computer use and physical complaints found in the studies.

Furthermore, the Committee notes that various exposure measures for computer, keyboard and mouse use sometimes investigated in a single study are not independent of one another.

3.9 Summary of longitudinal studies

A literature search for health effects of computer use yielded eleven prospective cohort studies in which employees were examined for upper limb complaints, such as neck, shoulder, arm, elbow, wrist and hand complaints, due to computer use. Additionally, three longitudinal studies investigating comparable complaints in students were identified.

The overview of the lowest observed adverse effect levels (LOAEL) for upper limb complaints (table 1) shows that use of a mouse in particular (from thirty minutes per day) is associated with significantly increased risks of shoulder, arm, elbow, wrist and hand complaints. With a half hour of mouse use per day, the risk of complaints is increased by about 50%. Multiple longitudinal studies found exposure-response relationships between mouse use and the complaints listed. This means that an increase in the duration of mouse use increased the risk of complaints. None of the longitudinal studies found a significant association between mouse use and neck complaints, except in combination with shoulder complaints. In that situation, four hours of mouse use per day or more increased the risk of neck and shoulder complaints by 50%.

Keyboard use from 10 hours per week was also associated with elbow, forearm, wrist and hand complaints, with risks being increased by 150 to 300%.

Computer use was only associated with an increased risk of complaints once. The risk of wrist/hand/arm complaints was 90% higher for four to six hours of computer use per day.

Both exposure and effects were self-reported by employees for all of the studies listed in table 1. Although two longitudinal studies also recorded computer use, it turned out that there was only a significant association between recorded mouse use and shoulder complaints. The risk of shoulder complaints was increased by 10% with nine hours of mouse use per week or more (OR = 1.10; 95% CI 1.05-1.16).

Three longitudinal studies into the relationship between computer use and upper limb complaints were conducted among students and school children. Two studies found significantly elevated risks for computer use. In a three-week study with about 30 participants, male students who used a computer for 2.5 hours per day had almost twice as high a risk of upper limb complaints (OR = 1.96; 95% CI 1.12-3.42). The risks were not significantly elevated for female students.

A two-years study among 1.200 students, found that computer use for two four-hour periods per week or more increased the risk of neck/upper back complaints by 40% (OR = 1.4; 95% CI 1.11-1.71).

Table 1 Overview of lowest observed adverse effect levels (LOAEL) (self-reported) for upper limb complaints due to computer use at work.

Computer use at work, expressed as	Duration[a] (hours)	Per day or week	Effect	Risk measure OR/RR (95% CI)	Ref
Mouse use	0.5-<3	day	shoulder	1.62 (1.12-2.34)	30
	0.5-<3	day	arm/hand	1.44 (1.01-2.05)	30
	5-9	week	forearm	2.7 (1.3-5.6)	32
	5-<10	week	elbow	2.35 (1.51-3.70)	33
	5-<10	week	wrist/hand	2.16 (1.46-3.22)	33
	≥ 4	day	neck/shoulder	1.5 (1.1-2.0)	26
	20-<25	week	wrist (CTS)	2.6 (1.2-5.5)	37
	≥ 30	week	shoulder	3.3 (1.2-8.9)	24
Keyboard use	10-<15	week	elbow	2.49 (1.08-6.53)	33
	≥20	week	forearm	2.9 (1.2-7.1)	32
	≥20	week	wrist/hand	1.61 (1.13-2.28)	33
Computer use	4-<6	day	arm/wrist/hand	1.9 (1.1-3.1)	26

[a] Level of exposure was self-reported.

Chapter 4

Possibilities for health-based recommended occupational exposure limits

The Committee was asked to investigate the possibilities for defining health-based occupational exposure limits for using a computer at work. In this chapter, the Committee explores these possibilities based on available data. Additionally, the Committee examines the significance of the complaints observed in the epidemiological studies: when are they serious and can they be considered to be adverse health effects?

4.1 Health based recommended OEL

For the occupational risk computer use, the Committee expects that it should in theory be possible to identify an exposure level below which the risk of harmful health effects is zero. To derive health-based recommended limits, standard procedure is to determine to what degree epidemiological literature contains indications for the height of the threshold value.

Various longitudinal studies on using a computer at work are available that examined exposure-response relationships with health complaints. More time spent behind a computer monitor increases the risk of health complaints in the upper limbs. A single study found a statistically significant effect for (self-reported) exposure of just thirty minutes or more per day.

However, in Chapter 3, the Committee concluded that the epidemiological data currently available do not allow evidence-based conclusions to be drawn

about the precise value of health-based recommended occupational exposure limits for using a computer at work.

4.2 Reference values

The Committee considers computer use to be a relevant occupational risk. An health-based recommended occupational exposure limit would be a useful tool for managing the health consequences of using a computer at work. The fact that, based on the available data, it is impossible to indicate a level of computer use that does not have health effects for employees, therefore concerns the Committee. The Committee therefore suggests an alternative approach. This approach is one derived from the approach previously proposed for genotoxic carcinogens.[55,56] This approach has been elaborated previously for the report on the risks of working in a standing, kneeling or squatting position. In this approach, the Committee determines risk levels for predefined reference values.

Health-based recommended occupational exposure limit	*Exposure or burden level* at which harmful health effects may reasonably be expected to be prevented.
Risk value or risk level	*Exposure or burden level* that may reasonably be related tot a certain (predefined) additional risk of adverse health effects
Reference value	An accepted *additional risk* of an effect due to exposure or burden, compared with the risk of an effect in the general population

The Committee would like to point out that the choice of a reference value is explicitly dependent on the (type of) occupational risk. Health considerations are not the only ones that play a role in this regard. Policy-related and social considerations should also be taken into account.

4.3 Significance of neck, shoulder, arm and hand complaints

Chronic non-specific complaints in the neck, shoulders, arms or hands are clear examples of adverse health effects. In the majority of longitudinal studies, participants were asked to report (pain) complaints or discomfort they experienced in the previous week or month, i.e. acute complaints. The question arises to what degree such brief episodes of pain symptoms are heralds for chronic complaints, and what the consequences of having such complaints are. In order to answer this question, the Committee checked what is known about the prevalence, incidence and prognosis of upper limb complaints, as well as disease burden and absenteeism.

4.3.1 *Prevalence of complaints*

In order to assess the relevance of the complaints that develop due to computer use at work, or mouse, keyboard and general computer use, the results of the longitudinal studies are compared with prevalence figures for upper limb complaints in the general population. Prevalence is defined as the occurrence (number of cases) of a specific condition in a population of employees or the general population.

In 2007, 26% of the Dutch population aged 25 and above reported complaints of the arm, neck and/or shoulder (CANS) in the previous year.[6] In a sample survey of about 3,500 Dutch people over the age of 25 years by Picavet et al., the following prevalence figures were found for upper limb complaints:

- over a twelve-month period: neck 31%, shoulder 30%, upper back 19%, elbow 11%, wrist/hand 18%, CANS* 37%
- at a random moment (point prevalence) neck 21%, shoulder 21%, upper back 9.1%, elbow 7.5%, wrist/hand 13%, CANS 26%
- for chronic pain in the past 12 months: neck 14%, shoulder 15%, upper back 6.2%, elbow 5.3%, wrist/hand 9.3%, CANS 19%.

Over 43% of individuals with CANS had these symptoms in more than one body part.[57,58]

A number of longitudinal studies provide information about the prevalence of upper limb complaints among employees. Over a twelve-month period, the prevalence of pain complaints was 10.6% for neck, 7.6% for shoulder, 27.5% for right elbow, 7.6% for left elbow, 46.2% for right wrist/hand, 11% for left wrist/hand, 4.3% for right forearm, and 1.0% for left forearm.[24,32,33] In the only longitudinal study among Dutch employees, the prevalence of serious neck/shoulder complaints over a three-month period was 15%, and the prevalence of arm/wrist/hand complaints was 11%.[26]

The prevalence figures from the longitudinal studies are difficult to compare with general population figures, due to the different periods (three versus twelve months) and different definitions for complaints. The relatively low prevalence figures for neck and shoulder complaints reported by Brandt et al. may be due to the definition used in their study, since the pain complaints had to be at least moderate.[24] Furthermore, Lassen et al.'s data suggest a higher prevalence of elbow and wrist/hand complaints among employees.[33] The prevalence figures for

* CANS, complaints of the arm, neck and/or shoulder not caused by acute trauma or chronic disease.

serious elbow and wrist/hand complaints (5.5% and 8.1%, respectively, for the right side) from this study are, however, comparable to the prevalence figures for chronic pain from the Dutch sample survey.[58]

4.3.2 Incidence

A number of the longitudinal studies also report how many employees developed certain complaints after a period of computer use (incidence). These figures also provide information about the significance of the health effects. Nine longitudinal studies were available with data from employees (Annex F). Incidence figures from these studies are difficult to compare, however, due to differences in study periods and definitions of complaints.

IJmker et al. (2011) found an incidence of serious neck/shoulder complaints ranging from 3.9 to 8.8% over a three-month period for Dutch office workers. Incidence varied between 2.8 and 4.6% for serious arm/wrist/hand complaints.[26] That the incidence of serious or chronic complaints is a few percent per year was confirmed by other longitudinal studies.[23,33] These incidence figures in part reflect the effects of computer use.

The Committee did not have incidence data for upper limb complaints in the general population (with no computer work) available.

4.3.3 Prognosis

The significance of the complaints due to computer use at work, or mouse, keyboard and general computer use can also be evaluated based on scientific data on the course of such complaints. The study by Picavet et al. (2003) in a sample of the Dutch population showed that only 6.3% of the people with neck, shoulder or upper back complaints, and only 7.5% of people with elbow or wrist complaints experienced a single episode of pain.[58] Of the people with neck, shoulder or upper back complaints, 47% reported recurrent mild pain; the percentage was 43% for the people with elbow or wrist complaints. 26% of respondents had continuous mild pain in the neck, shoulders or upper back, and 29% in the elbow or wrist. Severe pain complains were less common: recurring severe neck, shoulder or upper back pain was reported by 8.3% of respondents, and 11% reported recurring severe elbow or wrist pain. Continuous severe pain in the neck, shoulders or upper back was experienced by 3.1%; the figure was 4.0% for the elbow or wrist.

Table 2 Results from the study by Picavet et al. (2003) on the course of pain complaints.[58]

Complaints	Of the people with complaints			
	Percentage with persistent severe pain (%)	Percentage with persistent mild pain (%)	Percentage with recurrent severe pain (%)	Percentage with recurrent mild pain (%)
Neck/shoulder	3.1	25.9	8.3	46.7
Elbow/wrist/hand	4.0	29.2	11.0	43.3

4.3.4 *Absenteeism and disease burden*

Other measures to assess the significance and severity of complaints due computer use at work are absenteeism and disease burden. Picavet et al. (2003) also examined the consequences of having musculoskeletal complaints in the Dutch population.[58] Of the people with neck, shoulder or upper back complaints, 41% had visited the GP in the past year, 30% had consulted a medical specialist and 33% had seen a physiotherapist. 27% of them used medication. For people with elbow or wrist complaints, these percentages were 34%, 27%, 22% and 18%, respectively. 72% of people with neck, shoulder or upper back complaints and 78% of people with elbow or wrist complaints reported they had not missed work in the past year. For people with neck, shoulder or upper back complaints, if work was missed, this amounted to less than one week for 7.7%, to one to four weeks for the same percentage of people, and to more than four weeks for 5.9%. For people with elbow or wrist complaints, absenteeism percentages were: 4.8% less than one week; 5.9% one to four weeks and 5.3% more than four weeks. Partial work disability was reported by 6.1% of people with neck, shoulder or upper back complaints and by 4.0% of people with elbow or wrist complaints.

In the Netherlands, about half of the working population is regularly exposed to computer use at work, with one in three Dutch employees experiencing regular or persistent arm, wrist, hand, shoulder or neck complaints.[5,6,18] These complaints, mostly described as pain, stiffness and tingling/numbness, may not only limit wellbeing during daily life, but also result in a loss of productivity at work and absenteeism. The costs to society of absenteeism and work disability due to health complaints related to computer use are high: each year, 340,000 to 675,000 employees visit a doctor with work-related arm, neck or shoulder complaints.[6,13] In 2005, these complaints were responsible for 5% of absenteeism and 6% of new claimants under the Disablement Insurance Act.[6,7]

4.4 Conclusion

The Committee concludes that, based on available data on the risks of computer use, it is not possible to set an health based or safey based occupational exposure limit that is guaranteed to be safe. At this time, the challenge is to define a normative framework, as has been recommended for other risks (working while standing, kneeling or squatting). This would allow acceptable and unacceptable risks to be distinguished. Which health risks are due to exposure, to what degree do they present themselves, and what impact do they have? The Committee notes that, for non-specific self-reported musculoskeletal complaints (in the past year), it is important to determine how long these complaints persist (chronic or isolated) and how serious the pain complaints are.

Chapter 5

Meta-analysis

After describing the original studies found during the systematic literature review, the Committee presents the combined results in this chapter. By analysing the results of previous studies jointly (meta-analysis), conclusions may possibly be drawn and insights be generated that were not possible based on each individual study. A meta-analysis is performed in this chapter in order to evaluate the effect of computer use at work on various health outcomes.

5.1 Conditions and assumptions

The Committee chooses only to include longitudinal studies. This is because in this type of study, the level of exposure is determined before the health effect, which minimises the risk of confounding of the association and thus provides the most accurate picture. The Committee realises that the meta-analyses are based on only a few longitudinal studies. Of course, this affects how generally applicable the outcomes of the meta-analyses are.

Studies must meet a number of conditions for meta-analyses to be conducted. For example, it is necessary for exposure and health effects in various studies to be comparable. In the selected longitudinal studies, the influence of exposure duration turned out to be the main measure. Minor differences in the definitions for exposure and health effects were accepted.

In summary, the Committee sets the following requirements for the epidemiological studies:

- a longitudinal study design
- a comparable reference group (i.e.: not or minimally exposed)
- a comparable method for measuring exposure to computer, mouse or keyboard use (self-reported)
- a comparable definition of a health outcome
- a comparable method for measuring the health outcome (self-reported).

The Committee also made two assumptions in order to perform the meta-analyses.

The Committee believes that, based on the results described in Chapter 3, it is reasonable to assume that the risk of health complaints increases with the time spent working behind a computer monitor. This is reflected by the results for mouse use and health complaints. Data regarding the nature of the exposure-response relationship are scarce, however. For physical occupational risks, a linear relationship is not necessarily expected, as postures, movement and burden are part of normal human movement. Therefore, both the lack of any physical burden as well as excessive burden may yield health risks. In such cases, the exposure-response curve is U-shaped.[59]

For computer use at work, particularly mouse use, longitudinal data provide some indication for a linear relationship with upper limb complaints (see Annex H, fig 4).[23,33] Additionally, the investigators involved in the Danish NUDATA study concluded that no threshold could be ascertained for mouse use. The exposure-response relationship was consistent with a linear relationship transecting the origin.[33]

The Committee concludes that for computer use, the longitudinal studies only provide limited indications about the shape of the relationship between exposure and effect. In most studies, information on health complaints associated with computer use is only available for two or three different exposure levels. Therefore, it is impossible to assess different exposure-response curves. Conclusions about the shape of the exposure-response relationship are therefore difficult to support. Given the limited available data, the Committee currently assumes a linear relationship between exposure to the degree of computer use at work and the complaints observed. This linear relationship appears to hold true for at least part of the exposure-response relationship.

The second assumption is that the reference group has not been exposed to computer, mouse or keyboard use, and that the prevalence or incidence of

musculoskeletal complaints in that group is equivalent to that in the general population.[57,58]

5.2 Execution

Considering the different cut-off values for exposure to computer, mouse or keyboard use found in the longitudinal studies, the Committee decided to convert the exposure-response relationships from these studies to a comparable risk measure of ten hours of exposure per week (or two hours per day for a five-day work week). This conversion was performed for each study using SPSS 16.0.*

The meta-analyses were performed using the calculated slope of the exposure-response curve for each study and expressed as a regression coefficient with associated standard error. In the meta-analyses, these regression coefficients were weighted for variance in order to account for discriminating power (based, among other things, on the size of the study population and the number of incident cases) of the original studies. Pooled risks were calculated to evaluate the effect of a ten-hour per week increase in exposure to computer, mouse or keyboard use on the following health outcomes:

- neck complaints
- shoulder complaints
- hand/arm complaints
- neck/shoulder complaints.

A total of nine studies from the systematic literature review were deemed suitable for inclusion in the meta-analyses.[24-30,32,33]

* If different risk measures were used for sequential exposure categories within one study: the slope of the exposure-response curve was calculated using a log linear regression model [$y = e^{\alpha+\beta X+\log(N)}$, in which: Y = number of people with new complaints (incident cases), X = exposure measure for computer, mouse or keyboard use, N = study population size]. The exposure measure was expressed as an odds ratio [exp (X)]. In each study, the middle value per broad exposure category was used as a point estimate for exposure (e.g. 30 hours for exposure category 20-40 hours per week).
In cases where a single risk measure was used within a study: this risk measure was converted to the risk for a ten-hour per week increase in exposure, with the middle value in a broad exposure category again being used as a point estimate for exposure.

5.3 Results

5.3.1 Computer use

Of the nine usable longitudinal studies, three studies investigated neck complaints as a result of self-reported computer use.[25,26,53] Based on these three longitudinal studies, a pooled risk measure of 1.12 (95% CI 1.01-1.25) was calculated per ten-hour per week increase in exposure to computer use. Based on three longitudinal studies, a pooled risk measure of 1.05 (95% CI 0.96-1.15) was found for the occurrence of shoulder complaints per ten-hour per week increase in exposure to computer use.[25,27,30] A total of six studies could be used for calculating a pooled risk measure for neck/shoulder complaints.[25-30] Per ten-hour per week increase in computer use, a pooled risk measure of 1.08 (95% CI 1.01-1.16) was found. Based on five longitudinal studies, a pooled risk measure of 1.18 (95% CI 1.08-1.29) was found for the occurrence of hand/arm complaints as a result of a ten-hour per week increase in computer use.[25-30] Table 3 provides an overview of the results.

5.3.2 Mouse use

Of the nine usable longitudinal studies, three studies investigated neck complaints as a result of mouse use.[24,25,30] Based on these three longitudinal studies, a pooled risk measure of 1.15 (95% CI 1.01-1.32) was calculated per ten-hour per week increase in mouse use. Based on three longitudinal studies, a pooled risk measure of 1.30 (95% CI 1.13-1.49) was found for the occurrence of shoulder complaints per ten-hour per week increase in mouse use.[24,25,30] A total of four studies could be used for calculating a pooled risk measure for neck/shoulder complaints[24-26,30] Per ten-hour per week increase in exposure to mouse use, a pooled risk measure of 1.22 (95% CI 1.11-1.34) was found. For the occurrence of hand/arm complaints due to a ten-hour per week increase in exposure to mouse use, a pooled risk measure of 1.42 (95% CI 1.24-1.63) was calculated based on four longitudinal studies.[25,26,30,32] Table 3 provides an overview of the results.

5.3.3 Keyboard use

Of the nine usable longitudinal studies, three examined the health effects of keyboard use.[24,32,33] However, these studies determined the effects of computer

use on various endpoints. The Committee combined these data in the meta-analysis. The Committee realises that the evidentiary power of this analysis is limited. Based on these studies, a pooled risk measure of 1.17 (95% CI 1.06-1.29) was found for neck/shoulder/hand/arm complaints per ten-hour per week increase in exposure to keyboard use (table 3).

5.4 Summary of the meta-analyses

Table 3 provides an overview of the results of the meta-analyses performed for further assessing the effect of computer use at work on health outcomes. The table displays various exposure-response relationships from selected studies converted to a comparable risk measure with ten hours per week of computer or mouse use.

The performed meta-analyses show that ten hours of computer use per week increases the risk of hand/arm complaints by 18% and the risk of neck complaints by 12%. Ten hours of mouse use per week increases the risk of hand/arm complaints by 42%, the risk of shoulder complaints by 30% and the risk of neck complaints by 15%.

Table 3 Results of the meta-analyses per ten-hour increase per week of exposure to computer, mouse or keyboard use based on longitudinal studies.

Risk	Health effect	Number of studies	Pooled risk (95% CI) (per 10 hours/week)
Computer use	Neck complaints	3[25,28,30]	1.12 (1.01 - 1.25)
	Shoulder complaints	3[25,27,30]	1.05 (0.96 - 1.15)
	Neck/shoulder complaints	6[25-30]	1.08 (1.01 - 1.16)
	Hand/arm complaints	5[25-27,29,30]	1.18 (1.08 - 1.29)
Mouse use	Neck complaints	3[24,25,30]	1.15 (1.01 - 1.32)
	Shoulder complaints	3[24,25,30]	1.30 (1.13 - 1.49)
	Neck/shoulder complaints	4[24-26,30]	1.22 (1.11 - 1.34)
	Hand/arm complaints	4[25,26,30,32]	1.42 (1.24 - 1.63)
Keyboard use	Neck/shoulder/hand/arm complaints	3[24,32,33]	1.17 (1.06 - 1.29)

Chapter 6

Health risks due to computer use at work

In this chapter, the Committee translates the results of the meta-analyses to the Dutch workplace: to what degree is computer use at work a risk factor for the development of physical complaints? The Committee indicates the possibilities it sees for setting health-based occupational exposure limits and any alternative approaches. Uncertainties in available scientific literature are also addressed.

The Committee notes that the available studies primarily examine the health effects of working at a traditional computer workplace. Little is known about the health effects of working at modern computer workplaces. The number of studies is too limited to determine whether laptop use among employees results in different risks.

The Committee is of the opinion that the available scientific literature shows computer use may cause musculoskeletal complaints, mainly upper limb complaints, such as neck, shoulder, arm, elbow, wrist and hand complaints. Additionally, the Committee found some indications for the development of eye complaints, psychological conditions and sleep disorders.

6.1 Neck complaints

In most individual longitudinal studies, no association was found between neck complaints and self-reported computer, keyboard or mouse use.[23-25,28,30] In the study by Andersen et al. (2008), in which mouse use was recorded using a workpace recorder, a non-significant association was found between mouse use

for nine hours per week or more and neck complaints (OR = 1.04; 95% CI 1.00-1.09).[23] For a combination of neck and shoulder complaints, IJmker et al. (2011) saw a significantly elevated risk if a mouse was used for four hours per day or longer (RR = 1.5; 95% CI 1.1-2.0). In the latter study, exposure was measured via self-reporting.[26]

In a study among students, Grimby-Ekman et al. (2009) found a 40% higher risk of neck/upper back pain if two four-hour periods per week or more were spent using a computer (OR = 1.4; 95% CI 1.11-1.71).[40]

Combining the data from available longitudinal studies in meta-analyses showed that ten hours of computer use per week resulted in a 12% higher risk of neck complaints (pooled risk 1.12; 95% CI 1.01-1.25), and that ten hours of mouse use per week yields a 15% higher risk (pooled risk = 1.15; 95% CI 1.01-1.32).

In order to gain an impression of the degree to which computer use at work (recorded as self-reported computer and mouse use) affects the incidence of neck complaints in the Netherlands, the Committee subsequently calculated how many additional cases of workers with neck complaints (relatively) would develop due to computer use at work, based on the meta-analysis results. The calculations were based on: the pooled risk measure from the meta-analysis (see Chapter 5) and the data from the longitudinal studies on the incidence of neck complaints after one year of exposure. The Committee notes that the exposure durations used for these calculations all fall within the observed exposure periods of the included studies.

In order to evaluate the consequences of the identified risks for the Dutch situation, the Committee searched for data on the incidence of neck complaints among the Dutch working population with minimal exposure to computer use at work (over the past twelve months). The Committee used the pooled incidence of neck complaints in the unexposed or low-exposed workers (self-reported computer use) from the studies by Korhonen et al., Hagberg et al. and Tornqvist et al.[25,28,30]

These calculations show that the incidence of workers with neck complaints is 2% higher with ten hours of computer use, measured based on self-reporting (at the group level). If the degree of computer use is expressed as hours of mouse use, this results in a 2.6% increase in the incidence of neck complaints for ten hours of self-reported mouse use.

Table 4 Neck complaints due to computer use at work.

Neck complaints	Computer use (hours per week)[a]					
	none[b]	5 hours	10 hours	15 hours	20 hours	30 hours
Pooled incidence per year (%)	22.2	23.2	24.2	25.3	26.4	28.6
Additional incidence(%)		1.0	2.0	3.1	4.2	6.4
	Mouse use (hours per week)					
	none	5 hours	10 hours	15 hours	20 hours	30 hours
Pooled incidence per year (%)	22.2	23.4	24.7	26.1	27.4	30.3
Additional incidence(%)		1.3	2.6	3.9	5.3	8.1

[a] The risks were calculated for exposures falling within the ranges investigated in the studies.

[b] Pooled incidence of neck complaints based on groups of unexposed workers (no or minimal self-reported computer use) in various studies: 22.2%.

6.2 Shoulder complaints

For shoulder complaints, the Committee found significantly elevated risks associated with mouse use in a number of longitudinal studies as well as in the meta-analyses.[23-25,27,30] Tornqvist et al. (2009) found that thirty minutes to three hours of mouse use per day (self-reported) increased the risk of shoulder complaints by 62% (RR = 1.62; 95% CI 1.12-2.34).[30] Brandt et al. (2004) concluded that the risk of developing shoulder complaints was three times as high for thirty hours per week or more spent using a mouse (self-reporting) (RR = 3.3; 95% CI 1.2-8.9).[24] Registered mouse use for nine hours per week or more was also associated with shoulder complaints, according to the study by Andersen et al. (OR = 1.10; 95% CI 1.05-1.16). Computer and keyboard use were not associated with a significantly increased risk of shoulder complaints.[23]

The meta-analyses confirmed the findings from the individual studies: per ten hours of mouse use per week, the risk of shoulder complaints increased by 30% (pooled risk = 1.30; 95% CI 1.13-1.49). There was no significantly elevated risk for computer use.

In order to gain an impression of the degree to which computer use at work (recorded as self-reported computer and mouse use) affects the incidence of shoulder complaints in the Netherlands, the Committee subsequently calculated how many additional cases of workers with shoulder complaints (relatively) would develop due to computer use at work, based on the meta-analysis results. The calculations are based on: the pooled risk measure from the meta-analysis (see Chapter 5) and the data from the longitudinal studies on the incidence of shoulder complaints after one year of exposure. The durations of exposure used in these calculations fall within the observed exposure range for both studies.

Table 5 Shoulder complaints due to computer use at work.

Shoulder complaints[a]	Computer use (hours per week)[b]					
	none[c]	5 hours	10 hours	15 hours	20 hours	30 hours
Pooled incidence per year (%)	15.0	15.3	15.6	16.0	16.3	17.0
Additional incidence(%)		0.3	0.6	1.0	1.3	2.0
	Mouse use (hours per week)					
	none	5 hours	10 hours	15 hours	20 hours	30 hours
Pooled incidence per year (%)	15.0	16.7	18.7	20.7	23.0	27.9
Additional incidence(%)		1.7	3.7	5.7	8.0	12.9

[a] Pooled risk measure from the meta-analysis was not significant.
[b] The risks were calculated for exposures falling within the ranges investigated in the included studies.
[c] Pooled incidence of shoulder complaints based on groups of unexposed workers (no or minimal self-reported computer use) in various studies: 15.0%.

In order to also evaluate the consequences of the identified risks for the Dutch situation, the Committee searched for data on the incidence of shoulder complaints among the Dutch working population with minimal exposure to computer use at work (over the past twelve months). The Committee used the pooled incidence of shoulder complaints in the unexposed or low-exposed workers from the studies by Juul-Kristensen, Hagberg et al. and Tornqvist et al.[25,27,30]

These calculations show that the incidence of workers with shoulder complaints is 0.6% higher for ten hours of computer use (measured based on self-reported computer use, at the group level). If the degree of computer use is expressed as hours of mouse use, this results in a 3.7% increase in the incidence for ten hours of self-reported mouse use.

6.3 Arm and hand complaints

Both the longitudinal studies and the meta-analyses found significantly elevated risks for arm, elbow, wrist and hand complaints due to mouse, keyboard and computer use[25-27,29,30,32,33]. Tornqvist et al. found that half an hour per day or more spent using a mouse (self-reported) increased the risk of arm/hand complaints by 44% (RR = 1.44; 95% CI 1.01-2.05)[30]. The study by Lassen et al. showed that ten hours or more of keyboard use per week was associated with serious elbow complaints (OR = 2.49; 95% CI 1.08-6.53)[33]. IJmker et al. found that four or more hours per day (self-reported) of computer use doubled the risk of arm/hand complaints (RR = 1.9; 95% CI 1.1-3.1)[26]. The risk of carpal tunnel syndrome was only associated with mouse use[37]. More than twenty hours per

week spent using a mouse resulted in a two and a half times higher risk (OR = 2.6; 95% CI 1.2-5.5).

The highest pooled risk measures from the meta-analyses were those for hand/arm complaints. For ten hours per week of mouse use, the risk of such complaints was increased by 42% (pooled risk = 1.42; 95% CI 1.24-1.63), and for ten hours of keyboard use, it was increased by 18% (pooled risk = 1.08; 95% CI 1.08-1.29).

In order to gain an impression of the degree to which computer use at work (recorded as self-reported computer and mouse use) affects the incidence of hand/arm complaints in the Netherlands, the Committee subsequently calculated how many additional cases of workers with hand and arm complaints (relatively) would develop due to computer use at work, based on the meta-analysis results. The calculations are based on: the pooled risk measure from the meta-analysis (see Chapter 5) and the data from the longitudinal studies on the incidence of hand and arm complaints after one year of exposure. The durations of exposure used in these calculations fall within the observed exposure range for both studies.

In order to also evaluate the consequences of the identified risks for the Dutch situation, the Committee searched for data on the incidence of hand and arm complaints among the Dutch working population with minimal exposure to computer use at work (over the past 12 months). The Committee used the pooled incidence of hand and arm complaints in the unexposed workers from the studies by IJmker et al., Hagberg et al., Tornqvist et al. and Juul-Kristensen et al.[25-27,30]

Table 6 Hand and arm complaints due to computer use at work.

Hand/arm complaints	Computer use (hours per week)[a]					
	none[b]	5 hours	10 hours	15 hours	20 hours	30 hours
Pooled incidence per year (%)	13.6	14.6	15.6	16.8	17.9	20.5
Additional incidence(%)		1.0	2.0	3.2	4.3	6.9
	Mouse use (hours per week)					
	none	5 hours	10 hours	15 hours	20 hours	30 hours
Pooled incidence per year (%)	13.6	15.8	18.2	21.0	24.1	31.0
Additional incidence(%)		2.2	4.6	7.4	10.5	17.4

[a] The risks were calculated for exposures falling within the ranges investigated in the studies.

[b] Incidence of hand/arm complaints based on groups of unexposed employees (no or minimal self-reported computer use) in various studies: 13.6%.

These calculations show that the incidence of workers with hand and arm complaints is 2.0% higher for ten hours of computer use (measured based on self-reported computer use, at the group level). If the degree of computer use is expressed as hours of mouse use, this results in a 4.6% increase in the incidence for ten hours of self-reported mouse use.

6.4 Other health risks

Other than non-specific and specific upper limb complaints, the Committee also found some indications for other types of complaints due to computer use at work. More frequent eye complaints (dryness, glaucoma), psychological conditions and sleeping disorders have been reported among computer users (see Section 3.7). However, these complaints have been investigated far less thoroughly than musculoskeletal complaints. In all cases, the studies were cross-sectional in design, and only one study was available for psychological conditions and sleeping disorders.

Six cross-sectional studies examined eye complaints. These showed that, among employees who work behind a computer for several hours per day, prevalence of eye complaints was significantly (about 25%) higher[45,46]. Among students, computer use was also associated with significantly (16%) more cases of myopia [49].

6.5 Occuaptional exposure limits based on risk calculation

The Committee is of the opinion that in principle, the results of the meta-analysis allow health-based occupational exposure limits to be derived based on a risk calculation. This method entails calculating exposure levels based on predefined risks.

Determining the accepted additional risk

When performing a risk calculation, choices must be made regarding the adverse health effect and the accepted additional risk. For computer use at work, the health effects are pain in the shoulder, neck, hand/arm, and so forth. There is no 'fixed recipe' for what additional risk is accepted for these complaints. For comparable occupational health risks the Committee is aware of, the choice was made following extensive discussion. The Committee believes such discussion falls outside the scope of the current assignment. When determining the additional risk, the degree to which the health effect occurs in the working

population without there being exposure to computer use at work, should be taken into account.

Chapter 7

Conclusions

The Minister of Social Affairs and Employment asked the Health Council of the Netherlands to indicate whether there are *currently* new (international) scientific insights with regard to concrete occupational health-based or safety-based exposure limits for working behind a computer monitor, or whether any such scientific insights are *expected*. To answer the Minister's questions, the Committee studied data on the adverse health effects of this working posture. In this chapter, the Committee formulates its conclusions regarding the health risks of working behind a computer monitor and the possibilities it sees for recommending health-based occupational exposure limits.

7.1 Risks of computer use at work

The consequences of working behind a computer monitor have been studied extensively in the scientific literature. However, many of these studies have their limitations. Study designs vary, for example. Additionally, both exposure levels and health complaints in available research have often been recorded using self-report. Moreover, in many of the studies, there was concurrent exposure to other physical occupational risks. In order to minimise the risk of confounding of the association, the Committee decided to give the greatest weight to results from longitudinal studies.

The studies into the health effects due to computer use apply to the traditional computer workplaces of the past ten years. The current working environment is

changing, however. This includes changes regarding technology (such as the use of laptops, tablets and smartphones instead of traditional computer monitors) and changing work patterns. The Committee does not know to what degree the results of this advisory report also apply to modern (or future) working environments. However, the Committee did not find any data in the available literature to indicate these changes will result in different health risks. Studies among students, for whom the Committee assumes computer use is more variable, show similar health complaints as those seen among employees. Information on this topic is limited, however. The Committee is therefore of the opinion that more research is required into the health consequences of greater computer use diversity.

The available epidemiological studies and the meta-analyses performed lead the Committee to conclude that computer use at work leads to non-specific pain complaints in the neck, shoulders, arms, wrists and hands.

In addition to non-specific upper limb complaints, the scientific literature indicates associations between the development of eye complaints (dryness or glaucoma) and computer monitor or computer use. Furthermore, there is an indication that psychological complaints and sleeping disorders are more common among computer users.

The Committee is of the opinion that, based on available data, it is not possible to indicate a level of computer use that does not result in development of health complaints. By combining the results of the longitudinal studies, the Committee has been able to gain insight into the magnitude of the risks in terms of additional annual incidences.

7.2 Additional comments

7.2.1 Exposure

In most studies, the degree of computer use is quantified by measuring computer use, mouse use or keyboard use per week. These data were obtained via self-report in the studies included in the meta-analysis. The Committee wishes to point out that this method for estimating exposure has limitations. IJmker et al. (2011) investigated the difference between reported exposure and recorded exposure. Employees generally overestimate their computer use. Studies in which the degree of computer use is obtained via 'objective' estimates are scarce. For exposure recorded using (objective) software measurements, IJmker et al.

found no association between exposure and serious health complaints of the neck, shoulder and hand/arm, while these associations were found for exposure recorded via self-report. The Committee therefore doubts whether recording exposure via software registration encompasses all relevant aspects. Exposure quantified using self-report likely represents a general measure for work involving a computer.

However, the question is how this self-reported exposure can be translated into a practical standard. The Committee does see possibilities to do so, if it is assumed self-reported exposure is a measure for desk work including computer use. Tables 7 and 8 present self-reported exposure to mouse use or computer use. The Committee recommends using the most critical definition for exposure: self-reported mouse use.

Finally, the Committee would like to point out that the health risks were calculated for exposure measured in hours per week. Based on these data, it is impossible to examine the consequences of resting or different types of work on

Table 7 Incidence of complaints related to computer use (expressed as self-reported duration of work using a computer).

Computer use (hours/week)	Additional incidence of shoulder complaints (%)[a]	Additional incidence of neck complaints (%)[b]	Additional incidence of hand/arm complaints (%)[c]
None	0	0	0
5	0.3	1.0	1.0
10	0.6	2.0	2.0
15	1.0	3.1	3.2
20	1.3	4.2	4.3
30	2.0	6.4	6.9

[a] Pooled incidence of shoulder complaints in a group of unexposed employees 15.0%.
[b] Pooled incidence of neck complaints in a group of unexposed employees 22.2%.
[c] Pooled incidence of hand/arm complaints in a group of unexposed employees 13.6%.

Table 8 Incidence of complaints related to computer use (expressed as self-reported duration of work using a mouse).

Mouse use (hours/week)	Additional incidence of shoulder complaints (%)	Additional incidence of neck complaints (%)	Additional incidence of hand/arm complaints (%)
None	0	0	0
5	1.7	1.3	2.2
10	3.7	2.6	4.6
15	5.7	3.9	7.4
20	8.0	5.4	10.5
30	12.9	8.1	17.4

the health complaints. This also means the Committee cannot compare the calculated risks to the current standard (a maximum of two consecutive hours spent using a computer, alternated with rest periods or different types of work).

7.2.2 Health complaints

The key health complaints that develop after computer use are non-specific neck, shoulder and hand/arm complaints. Employees are asked to indicate whether they have experienced these health complaints during a specific period. These complaints are clearly acute adverse health effects. To what degree these complaints are transient or progress to chronic complaints is not asked in most studies. One study in a sample of the Dutch population shows that of the people with (moderate and severe) neck, shoulder or hand/arm pain, about one third indicate the complaints are chronic in nature.

7.2.3 Exposure-response relationship

Based on the meta-analyses performed, impressions were obtained of the relationships between exposure and response. These correlations were subsequently used to estimate the additional incidence of musculoskeletal complaints for various durations of computer and mouse use. It should be remembered that the additional incidence estimated is in part determined by the incidence in the general population that does not work with computers. These incidence figures are not available for the general Dutch population.

7.3 Recommendation

Based on available scientific evidence, the Committee cannot see any way to determine a level of traditional computer use below which no health effects occur, a so-called health-based recommended limit. The Committee was able to outline the consequences of computer use at work in this advisory report. Based on risk calculations, it should be possible to determine a health-based occupational exposure limit for computer use at work. However, this requires selection of an adverse health effect and the acceptable additional risk. In other words, a normative framework is required. In particular the decision of what additional risk of a specific adverse health effect is accepted, taking into account the prevalence and incidence of this health effect in the general population, requires social considerations.

Literatuur

1 Douwes M, Blatter BM, Kraker de H. Duur van computergebruik in het bankwezen: Tikken, Klikken en kijken. TNO Kwaliteit van Leven. 2011.

2 Meulen van der S, Settels P. Beeldschermwerk. Praktijkgids voor arbeidshygiënisten. Nederlandse Vereniging voor Arbeidshygiënisten. 2008.

3 Voskamp P, Peereboom K, van Scheijndel P. Handboek Ergonomie. Alphen aan den Rijn: Kluwer; 2008.

4 Tittiranonda P, Burastero S, Rempel D. Risk factors for musculoskeletal disorders among computer users. Occup Med 1999; 14(1): 17-38, iii.

5 IJmker S. Risk factors for arm-wrist-hand and neck-shoulder symptoms among office workers - A Longitudinal perspectieve. Proefschrift. Vrije Universiteit Amsterdam. 2008.

6 Eysink P.E.D., Blatter B.M., Gool van C.H., Gommer A.M., Bossche van der S, Hoeymans N. Ziektelast van ongunstige arbeidsomstandigheden in Nederland. Bilthoven: RIVM; 2007: Rapport 270012001.

7 Centraal Bureau voor de statistiek. 2011. Internet: http://www.cbs.nl.

8 Blatter BM BP. Duration of computer use and mouse use in relation to musculoskeletal disorders of neck or upper limb. Int J Industrial Ergonomics 30, 295-306. 2002.

9 Arbeidsomstandighedenbesluit. 2011. Internet: www.arbo.nl/wet-regelgeving.

10 The European Directive 90/270/EEC on the Minimum Health and Safety Requirements for Work and Display Screeen Equipment. European DIrective; 1990.

11 International Standard NEN-EN-ISO 9241: Ergonimische eisen voor kantoorarbeid met beeldschermen. 1997.

12 Registratierichtlijnen. 2011. Internet: http://www.beroepsziekten.nl/content/registratierichtlijnen.

13 Blatter B., Houtman I, Bossche van der S, Kraan K, Heuvel S. Gezondheidschade en kosten als gevolg van RSI en psychosociale arbeidsbelasting in NEderland. TNO Kwaliteit van Leven, editor. 2005.

14 Blehm C, Vishnu S, Khattak A, Mitra S, Yee RW. Computer vision syndrome: a review. Surv.Ophthalmol. 50[3], 253-262. 2005. Internet: PM:15850814.

15 Gerr F, Monteilh CP, Marcus M. Keyboard use and musculoskeletal outcomes among computer users. J.Occup.Rehabil. 16[3], 265-277. 2006. Internet: PM:16802184.

16 Griffiths KL, Mackey MG, Adamson BJ. The impact of a computerized work environment on professional occupational groups and behavioural and physiological risk factors for musculoskeletal symptoms: a literature review. J Occup Rehabil 2007; 17(4): 743-765.

17 IJmker S, Huysmans MA, Blatter BM, van der Beek AJ, van MW, Bongers PM. Should office workers spend fewer hours at their computer? A systematic review of the literature. Occup.Environ.Med. 64[4], 211-222. 2007. Internet: PM:17095550.

18 Nederlandse Vereniging voor arbeids- en bedrijfsgeneeskunde. Handelen van de bedrijfsarts bij het oogonderzoek bij beeldschermwerkers. 2001.

19 Punnet, Bergqvist U. Visual display unit work and upper extremity musculoskeletal disorder. National Institute for Working life. 1-160. 1997.

20 Thomsen JF, Gerr F, Atroshi I. Carpal tunnel syndrome and the use of computer mouse and keyboard: a systematic review. BMC.Musculoskelet.Disord. 9, 134. 2008. Internet: PM:18838001.

21 Thomson WD. Eye problems and visual display terminals--the facts and the fallacies. Ophthalmic.Physiol.Opt. 18[2], 111-119. 1998. Internet: PM:9692030.

22 Wahlstrom J. Ergonomics, musculoskeletal disorders and computer work. Occup.Med.(Lond) 55[3], 168-176. 2005. Internet: PM:15857896.

23 Andersen JH, Harhoff M, Grimstrup S, Vilstrup I, Lassen CF, Brandt LP et al. Computer mouse use predicts acute pain but not prolonged or chronic pain in the neck and shoulder. Occup.Environ.Med. 65[2], 126-131. 2008. Internet: PM:17681996.

24 Brandt LP, Andersen JH, Lassen CF, Kryger A, Overgaard E, Vilstrup I et al. Neck and shoulder symptoms and disorders among Danish computer workers. Scand.J.Work Environ.Health 30[5], 399-409. 2004. Internet: PM:15529803.

25 Hagberg M, Vilhemsson R, Tornqvist EW, Toomingas A. Incidence of self-reported reduced productivity owing to musculoskeletal symptoms: association with workplace and individual factors among computer users. Ergonomics 50[11], 1820-1834. 2007. Internet: PM:17972204.

26 IJmker S, Huysmans MA, van der Beek AJ, Knol DL, van MW, Bongers PM et al. Software-recorded and self-reported duration of computer use in relation to the onset of severe arm-wrist-hand pain and neck-shoulder pain. Occup.Environ.Med. 68[7], 502-509. 2011. Internet: PM:21045214.

27 Juul-Kristensen B, Sogaard K, Stroyer J, Jensen C. Computer users' risk factors for developing shoulder, elbow and back symptoms. Scand J Work Environ Health 2004; 30(5): 390-398.

28 Korhonen T, Ketola R, Toivonen R, Luukkonen R, Hakkanen M, Viikari-Juntura E. Work related and individual predictors for incident neck pain among office employees working with video display units. Occup Environ Med 2003; 60(7): 475-482.

29 Marcus M, Gerr F, Monteilh C, Ortiz DJ, Gentry E, Cohen S et al. A prospective study of computer users: II. Postural risk factors for musculoskeletal symptoms and disorders. Am J Ind Med 2002; 41(4): 236-249.

30 Tornqvist EW, Hagberg M, Hagman M, Risberg EH, Toomingas A. The influence of working conditions and individual factors on the incidence of neck and upper limb symptoms among professional computer users. Int.Arch.Occup.Environ.Health 82[6], 689-702. 2009. Internet: PM:19205721.

31 Zairina AR, Abdul SA. Prevalence of work-related upper limbs symptoms (WRULS) among office workers. Asia Pac J Public Health 2009; 21(3): 252-258.

32 Kryger AI, Andersen JH, Lassen CF, Brandt LP, Vilstrup I, Overgaard E et al. Does computer use pose an occupational hazard for forearm pain; from the NUDATA study. Occup Environ Med 2003; 60(11): e14.

33 Lassen CF, Mikkelsen S, Kryger AI, Brandt LP, Overgaard E, Thomsen JF et al. Elbow and wrist/ hand symptoms among 6,943 computer operators: a 1-year follow-up study (the NUDATA study). Am.J.Ind.Med. 46[5], 521-533. 2004. Internet: PM:15490472.

34 Walker-Bone K, Reading I, Coggon D, Cooper C, Palmer KT. Risk factors for specific upper limb disorders as compared with non-specific upper limb pain: assessing the utility of a structured examination schedule. Occup.Med.(Lond) 56[4], 243-250. 2006. Internet: PM:16627547.

35 Shuval K.D. Prevalence of upper extremity musculoskeletal symptoms and ergonomic risk at a Hi-Tech company in Israel. Int J Industrial Ergonomics 35, 569-581. 2005.

36 Atroshi I, Gummesson C, Ornstein E, Johnsson R, Ranstam J. Carpal tunnel syndrome and keyboard use at work: a population-based study. Arthritis Rheum. 56[11], 3620-3625. 2007. Internet: PM:17968917.

37 Andersen JH, Thomsen JF, Overgaard E, Lassen CF, Brandt LP, Vilstrup I et al. Computer use and carpal tunnel syndrome: a 1-year follow-up study. JAMA 2003; 289(22): 2963-2969.

38 Brink YC. The association between postural alignment and psychosocial factors to upper quadrant pain in high school students: A prospective study. Manual Therapy 2009; 14(6): December.

39 Chang CH, Amick BC, III, Menendez CC, Katz JN, Johnson PW, Robertson M et al. Daily computer usage correlated with undergraduate students' musculoskeletal symptoms. Am J Ind Med 2007; 50(6): 481-488.

40 Grimby-Ekman AA. Analyzing musculoskeletal neck pain, measured as present pain and periods of pain, with three different regression models: A cohort study. BMC Musculoskeletal Disorders 1973; 10(1): 73.

41 Menendez CCA. Computer use patterns associated with upper extremity musculoskeletal symptoms. Journal of Occupational Rehabilitation 2008; 18(2): Jun.

42 Palm PR. Computer use, neck and upper-extremity symptoms, eyestrain and headache among female and male upper secondary school students. Scandinavian Journal of Work, Environment and Health, Supplement 2007; 33(3): 2007.

43 Schlossberg EBM. Upper extremity pain and computer use among engineering graduate students. American Journal of Industrial Medicine 2004; 46(3): Sep.

44 Smith LL. Prevalence of neck pain and headaches: Impact of computer use and other associative factors. Cephalalgia 2009; 29(2): February.

45 Tatemichi M, Nakano T, Tanaka K, Hayashi T, Nawa T, Miyamoto T et al. Possible association between heavy computer users and glaucomatous visual field abnormalities: a cross sectional study in Japanese workers. J.Epidemiol.Community Health 58[12], 1021-1027. 2004. Internet: PM:15547065.

46 Uchino M, Schaumberg DA, Dogru M, Uchino Y, Fukagawa K, Shimmura S et al. Prevalence of dry eye disease among Japanese visual display terminal users. Ophthalmology 115[11], 1982-1988. 2008. Internet: PM:18708259.

47 Woods V. Musculoskeletal disorders and visual strain in intensive data processing workers. Occup.Med.(Lond) 55[2], 121-127. 2005. Internet: PM:15757986.

48 Ye Z, Honda S, Abe Y, Kusano Y, Takamura N, Imamura Y et al. Influence of work duration or physical symptoms on mental health among Japanese visual display terminal users. Ind.Health 45[2], 328-333. 2007. Internet: PM:17485878.

49 Khader YS, Batayha WQ, bdul-Aziz SM, Al-Shiekh-Khalil MI. Prevalence and risk indicators of myopia among schoolchildren in Amman, Jordan. East.Mediterr.Health.J. 12[3-4], 434-439. 2006. Internet: PM:17037714.

50 Yoshioka E, Saijo Y, Fukui T, Kawaharada M, Kishi R. Association between duration of daily visual display terminal work and insomnia among local government clerks in Japan. Am.J.Ind.Med. 51[2], 148-156. 2008. Internet: PM:18161872.

51 Heinrich J, Blatter BM, Bongers PM. A comparison of methods for the assessment of postural load and duration of computer use. Occup Environ Med 2004; 61(12): 1027-1031.

52 Beek AJ van der, Frings-Dresen MH. Assessment of mechanical exposure in ergonomic epidemiology. Occup Environ Med 1998; 55(5): 291-299.

53 Winkel J, Mathiassen SE. Assessment of physical work load in epidemiologic studies: concepts, issues and operational considerations. Ergonomics 1994; 37(6): 979-988.

54 Deeney C, O'Sullivan L. Work related psychosocial risks and musculoskeletal disorders: potential risk factors, causation and evaluation methods. Work 2009; 34(2): 239-248.

55 Gezondheidsraad. Calculating cancer risk: due to occupational exposure to genotoxic carcinogens = Berekening van het risico op kanker : door beroepsmatige blootstelling aan genotoxisch carcinogene stoffen. Den Haag: Gezondheidsraad; 1995: 1995/06WGD. Internet: www.gr.nl.

56 Gezondheidsraad. Leidraad berekening risicogetallen voor carcinogene stoffen. Den Haag: Gezondheidsraad; 2012: 2012/16.

57 Huisstede BM, Wijnhoven HA, Bierma-Zeinstra SM, Koes BW, Verhaar JA, Picavet S. Prevalence and characteristics of complaints of the arm, neck, and/or shoulder (CANS) in the open population. Clin J Pain 2008; 24(3): 253-259.

58 Picavet HS, Schouten JS. Musculoskeletal pain in the Netherlands: prevalences, consequences and risk groups, the DMC(3)-study. Pain 2003; 102(1-2): 167-178.

59 Hagberg M, Silverstein B., Wells R., Smith M.J., Hendrick H.W., Carayon P. et al. Taylor & Francis. Work relatted Musculoskeletal Disorders (WMSDs): A Reference Book for Prevention. London: 1995.

60 Thomsen JF, Gerr F, Atroshi I. Carpal tunnel syndrome and the use of computer mouse and keyboard: a systematic review. BMC Musculoskelet Disord 2008; 9: 134.

61 Gerr F, Marcus M, Monteilh C. Epidemiology of musculoskeletal disorders among computer users: lesson learned from the role of posture and keyboard use. J Electromyogr Kinesiol 2004; 14(1): 25-31.

Annexes

Annex **A**

Request for advice

In a letter dated 10 July 2007, reference number ARBO/A&V/2007/22676, the Minister of Social Affairs and Employment wrote to the President of the Health Council of the Netherlands:

On 26 September 2006, during deliberation in the Dutch House of Representatives of a bill to modify the Working Conditions Act, a motion by House members Koopmans and Stuurman was adopted[1]. This motion requests the government to promptly set up a work programme yielding health-based and safety-based limit values (regulations comprising concrete figures), to which end advice is to be requested of the government's social partners.

In the debate in the Dutch House of Representatives the former State Secretary for Social Affairs and Employment indicated, in reference to this motion, that it was not the government's intention to include an unbridled number of scientific limit values for every conceivable work risk in the Working Conditions Act. This would undermine the essential nature of the Act and run counter to the government's active policy of stimulating customisation in enterprises and sectors, reducing regulatory overhead, and slimming down Dutch supplements to European legislation on working conditions. During the debate the motion's proposers confirmed that it was not their intention that the motion lead to an unbridled number of new concrete regulations in the legislation and regulation, but that the motion would help to support, facilitate and curtail that which the government specified in a working programme.

In a letter of 18 January 2007 to the Dutch House of Representatives on the status of the Working Conditions Act, a proposal was made for the further elaboration of the motion. During its General Consultations of 7 February 2007 the Dutch House of Representatives made no remarks on this elaboration, but it did indicate that it wished to be informed on the different phases sketched therein:

- a committee shall be established within an independent scientific institute, which can survey the scientific domain of working conditions
- this committee shall provide periodic reports of any new (international) scientific insights into concrete health-based or safety-based limit values
- on the basis of the results of these reports the Ministry of Social Affairs and Employment can initiate, where appropriate, further scientific research into health-based and / or safety-based limit values
- the Ministry of Social Affairs and Employment will then assess the need for and desirability of including a limit value (as a concrete regulatory paragraph) in the Working Conditions Act and associated regulations. The department will hereby observe the provisions given in the Explanatory Memorandum on the Working Conditions Act, which stipulate that scientific limit values will be included in the legislation and regulation if these are generally recognised, have broad social support, and are generally applicable
- the Ministry of Social Affairs and Employment will then present its opinion on the inclusion or otherwise of a limit value in the Working Conditions Act and associated regulations to the Social and Economic Council of the Netherlands (SER) for advice
- on the basis of the advice put forward by the SER, a decision will be taken on whether to actually adopt the limit value in the Working Conditions Act and its associated regulations.

In accordance with the stipulations of the motion, consultations have been held with the government's social partners. It is important that the evaluation of the revision of the Working Conditions Act can be sent to the Dutch House of Representatives within five years of the coming into force of the amendment of the law – that is to say, before 1 January 2012. This evaluation must comprise a report on the practical effects and efficacy of the Working Conditions Act.

On 21 February 2007 we consulted on the possibility of the Health Council establishing a committee comprising experts on working conditions, health, safety, and occupational disease, and the Health Council indicated its willingness to establish such a committee. I therefore request that you establish a committee for the purposes of surveying the scientific domain of working conditions and examining the following subjects:

1 periodic reports on whether *at this moment* new (international) scientific insights exist with regard to concrete health-based and / or safety-based limit values
2 periodic reports on whether *in due course* new (international) scientific insights may be expected with regard to concrete health-based and / or safety-based limit values.

The focus shall be on the first part, periodic reports of current new (international) scientific insights into concrete health-based and / or safety-based limit values. In the first instance, these reports will be based on those working condition risks included in the Working Conditions Act and its associated regulations. Other risks may be taken into consideration at a later date.

Please initiate the establishment of the committee and a Plan of Approach for the period 2007 to 2012, which should include reference to all the subjects mentioned above and comprise a budget. I should like to receive the Plan of Approach before next 1 September. The Health Council's Plan of Approach requires the approval of the Ministry of Social Affairs and Employment.

With regard to the periodicity of reporting, I would consider it important to publish an annual report. With this in mind I look forward to receiving the first of these annual reports before the end of 2007.

Yours sincerely,
The Minister of Social Affairs and Employment,
(signed)
J.P.H. Donner

Annex **B**

The Committee

- Professor T. Smid, *chairman*
  Endowed Professor of Working Conditions, VU Medical Center, Amsterdam and working conditions advisor, KLM Health Services, Schiphol-East
- Professor A.J. van der Beek
  Professor of Epidemiology of Work and Health, EMGO Institute, VU Medical Center, Amsterdam
- Professor A. Burdorf
  Professor of Occupational Epidemiology, Erasmus MC, Rotterdam
- Professor M.H.W. Frings-Dresen
  Professor of Occupational Health, Coronel Institute for Work and Health, AMC, Amsterdam
- Professor D.J.J. Heederik
  Professor of Health Risk Analysis, Institute for Risk Assessment Sciences, Utrecht
- Professor J.J.L. van der Klink
  Professor of Social Medicine, Work and Health, UMC, Groningen
- Dr. T. Spee
  Occupational Hygiene policy advisor, the Arbouw Foundation, Amsterdam
- J. van der Wal
  Health and Safety manager, Nederlandse Aardolie Maatschappij (NAM) BV, Assen

- H.J. van der Brugge, *observer*
  Ministry of Social Affairs and Employment, The Hague
- dr. P.C. Noordam, *observer*
  senior advisor, Labour inspectorate, The Hague
- Dr. A.S.A.M. van der Burght, *scientific secretary*
  Health Council of the Netherlands, The Hague
- Dr. V. Gouttebarge, *scientific secretary*
  Health Council of the Netherlands, The Hague

The Committee established the Working Group *Physical occupational risks* for the purpose of preparing the advisory report. The Working Group was composed of the following experts:
- Professor A. Burdorf, *chairman*
- Professor A.J. van der Beek
- Professor M.H.W. Frings-Dresen
- Professor J.H. van Dieën
  Professor of Biomechanics, VU University, Amsterdam
- Dr. A.S.A.M. van der Burght, *scientific secretary*
- Dr. V. Gouttebarge, *scientific secretary*

The Health Council and interests

Members of Health Council Committees are appointed in a personal capacity because of their special expertise in the matters to be addressed. Nonetheless, it is precisely because of this expertise that they may also have interests. This in itself does not necessarily present an obstacle for membership of a Health Council Committee. Transparency regarding possible conflicts of interest is nonetheless important, both for the chairperson and members of a Committee and for the President of the Health Council. On being invited to join a Committee, members are asked to submit a form detailing the functions they hold and any other material and immaterial interests which could be relevant for the Committee's work. It is the responsibility of the President of the Health Council to assess whether the interests indicated constitute grounds for non-appointment. An advisorship will then sometimes make it possible to exploit the expertise of the specialist involved. During the inaugural meeting the declarations issued are discussed, so that all members of the Committee are aware of each other's possible interests.

Annex C

Comments on the draft advisory report

In July 2012, the President of the Health Council of the Netherlands released a draft of this advisory report for a round of public commentary. The following individuals and institutions responded to the draft advisory report:

- Mr. van Eijk, OCÉ Technologies B.V., Venlo
- Ms. Schreibers and Ms. Blom, ErgoS Engineering & Ergonomics, Enschede

The Committee integrated the comments in the finalisation of its advisory report.

Annex **D**

Broad literature exploration into computer use at work

For the purpose of this advisory report, initially, a broad literature exploration was conducted in order to gain insight into recent developments surrounding the development of health-related and safety-related problems due to computer use. This literature exploration was the starting point for the systematic literature review, which was used to garner new scientific insights into possible adverse short-term or long-term effects of computer use on health and/or safety.

1 Goal and method

The goal of this literature exploration was to obtain an overview of and insight into recent developments regarding the occurrence of health and safety issues relating to computer use at work. To this end, recent review articles were consulted exclusively, preferably review articles published in peer-reviewed journals. Where possible, the Committee also made use of books and/or reports from renowned national and international advisory bodies and research institutes.

2 Overview of findings

In an extensive literature review published in 1997, Punnet and Bergqvist searched for studies examining the relationship between computer use and neck and upper limb complaints. The authors identified 56 epidemiological studies

published primarily in peer-reviewed journals.[19] These various studies showed that employees who used a computer all day were about two to three times more likely to develop upper limb complaints than employees who did not work with computers. An overview of the findings of this review is presented in table 9.

Many literature reviews have recently been published on the incidence of health complaints due to computer use. Gerr et al. wrote a literature review in 2006 based on epidemiological studies into the health effects of computer use.[15] Eleven of the 39 included studies found a statistically significant association ($p<0.05$) between keyboard use and shoulder/neck complaints, and 14 studies found a statistically significant association ($p<0.05$) between keyboard use and hand/arm complaints.

Table 9 Literature review by Punnet and Bergqvist (1997).[19]

Task/Activity	Type of complaints	Measure of association
Computer use all day	hand/wrist	OR 2.8 (95% CI 1.6 - 4.9)
Computer use all day	arm/elbow	OR 2.0 (95% CI 1.2 - 3.6)
Computer use all day	shoulder/neck	OR 1.7 (95% CI 1.1 - 2.6)
< 3 years of computer use	hand/arm	OR 1.9 (95% CI 0.7 - 5.2)
< 3 years of computer use	shoulder/neck	OR 4.1 (95% CI 1.5 - 11.2)
4-6 years of computer use	hand/arm	OR 1.9 (95% CI 0.7 - 5.3)
4-6 years of computer use	shoulder/neck	OR 5.6 (95% CI 2.0 - 15.7)
> 6 years of computer use	hand/arm	OR 3.9 (95% CI 1.2 - 12.0)
> 6 years of computer use	shoulder/neck	OR 4.3 (95% CI 1.4 - 13.6)
>4 hours per day of computer use	shoulder	OR 1.3 (95% CI 0.5 - 3.8)
>4 hours per day of computer use	neck	OR 10.3 (95% CI 2.4 - 43.3)
>4 hours per day of computer use	arm/elbow	PR 2.0 (95% CI 1.2 - 3.7)
>4 hours per day of computer use	shoulder/neck	PR 2.4 (95% CI 1.0 - 6.0)
Keyboard use 40-59% per day	neck	OR 2.6 (95% CI 1.4 - 5.0)
Keyboard use 40-59% per day	arm/elbow	OR 1.7 (95% CI 0.8 - 3.5)
Keyboard use 60-79% per day	neck	OR 2.2 (95% CI 1.0 - 4.7)
Keyboard use 60-79% per day	arm/elbow	OR 1.9 (95% CI 0.9 - 4.3)
Keyboard use 80-100% per day	neck	OR 2.8 (95% CI 1.4 - 5.7)
Keyboard use 80-100% per day	arm/elbow	OR 2.8 (95% CI 1.4 - 5.7)
> 5.6 hours of mouse use per day	left elbow	OR 4.3 (95% CI 1.4 - 13.0)
> 5.6 hours of mouse use per day	right elbow	OR 2.0 (95% CI 1.0 - 4.1)
> 5.6 hours of mouse use per day	left wrist	OR 3.4 (95% CI 1.1 - 11.0)
> 5.6 hours of mouse use per day	right wrist	OR 2.0 (95% CI 1.0 - 4.3)
> 5.6 hours of mouse use per day	left hand	OR 2.6 (95% CI 1.0 - 6.8)
> 5.6 hours of mouse use per day	right hand	OR 3.1 (95% CI 1.5 - 6.6)

OR, odds ratio; PR, prevalence ratio

In 2005, based on a literature review, Wahlström concluded that the duration of computer use was a risk factor for hand, wrist, arm, shoulder and neck complaints (without mentioning measures of association), with stronger evidence available for hand/arm complaints than for neck complaints[22].

In a systematic review, IJmker et al. (2007) searched for relevant articles on the association between computer use and hand, wrist, arm, shoulder and neck complaints[17].Based on a systematic search strategy in seven databases, and after application of inclusion and quality criteria, five cohort studies were finally included, which showed there was a positive relationship between computer use and the occurrence of hand, arm, shoulder and/or neck complaints. In one of the five studies, the measure of association (odds ratio) between computer or mouse use and neck complaints varied from 1.3 (95% CI 0.6-2.7) to 1.7 (95% CI 0.5-5.7), with the highest odds ratio found for mouse use during at least 50% of the working day. The same study found an association (odds ratio) between computer and/or mouse use and hand/wrist complaints that varied from 2.0 (95% CI 1.1-1.9) to 4.0 (95% CI 1.0-15.5), with the highest odds ratio for mouse use during at least 50% of the working day. This review also showed that the measure of association (odds ratio) between mouse and keyboard use and elbow complaints varied from 1.4 (95% CI 0.5-3.6) to 6.9 (95% CI 2.2-22.5). For example, employees were almost twice as likely to develop elbow complaints if they used a mouse for 10 to 15 hours per week than if they used one for less than 10 hours per week, and almost three times as likely to develop elbow complaints if they used a keyboard for 15 to 20 hours per week, compared to less than 15 hours per week. The association (odds ratio) between mouse and keyboard use and hand/wrist complaints turned out to vary from 1.4 (95% CI 0.6-3.0) to 4.8 (95% CI 2.1-10.9), with the highest odds ratio for mouse use during 20 to 25 hours per week versus less than 20 hours per week.

In 2007, Griffiths et al. provided a broad overview of the literature on potential health risks associated with computer use[16]. This review describes a number of epidemiological studies that showed that the duration of computer use was a risk factor for the development of musculoskeletal complaints. Employees were over twice as likely to develop hand/wrist complaints if they used a keyboard for longer than six hours per day, compared to employees who used one for less than six hours (OR = 1.9; 95% CI 1.6-2.3). Another study included in this review indicated that employees were four times as likely to develop neck/shoulder complaints if they used a keyboard for over four hours per day. There was also a statistically significant association between over five hours of computer monitor use and the occurrence of neck/shoulder complaints.

In 2008, Thomsen et al. published a literature review on the occurrence of carpal tunnel syndrome (CTS) due to computer use.[60] Using a systematic search strategy in four databases in epidemiological literature spanning 1966 to 2008, and after application of a number of inclusion and exclusion criteria, eight studies were finally included. Half of the studies found a positive association between computer use and CTS (OR between 2.1; 95% CI 1.3-3.6 and 4.4; 95% CI 1.3-14.9), with the highest odds ratio for keyboard use for more versus less than twelve hours per day. Other studies found that this relationship was negative (OR = 0.8; 95% CI 0.5-1.4). The conclusion of this literature review was that there was insufficient epidemiological evidence to establish computer use as a risk factor for CTS.

In addition to the occurrence of neck and upper limb complaints, computer use may also cause eye complaints. In 1998, Thomson concluded that eye complaints occurred in at least 50% of people using computers at work[21]. In 2005, Blehm et al. provided an overview of the literature published between 1970 and 2004 on the development of eye complaints due to computer use[14]. This review showed that computer users may develop a variety of eye complaints, such as irritation and eye fatigue, or blurred vision. In 2001, the Netherlands Society of Occupational Medicine published a guideline on eye testing for computer users, because "*computer use can lead to reversible eye complaints and fatigue, such as 'burning eyes'*".

3 Conclusion of the literature exploration

Many scientific literature reviews have recently been published on the development of health-related and safety-related problems due to computer use. Based on these literature reviews, the Committee can draw the following conclusions:

- exposure to computer use can be associated with an increased risk of health damage, particularly neck complaints and upper limb complaints, but also eye complaints
- in general, employees who use a computer for the entire work day are about two and a half times more likely to develop neck complaints and upper limb complaints
- employees who spend over four hours per day using a computer for work are about ten times more likely to develop neck complaints than employees who use a computer for less than four hours per day

- employees who use a keyboard for over 50% of the working day have a two to three times higher risk of neck complaints and upper limb complaints compared to employees who use a keyboard for less than 50% of the working day
- employees who use a mouse for over 50% of the working day have a two to four times higher risk of neck complaints and upper limb complaints compared to employees who use a mouse for less than 50% of the working day
- employees who spend over twenty hours per week using a mouse have an almost five times higher risk of hand/wrist complaints than employees who use a mouse for less than twenty hours per week.

This broad exploration of recently published literature delivered strong evidence that exposure to computer use increases the risk of neck complaints and upper limb complaints.

Annex **E**

Systematic literature review

The goal of the systematic literature review was to systematically obtain scientific data from epidemiological studies on the relationship between computer use at work and the development of health-related and safety-related problems. As many literature reviews found in the board literature exploration were published before or in 2007, the Committee limited its search during the systematic literature review to publications published in the past five years (from 2004).

1 Question

The following questions were formulated for this systematic literature review:

a What health-related and safety-related problems develop due to the occupational risk computer use?
b To what degree is exposure (in terms of duration, frequency and/or intensity) to the occupational risk computer use related to these problems?

2 Databases searched

With the search terms used in this literature review, the international databases Medline (via PubMed), PsycINFO (via Ovid) and Embase (via Ovid) were searched for English and Dutch language literature published between January 2004 and August 2009.

3 Search terms

For the occupational risk computer use, terms relating to the concepts *computer use*, *work-related*, *students* and *health effects* were searched for.

4 Search strategy

Medline search strategy

#1= computer use*[tiab] OR "video display terminal"[tiab] OR VDT[tiab] OR "visual display unit"[tiab] OR VDU[tiab] OR computer terminals[MeSH] OR mouse use*[tiab] OR keyboard use*[tiab]

#2= work-related[tw] OR occupations[MeSH] OR occupational exposure[MeSH] OR occupation*[tw] OR work[MeSH] OR workplace[MeSH] OR work*[tw] OR vocation*[tw] OR job[tw] OR employment[MeSH] OR industr*[tw] OR business[tw] OR profession*[tw] OR trade*[tw] OR enterprise*[tw]

#3= student[MeSH]

#4= "health effects"[tw] OR occupational health[MeSH] OR occupational diseases[MeSH] OR musculoskeletal diseases[MeSH] OR "occupational risk factor"[tw] OR safety[MeSH] OR safet*[tw] OR safety management[MeSH] OR risk management[MeSH] OR sprains and strains[MeSH] OR wounds and injuries[MeSH] OR health[tw] OR disorder[tw] OR disorders[tw] OR syndrome[tw] OR disease[tw] OR diseases[tw] OR wounds[tw] OR injuries[tw] OR injury[tw] OR sprains[tw] OR strains[tw] OR pain[tw] OR discomfort[tw] OR risk[MeSH]

#5 (students) = #1 AND #2 AND 3#

#6 (employees) = #1 AND #2 AND 4#

PsycINFO and Embase search strategy

#1= "computer use$".ti,ab OR "video display terminal".ti,ab OR VDT.ti,ab OR "visual display unit".ti,ab OR VDU.ti,ab OR "mouse use$".ti,ab OR "keyboard use$".ti,ab

#2= work-related OR occupation$ OR work$ OR vocation$ OR job OR industr$ OR business OR profession$ OR trade$ OR enterprise$

#3= student$.ti,ab

#4= "health effects" OR "occupational risk factor" OR safet$ OR health OR disorder OR disorders OR syndrome OR disease OR diseases OR wounds OR injuries OR injury OR sprains OR strains OR pain OR discomfort

#5 (students) = #1 AND #2 AND 3#

#6 (employees) = #1 AND #2 AND 4#

5 Inclusion and exclusion criteria

In order to include articles from the results of the search strategy, the following inclusion criteria were applied:

- the study describes the degree of exposure to the occupational risk computer use
- and the study describes short-term and/or long-term health and/or safety effects due to the occupational risk computer use
- and the study describes a degree of association between the occupational risk computer use and the development of adverse health effects in terms of relative risk, attributive risk, prevalence ratio or odds ratio.

6 Selection procedures

After the search strategy was performed in the various databases, the inclusion criteria were applied to titles and abstracts of the various studies found. If there were doubts about the inclusion or exclusion of a study based on title and abstract, it was included. The full text of the included titles and abstracts was requested and the inclusion criteria were subsequently applied to the full text of the articles. In the event of doubt about inclusion or exclusion of a study, an expert was consulted. Additionally, the reference lists of all included articles and any reviews were screened. Finally, the reference list of all included articles was submitted to four experts with the question of whether additional studies should be added.

7 Additional literature

Given the similarity between this exercise and the systematic literature review performed by IJmker et al. in 2007, the studies published prior to 2004 included in that review were included in the literature review for this advisory report.

8 Data extraction

Data extraction for included studies was classified in a standardised table listing the following information:

- 1st column: first author and year of publication
- 2nd column: study population (number, age, gender, profession, country)
- 3rd column: study design, definition of reference group used and any confounders

- 4th column: method used to measure exposure to the occupational risk and health effects
- 5th column: occupational risk's effect on health or safety
- 6th column: degree of association between occupational risk and effect on health or safety.

9 Quality description

The quality of the included studies (for studies among employees) was described based on four criteria drafted based on existing and accepted sources (IJmker et al. 2007, Von Elm et al. 2007; Dutch Cochrane Centre 2008). These four criteria were applied to the included studies independently by two people, with consensus being sought in case of doubt or disagreement between the two. The quality criteria are listed in table 10.

Tabel 10 Kwaliteitscriteria.

1	*Study population*
+	An appropriate definition and description (eligibility criteria, methods of selection and possible selection bias) of the subject groups involved in the study is clearly stated.
-	An appropriate definition and description (eligibility criteria, methods of selection and possible selection bias) of the subject groups involved in the study is *not* given.
?	Unclear information.
2	*Outcome*
+	The outcome of interest is clearly defined and assessed with standardized instrument(s) of acceptable quality (reliability and validity).
-	The outcome of interest is *not* clearly defined and *not* assessed with standardized instrument(s) of acceptable quality (reliability and validity).
?	Unclear information or other.
3	*Statistical analyses*
+	The statistical analyses applied are appropriated to the outcome studied.
-	The statistical analyses applied are *not* appropriated to the outcome studied.
?	Unclear information.
4	*Results*
+	Risk estimates, adjusted for age and sex, and their precision are reported.
-	Risk estimates, adjusted for age and sex, and their precision are *not* reported.
?	Unclear information.

10 Results of the search strategy for computer use among students

The previously mentioned search strategy for computer use among students was performed in the three databases on 21 January 2010. This search strategy yielded 35 PubMed hits, 21 hits in PsycINFO and 33 in Embase. After removal of six duplicate results, the inclusion criteria were applied to titles and abstracts. During this selection step, 63 abstracts turned out not to meet the inclusion criteria, resulting in 20 full-text articles being included for the final selection stage. After this final selection, seven studies remained[38-44], including one study added by the experts[39]. The studies examining upper limb complaints (arm, neck and/or shoulder complaints) were integrated in an extraction table (see Annex G): three longitudinal and four cross-sectional studies.

11 Results of the search strategy for computer use among employees

The previously mentioned search strategy for computer use among employees was performed in Pubmed and PsycINFO on 26 August 2009, yielding a total of 297 hits (232 and 65 hits, respectively). After removing 39 duplicate results, 258 titles were reviewed based on the inclusion criteria. The search strategy was performed later in Embase (22 October 2009) and yielded 201 hits, including 173 duplicates.

A total of 325 titles were reviewed based on the inclusion criteria. During the first selection step, 196 titles were excluded and 129 were included, with the abstracts of the latter being taken to the next selection step. During this selection step, 81 abstracts turned out not to meet the inclusion criteria, resulting in 48 full-text articles being included for the final selection stage. After this final selection, 17 articles were included, including 3 reviews (31 were excluded). Consultation of the four experts yielded two additional studies, and the reference check of the reviews yielded three more. The literature review by IJmker et al. (2007) yielded four original studies. Of the 26 included studies, 15 used upper limb complaints (arm, neck and/or shoulder complaints) as outcome measure. The data from the 15 original studies were included in an extraction table (see Annex F).

12 Results of the quality description of computer use among employees

The quality of the 17 included original studies from the search strategy was described based on the 5 quality criteria. In 11 of the 17 included studies, upper limb complaints (arm, neck and/or shoulder complaints) were used as outcome measure. Table 11 provides an overview of the quality description for these 11

studies. As can be seen in table 10, 4 of the 11 original studies were cross-sectional in design, and 7 were longitudinal. Exposure to computer use at work was measured via self-reporting in six of the seven longitudinal studies, as was the health outcome.

Table 11 Quality description of the 11 original studies with upper limb complaints (arm, neck and/or shoulder complaints) as outcome measure.

Author	Subject	Population	Exposure	Outcome	Statistical analysis	Results
Andersen	longitudinal	+	m	?	+	+
Atroshi	cross-sectional	?	s	+	+	+
Brandt	longitudinal	+	s	+	+	?
Hagberg	longitudinal	+	s	+	+	+
IJmker	longitudinal	+	s	?	+	+
Juul Kristensen	longitudinal	+	s	?	+	+
Lassen	longitudinal	?	s	?	+	+
Rahman	cross-sectional	+	s	+	+	+
Shuval	cross-sectional	?	s	+	+	+
Tornqvist	longitudinal	+	s	?	+	?
Walker-Bone	cross-sectional	?	s	+	+	+

Exposure: s, self-reported, m, measured.

Annex **F**

Extraction table computer use at work

Author	Study population	Study design	Measurement methods	Health effect	Degree of association
Andersen et al. 2008[23]	N = 2146 G = 561 men;1585 women A = 42 y (sd=8) O = 75% technical assistant C = Denmark (NUDATA-study)	Prospective cohort study (1 year) Ref = unexposed or minimal exposed group (<2.1h per week & <160h per year for mouse use; 0.4h per week & <30h per year for keyboard use; N = 1597-1844) Conf =sex, age, gender, seniority	Exp = Work Pace Recorder HEf = self-reported questionnaire (eight categories, from no pain to very severe pain), every week	1. Neck pain 2. Prolonged neck pain 3. Shoulder pain 4. Prolonged shoulder pain 5. Chronic neck pain 6. Chronic shoulder pain *Pain:* pain within the last 7 days (<4 weeks = prolonged; >30 days with quite a lot of trouble = chronic) Incidence acute severe pain in any week: neck: men 6.3%; women 9.1% shoulder: men 9.8%; women 10.2%	- Mouse use: D ≥9h per week 1. OR = 1.04 (CI 1.00-1.09) 2. HR = 1.01 (CI 0.97-1.06) 3. OR = 1.10 (CI 1.05-1.16) 4. HR = 1.02 (CI 0.96-1.08) - Keyboard use: D ≥1.7h per week 1. OR = 1.01 (CI 0.98-1.03) 2. HR = 1.08 (CI 0.80-1.47) 3. OR = 1.01 (CI 0.98-1.04) 4. HR = 0.87 (CI 0.60-1.26) - Mouse use: D ≥413h per year 5. OR = 0.77 (CI 0.55-1.07) 6. OR = 1.11 (CI 0.86-1.44) - Keyboard use: D ≥80h per year 5. OR = 1.05 (CI 0.74-1.51) 6. OR = 0.91 (CI 0.68-1.21)

				Incidence prolonged pain in any week: neck: men 0.21%; women 0.34% shoulder: men 0.15%; women 0.26% Incidence chronic pain in one year: neck: men 1.75%; women 2.13% shoulder: men 1.89%; women 2.5%	
Andersen et al. 2003[37]	N = 5658 G = 2042 men; 3616 women A = 42 y (sd=9) O = technical assistants and machine assistants C = Denmark (NUDATA-study)	Prospective cohort study (1 year) Ref = unexposed or minimal exposed group (N = 1279) Conf =personal and psychosocial factors	Exp = self-reported questionnaire (hours spent per week using a computer, mouse device and keyboard); at baseline and one year follow-up HEf = self-reported questionnaire (five categories from no to daily symptoms); at baseline and one year follow-up; clinical examination	Carpal tunnel syndrome *Symptom*: any tingling or numbness in the fingers at least once a week or daily within the last three months Incidence of new or worsened more frequent CTS symptoms 5.5% Incidence of symptoms median nerve 1.2%	-Mouse use right hand: D 2.5- <5 h per week OR = 0.7 (CI 0.3-1.9) -Mouse use right hand: D 5- <10 h per week OR = 1.9 (CI 0.9-4.0) -Mouse use right hand: D 10- <15 h per week OR = 1.6 (CI 0.8-3.3) -Mouse use right hand: D 15- <20 h per week OR = 2.0 (CI 0.9-4.2) -Mouse use right hand: D 20- <25 h per week OR = 2.6 (CI 1.2-5.5) -Mouse use right hand: D 25- <30 h per week OR = 3.2 (CI 1.3-7.9) -Mouse use right hand: D ≥30 h per week OR = 2.7 (CI 1.0-7.6) Keyboard use: D 2.5- <5 h per week OR = 0.9 (CI 0.4-1.8) Keyboard use: D 5- <10 h per week OR = 0.8 (CI 0.4-1.5)

					Keyboard use: D 10- <15 h per week OR = 1.2 (CI 0.6-2.5) Keyboard use: D 15- <20 h per week OR = 0.8 (CI 0.4-1.5) Keyboard use: D ≥20 h per week OR = 1.4 (CI 0.5-4.3)
Atroshi et al. 2007[36]	N = 2003 G = 925 men; 1078 women A = men 46 y (sd=12); women 45 y (sd=12) O = various C = Sweden	Cross-sectional within prospective cohort study (5 years) Ref = unexposed group (N = 636) Conf = age, sex, body mass index	Exp = self-reported questionnaire (average daily exposure duration; five categories, from none to >6 hours) HEf = self-reported questionnaire, clinical examination and nerve conduction test	Carpal tunnel syndrome *Symptom*: hand numbness or tingling in the median nerve distribution during the preceding four weeks	- Keyboard use: D <1h per day PR = 0.93 (CI 0.52-1.7) - Keyboard use: D 1-<4h per day PR = 0.55 (CI 0.26-1.2) - Keyboard use: D ≥4h per day PR = 0.52 (CI 0.23-1.2)
Brandt et al. 2004[24]	N = 5658 G = 2093 men, 3564 women A = 41.3 y (sd=9.0) O = technical assistants and machine technicians C = Denmark (NUDATA-study)	Prospective cohort study (1 year) Ref = unexposed or minimal exposed group Conf = personal characteristics, work and psychosocial factors	Exp = self-reported questionnaire (average weekly exposure duration during the last 4 weeks), at baseline and one year follow-up HEf = self-reported questionnaire (8 categories, from no pain to very severe pain), at baseline and one year follow-up; physical examination and nerve conduction tests	1. Neck symptoms 2. Right shoulder symptoms *Symptoms:* pain or discomfort during the previous 7 days and 12 months Prevalence of symptoms at baseline: neck 10.6% shoulder 7.6% Incidence of symptoms at one year follow-up: neck 1.5% shoulder 1.9%	- Work with mouse: D 2.5-4h per week 1. PRR = 1.0 (CI 0.6-1.5) 2. PRR = 1.0 (CI 0.6-1.7) - Work with mouse: D 5-9h per week 1. PRR = 1.2 (CI 0.9-1.8) 2. PRR = 1.7 (CI 1.1-2.5) - Work with mouse: D 10-14h per week 1. PRR = 1.1 (CI 0.8-1.5) 2. PRR = 1.4 (CI 0.9-2.1) - Work with mouse: D 15-19h per week 1. PRR = 1.4 (CI 0.98-1.9) 2. PRR = 1.6 (CI 1.1-2.4) - Work with mouse: D 20-24h per week 1. PRR = 1.3 (CI 0.9-1.9) 2. PRR = 1.7 (CI 1.1-2.6) - Work with mouse: D 25-29h per week 1. PRR = 1.7 (CI 1.1-2.6) 2. PRR = 2.6 (CI 1.6-4.2)

- Work with mouse: D ≥30h per week
1. PRR = 1.8 (CI 1.1-2.9)
2. PRR = 2.5 (CI 1.4-4.3)

- Work with keyboard: D ≥20h per week
1. PRR = 1.2 (CI 0.7-1.9)
2. PRR = 1.3 (CI 0.7-2.4)

Risk for new symptom case
- Work with mouse: D 10-19h per week
1. RR = 1.1 (CI 0.6-1.9)
2. RR = 1.2 (CI 0.7-2.1)

- Work with mouse: D 20-29h per week
1. RR = 0.9 (CI 0.4-1.9)
2. RR = 1.9 (CI 1.0-3.5)

- Work with mouse: D ≥30h per week
1. RR = 2.4 (CI 0.8-6.8)
2. RR = 3.3 (CI 1.2-8.9)

- Work with keyboard: D 5-9h per week
1. RR = 1.1 (CI 0.5-2.2)
2. RR = 1.3 (CI 0.7-2.6)

- Work with keyboard: D 10-14h per week
1. RR = 1.0 (CI 0.4-2.2)
2. RR = 1.6 (CI 0.8-3.3)

- Work with keyboard: D ≥15h per week
1. RR = 1.8 (CI 0.8-3.9)
2. RR = 2.2 (CI 1.0-4.9)

Hagberg et al. 2007[25] (see also Tornqvist et al. 2009)	N = 1039 G = 449 men; 590 women A = ? O = computer users in various sectors (management, administration, engineering) C = Sweden	Prospective cohort study (10 months) Ref = unexposed or minimal exposed group (N = 201-698) Conf = sex, age	Exp =self-reported questionnaire partly validated and ergonomic observation (exposure duration) HEf = monthly self-reported questionnaire partly validated and medical examination of incident cases	1. Neck symptoms 2. Back symptoms 3. Shoulder symptoms 4. Forearm/hand symptoms *Symptoms:* pain or stiffness for at least 3 days duration in the preceding month in any of the body regions asked for. Incidence of self-reported reduced productivity per 100 person months: neck 0.92 shoulder 0.40 arm/hand 0.54 (incidence of symptoms resp. 6.1, 8.5 and 7.2 times higher)	- Computer work: D 2-<4h per day 1. HR = 1.4 (90%CI 0.81-2.57) 2. HR = 0.7 (90%CI 0.33-1.30) 3. HR = 1.2 (90%CI 0.51-2.75) 4. HR = 2.2 (90%CI 1.0-4.63) - Computer work: D ≥4h per day 1. HR = 1.2 (90%CI 0.68-2.10) 2. HR = 0.7 (90%CI 0.38-1.33) 3. HR = 1.4 (90%CI 0.65-3.10) 4. HR = 1.6 (90%CI 0.76-3.53) - Data/text entry: D 0.5-<3h per day 1. HR = 0.8 (90%CI 0.50-1.35) 2. HR = 0.8 (90%CI 0.39-1.44) 3. HR = 0.8 (90%CI 0.37-1.51) 4. HR = 1.1 (90%CI 0.64-1.91) - Data/text entry: D ≥3h per day 1. HR = 0.5 (90%CI 0.22-1.22) 2. HR = 0.2 (90%CI 0.04-1.11) 3. HR = 0.7 (90%CI 0.24-1.81) 4. HR = 0.2 (90%CI 0.03-0.90) - Continuous computer work without break (break >10min): D 2-3h per day or >3h less than a few times a week 1. HR = 1.3 (90%CI 0.86-2.08) 2. HR = 1.3 (90%CI 0.71-2.18) 3. HR = 1.2 (90%CI 0.65-2.22) 4. HR = 1.2 (90%CI 0.73-2.08) - Continuous computer work without break (break >10min): D >3h at least a few times a week 1. HR = 1.6 (90%CI 0.88-2.78) 2. HR = 1.4 (90%CI 0.65-3.01) 3. HR = 1.5 (90%CI 0.71-3.35) 4. HR = 1.2 (90%CI 0.57-2.50) - Mouse use: D 0.5-<3h per day 1. HR = 1.6 (90%CI 0.94-2.58) 2. HR = 1.9 (90%CI 0.94-3.77) 3. HR = 3.4 (90%CI 1.40-8.17) 4. HR = 2.1 (90%CI 1.12-4.08) - Mouse use: D ≥3h per day 1. HR = 1.4 (90%CI 0.69-2.52) 2. HR = 1.2 (90%CI 0.45-3.27) 3. HR = 3.0 (90%CI 0.97-9.52) 4. HR = 1.4 (90%CI 0.52-3.63)

IJmker et al.2011[26]	N = 1951 G = 1017 men; 934 women A = 41 y O = office worker C = Netherlands	Prospective cohort study (2 years) Ref = unexposed or minimal exposed group (N = 276) Conf = personal factors	Exp = self-reported questionnaire at baseline and at 12 months follow-up (exposure duration; 7 categories, from 0-1 to >8 hours per day); and registration by Work pace recorder for three months HEf = self-reported questionnaire (four categories, from never to yes prolonged) every three months	1. Neck-shoulder symptoms 2. Arm-wrist-hand symptoms *Symptoms:* pain or discomfort during the last three months (four categories) Prevalence in symptoms during past three months (at baseline): Neck-shoulder 15 % Arm-wrist-hand 11% Three monthly incidence of severe symptoms during two year follow-up: Neck-shoulder 3.9-8.8% Arm-wrist-hand 2.8-4.6% Two year follow-up: 73% no incident neck-shoulder 82% no incident arm-wrist-hand 20% one incident neck-shoulder 14% one incident arm-wrist-hand	- self-reported computer use: D 4-<6h per day 1. RR = 1.1 (CI 0.8-1.5) 2. RR = 1.9 (CI 1.1-3.1) - self-reported computer use: D ≥6h per day 1. RR = 1.2 (CI 0.9-1.6) 2. RR = 2.0 (CI 1.2-3.2) - self-reported mouse use: D 2-<4h per day 1. RR = 1.1 (CI 0.8-1.5) 2. RR = 1.1 (CI 0.7-1.7) - self-reported mouse use: D ≥4h per day 1. RR = 1.5 (CI 1.1-2.0) 2. RR = 1.4 (CI 0.9-2.1) -registered computer use: D 10-<14 h per week 1.RR = 1.2 (0.8-1.6) 2.RR = 1.0 (0.7-1.5) -registered computer use: D 14-36 h per week 1.RR = 0.8 (0.6-1.1) 2.RR = 0.9 (0.6-1.4) -registered mouse use: D 5-<7 h per week 1.RR = 0.8 (0.6-1.1) 2.RR = 0.8 (0.6-1.2) -registered mouse use: D 7-22 h per week 1.RR = 0.8 (0.6-1.1) 2.RR = 0.9 (0.6-1.3) -registered keyboard use D 2-3 h per week 1.RR = 1.1 (0.8-1.6) 2.RR = 1.0 (0.7-1.4) -registered keyboard use D 3-13 h per week 1.RR = 1.0 (0.7-1.4) 2.RR = 0.7 (0.5-1.1)

Juul-Kristensen et al. 2004[27]	N = 1987 G = 766 men;1221 women A = 18 - >50 y O = office worker C = Denmark	Prospective cohort study (17-23 months) Ref = unexposed group or minimal exposed group (N = 302) Conf = age, gender	Exp = self-reported valid questionnaire (exposure duration; dichotomous, never or seldom-to-always); at baseline and follow-up HEf = self-reported valid questionnaire; at baseline and follow-up	1. Shoulder symptoms 2. Elbow symptoms 3. Low back symptoms *Symptoms:* trouble, ache or pain during the last 12 months Incidence of increase in frequency (days) of symptoms during last twelve months: Shoulder 18% Elbow 10% Incidence of increase in mean intensity of symptoms in last three months: Shoulder 20% Elbow 14%	Increase in frequency (days) of symptoms: - Computer use: D 50% of workday 1. OR = 1.31 (CI 0.76-2.28) 2. OR = 1.01 (CI 0.53-1.94) 3. OR = 0.94 (CI 0.57-1.55) - Computer use: D 75% of workday 1. OR = 1.22 (CI 0.72-2.08) 2. OR = 0.97 (CI 0.52-1.81) 3. OR = 1.03 (CI 0.64-1.65) - Computer use: D almost all the workday 1. OR = 1.06 (CI 0.63-1.77) 2. OR = 1.08 (CI 0.60-1.93) 3. OR = 1.25 (CI 0.80-1.95) Increase in mean intensity of symptoms: -Computer use: D 50% of workday 1. OR = 1.23 (CI 0.76-1.99) 2. OR = 1.47 (CI 0.86-2.49) 3. OR = 0.86 (CI 0.54-1.36) - Computer use: D 75% of workday 1. OR = 1.01 (CI 0.63-1.62) 2. OR = 1.02 (CI 0.59-1.76) 3. OR = 1.02 (CI 0.66-1.59) - Computer use: D almost all the workday 1. OR = 1.31 (CI 0.84-2.04) 2. OR = 1.50 (CI 0.92-2.47) 3. OR = 1.35 (CI 0.89-2.03)
Korhonen et al. 2003[28]	N = 180 G = 100 men; 80 women A = mean 47 y; median 49 y O = municipal administrators C = Finland	Prospective cohort study (1 year) Ref = unexposed or exposed without neck pain for more than eight days in preceding 12 months (N = 144) Conf = age, gender	Exp = self-reported questionnaire (percent of working time during preceding month used for VDU work); at baseline and follow-up HEf = self-reported questionnaire (five categories from 0 days to 8 or more days); at baseline and follow-up	local and/or radiating neck pain *Symptom*: number of days with local or radiating neck pain during preceding 12 months Incidence at follow up: Local and radiating neck pain 34.4% (CI 25.5-41.3%) Local neck pain: 13.3% radiating neck pain: 14.4 %	Computer use ≥ 50% of working time OR = 1.0 (CI 0.6-2.9)

Kryger et al. 2002[32]	N = 5658 G = 2093 men; 3565 women A = 41.3 y (sd 9.0) O = technical assistants and machine technicians C = Denmark (NUDATA-study)	Prospective cohort study (1 year) Ref = unexposed or minimal exposed group (N = 5116) Conf = personal and psychosocial factors	Exp = self-reported questionnaire (average weekly exposure duration during past 4 weeks); at baseline and follow-up HEf = self-reported questionnaire (eight categories for pain, four categories for discomfort due to pain, five categories for duration of pain); at baseline and follow-up; and clinical examination	Forearm pain 1.present symptom case 2.chronic symptom case *Symptom*: moderate pain within the past seven days (quite a lot of pain more than 30 days in past 12 months = chronic) Prevalence of symptoms: Right forearm 4.3% Left forearm 1% Incidence of symptoms: Right forearm 1.3% Left forearm 0.4%	-Mouse use right hand: D 2.5-4 h per week 1.OR = 1.5 (CI 0.6-3.6) 2.OR = 1.2 (CI 0.5-2.8) -Mouse use right hand: D 5-9 h per week 1.OR = 2.7 (CI 1.3-5.6) 2.OR = 2.7 (CI 1.4-5.1) -Mouse use right hand: D 10-14 h per week 1.OR = 1.9 (CI 0.9-4.0) 2.OR = 2.2 (CI 1.1-4.2) -Mouse use right hand: D 15-19 h per week 1.OR = 4.1 (CI 2.0-8.2) 2.OR = 3.8 (CI 2.0-7.1) -Mouse use right hand: D 20-24 h per week 1.OR = 3.3 (CI 1.6-7.0) 2.OR = 2.9 (CI 1.5-5.7) -Mouse use right hand: D 25-29 h per week 1.OR = 7.5 (CI 3.4-16) 2.OR = 5.8 (CI 2.9-12) -Mouse use right hand: D ≥30 h per week 1.OR = 7.3 (CI 3.1-17) 2.OR = 6.3 (CI 2.9-14) -Keyboard time: D 2.5-4 h per week 1.OR = 1.1 (CI 0.6-2.2) 2.OR = 0.9 (CI 0.5-1.6) -Keyboard time: D 5-9 h per week 1.OR = 1.1 (CI 0.6-2.1) 2.OR = 1.0 (CI 0.6-1.6) -Keyboard time: D 10-14 h per week 1.OR = 1.6 (CI 0.8-3.1) 2.OR = 0.8 (CI 0.5-1.4)

					-Keyboard time: D 15-19 h per week 1.OR = 1.8 (0.9-3.7) 2.OR = 1.3 (CI 0.7-2.3) -Keyboard time: D ≥20 h per week 1.OR = 2.9 (CI 1.2-7.1) 2.OR = 2.1 (CI 0.9-4.5) New symptom case -Mouse in right hand: D 10-19 h per week 1.OR = 2.2 (CI 1.0-4.7) D 20-29 h per week 1.OR = 2.6 (CI 1.0-6.6) D ≥30 h per week 1.OR = 8.4 (CI 2.5-29) -Keyboard time: D 5-9 h per week 1.OR = 1.2 (CI 0.5-2.9) D10-14 h per week 1.OR = 1.3 (CI 0.5-3.4) D ≥15 h per week 1.OR = 2.6 (CI 0.9-7.3)
Lassen et al. 2004[33]	N = 5658 G = 1980 men; 3678 women A = 86% 30-59 y men; 90% 30-59 y women O = machine technician and engineering technical assistant C = Denmark (NUDATA-study)	Prospective cohort study (1 year) Ref = unexposed of minimal exposed group (<2.5h per day; N = 473-814)) Conf = personal and psychosocial factors	Exp = self-reported questionnaire (average hours of computer work, mouse and keyboard use per week during the past 4 weeks); at baseline and one year follow-up HEf = self-reported questionnaire and standardized clinical examination; at baseline and one year follow-up	1. Elbow pain 2. Severe elbow pain 3. Wrist/hand pain 4. Severe Wrist/hand pain *Pain:* any pain or discomfort (>30 days = severe) during the past 12 months Prevalence at baseline 1.right 27.5%, left 7.6% 2.right 5.5%, left 1.3% 3.right 46.2%, left 11.0% 4.right 8.1%, left 1.7%	- Mouse use: D 2.5-<5h per week 1. OR (baseline) = 1.37 (CI 0.99-1.89) 1. OR (follow-up) = 1.47 (CI 0.84-2.54) 2. OR (baseline) = 1.84 (CI 0.88-3.82) 2. OR (follow-up) = 1.16 (CI 0.34-3.54) 3. OR (baseline) = 1.51 (CI 1.15-1.98) 3. OR (follow-up) = 1.57 (CI 0.99-2.51) 4. OR (baseline) = 1.29 (CI 0.69-2.34) 4. OR (follow-up) = 0.73 (CI 0.23-2.01) - Mouse use: D 5-<10h per week 1. OR (baseline) = 1.57 (CI 1.19-2.06) 1. OR (follow-up) = 2.35 (CI 1.51-3.70) 2. OR (baseline) = 2.55 (CI 1.40-4.81) 2. OR (follow-up) = 1.42 (CI 0.58-3.64) 3. OR (baseline) = 1.78 (CI 1.41-2.26) 3. OR (follow-up) = 2.16 (CI 1.46-3.22) 4. OR (baseline) = 2.01 (CI 1.23-3.33) 4. OR (follow-up) = 1.55 (CI 0.74-3.34)

Incidence at follow-up 1.right 14.1%, left 7.2% 2.right 2.7%, left 1.0% 3.right 21.0%, left 9.3% 4.right 4.0%, left 1.2%	- Mouse use: D 10-<15h per week 1. OR (baseline) = 1.72 (CI 1.33-2.25) 1. OR (follow-up) = 2.20 (CI 1.42-3.45) 2. OR (baseline) = 2.49 (CI 1.38-4.68) 2. OR (follow-up) = 2.14 (CI 0.93-5.32) 3. OR (baseline) = 2.62 (CI 2.09-3.29) 3. OR (follow-up) = 2.05 (CI 1.37-3.07) 4. OR (baseline) = 1.60 (CI 0.98-2.67) 4. OR (follow-up) = 1.40 (CI 0.68-3.01) - Mouse use: D 15-<20h per week 1. OR (baseline) = 2.28 (CI 1.75-2.97) 1. OR (follow-up) = 3.12 (CI 2.01-4.92) 2. OR (baseline) = 2.97 (CI 1.66-5.55) 2. OR (follow-up) = 1.45 (CI 0.59-3.78) 3. OR (baseline) = 2.91 (CI 2.31-3.66) 3. OR (follow-up) = 2.46 (CI 1.65-3.72) 4. OR (baseline) = 2.87 (CI 1.81-4.68) 4. OR (follow-up) = 1.68 (CI 0.82-3.58) - Mouse use: D 20-<25h per week 1. OR (baseline) = 2.30 CI 1.75-3.05) 1. OR (follow-up) = 3.21 (CI 2.03-5.17) 2. OR (baseline) = 2.04 (CI 1.06-4.01) 2. OR (follow-up) = 2.88 (CI 1.18-7.54) 3. OR (baseline) = 3.89 (CI 3.05-4.99) 3. OR (follow-up) = 2.07 (CI 1.32-3.26) 4. OR (baseline) = 2.33 (CI 1.41-3.92) 4. OR (follow-up) = 4.21 (CI 2.12-8.85) - Mouse use: D 25-<30h per week 1. OR (baseline) = 3.13 (CI 2.26-4.36) 1. OR (follow-up) = 4.83 (CI 2.79-8.40) 2. OR (baseline) = 3.26 (CI 1.60-6.71) 2. OR (follow-up) = 4.16 (CI 1.45-12.13) 3. OR (baseline) = 4.00 (CI 2.97-5.46) 3. OR (follow-up) = 3.16 (CI 1.82-5.46) 4. OR (baseline) = 3.49 (CI 1.98-6.21) 4. OR (follow-up) = 4.81 (CI 2.18-10.99) - Mouse use: D ≥30h per week 1. OR (baseline) = 3.04 (CI 2.09-4.41) 1. OR (follow-up) = 4.74 (CI 2.51-8.95) 2. OR (baseline) = 5.57 (CI 2.70-11.76) 2. OR (follow-up) = 6.91 (CI 2.21-22.53) 3. OR (baseline) = 3.76 (CI 2.66-5.30) 3. OR (follow-up) = 3.05 (CI 1.63-5.67) 4. OR (baseline) = 5.68 (CI 3.11-10.49) 4. OR (follow-up) = 2.30 (CI 0.83-6.26)

- Keyboard use: D 2.5-<5h per week
1. OR (baseline) = 0.87 (CI 0.66-1.15)
1. OR (follow-up) = 1.04 (CI 0.65-1.69)
2. OR (baseline) = 1.24 (CI 0.70-2.29)
2. OR (follow-up) = 1.09 (CI 0.44-2.9)
3. OR (baseline) = 0.89 (CI 0.69-1.15)
3. OR (follow-up) = 0.63 (CI 0.41-0.98)
4. OR (baseline) = 0.90 (CI 0.56-1.46)
4. OR (follow-up) = 1.14 (CI 0.58-2.38)

- Keyboard use: D 5-<10h per week
1. OR (baseline) = 0.94 (CI 0.73-1.20)
1. OR (follow-up) = 1.47 (CI 0.98-2.26)
2. OR (baseline) = 1.07 (CI 0.63-1.92)
2. OR (follow-up) = 1.58 (CI 0.71-4.03)
3. OR (baseline) = 0.91 (CI 0.72-1.14)
3. OR (follow-up) = 0.73 (CI 0.50-1.07)
4. OR (baseline) = 0.99 (CI 0.65-1.55)
4. OR (follow-up) = 0.99 (CI 0.54-1.95)

- Keyboard use: D 10-<15h per week
1. OR (baseline) = 0.94 (CI 0.72-1.23)
1. OR (follow-up) = 1.33 (CI 0.85-2.11)
2. OR (baseline) = 0.86 (CI 0.48-1.60)
2. OR (follow-up) = 2.49 (CI 1.08-6.53)
3. OR (baseline) = 0.98 (CI 0.76-1.25)
3. OR (follow-up) = 0.80 (CI 0.53-1.20)
4. OR (baseline) = 1.01 (CI 0.64-1.64)
4. OR (follow-up) = 1.46 (CI 0.76-2.98)

- Keyboard use: D 15-<20h per week
1. OR (baseline) = 0.92 (CI 0.68-1.25)
1. OR (follow-up) = 1.29 (CI 0.78-2.17)
2. OR (baseline) = 1.29 (CI 0.70-2.49)
2. OR (follow-up) = 2.86 (CI 1.08-8.12)
3. OR (baseline) = 0.96 (CI 0.73-1.26)
3. OR (follow-up) = 0.87 (CI 0.55-1.38)
4. OR (baseline) = 1.20 (CI 0.73-2.01)
4. OR (follow-up) = 1.89 (CI 0.90-4.10)

- Keyboard use: D ≥20h per week
1. OR (baseline) = 0.88 (CI 0.58-1.33)
1. OR (follow-up) = 1.98 (CI 0.96-3.95)
2. OR (baseline) = 1.11 (CI 0.44-2.62)
2. OR (follow-up) = 3.79 (CI 0.91-14.11)
3. OR (baseline) = 1.61 (CI 1.13-2.28)
3. OR (follow-up) = 1.04 (CI 0.51-2.04)
4. OR (baseline) = 1.68 (CI 0.86-3.22)
4. OR (follow-up) = 1.60 (CI 0.43-4.94)

Marcus et al. 2002[29] and Gerr et al. 2002[61]	N = 632 G = men and women A = ? O = computer users C = USA	Prospective cohort study (follow up 38 months) Ref = unexposed or minimal exposed (newly hired) Conf = age, gender	Exp = self-reported daily questionnaire (number of hours keying) and measurements of worker posture and workstation configuration HEf = self-reported weekly questionnaire and clinical examination	1.Neck/shoulder symptoms 2.Neck/shoulder disorder 3.Hand/arm region symptoms 4.Hand/arm disorder *Symptom*: discomfort with intensity of at least six at visual analog scale (VAS) or report of medication use	Per hour keying per week: 1.HR = 1.01 (CI 0.99-1.03) 2.HR = 1.01 (CI 0.99-1.04) 3.HR = 1.04 (CI 1.02-1.06) 4.HR = 1.04 (CI 1.02-1.06)
Rahman and Abdul 2004[31]	N = 463 G = 126 men; 337 women A = 34.1 (18-55) O = office worker C = Malaysia	Cross-sectional study Ref = unexposed group Conf = gender, hobbies	Exp = self-reported questionnaire derived from the Dutch Musculoskeletal Questionnaire (dichotomous) HEf = self-reported questionnaire derived from the Dutch Musculoskeletal Questionnaire	Upper limbs symptoms *Symptom:* pain, ache, stiffness, burning, tingling or numbness of the neck, shoulder, elbow, forearms, wrist and/or fingers occurring at least once a month within the past year	- Computer use: D >2h per day OR = 2.0 (CI 1.1-3.4) -Computer use: D ≥5h per day OR = 7.5 (CI 2.3-24.2)
Shuval 2005[36]	N = 84 G = 57 men; 27 women A = 87.8% 23-29 y O = computer programmer and related field C = Israel	Cross-sectional study Ref = less exposed group (2-7h per workday; N = 31) Conf = none	Exp = self-reported questionnaire (exposure duration) HEf = self-reported questionnaire based on the Standardized Nordic Questionnaire	Hand / wrist / finger symptoms *Symptom:* pain, ache, discomfort in the past year	- Visual display terminal: D 7.1-9h per day OR = 4.39 (CI 1.27-15.17) - Visual display terminal: D 9.1-12h per day OR = 1.73 (CI 0.39-7.56)

Tornqvist et al. 2009 (see also Hagberg et al. 2007)[25,30]	N = 1247 G = 498 men;785 women A = 44 y (20-65) O = various C = Sweden	Prospective cohort study (10 months) Ref = minimal exposed group (<2h per day for computer work; <0.5h per day for data/text entry and mouse use; N = 53-781) Conf = age, sex	Exp = self-reported questionnaire (average daily exposure duration; percentage transform to 3 categories, from low to highly exposed) HEf = monthly self-reported questionnaire	1. Neck symptoms 2. Shoulder symptoms 3. Hand/arm symptoms *Symptom:* pain or aches in any of the body regions asked about, or numbness in the hand/fingers, ≥3 days during the preceding month. Incidence rate per 100 person years: neck 67 cases shoulder 41 cases arm/hand 47 cases	- Computer work: D 2-<4h per day 1. RR = 1.20 (CI 0.82-1.74) 1. RR (crude) = 1.61 (CI 1.19-2.16) 2. RR = 0.74 (CI 0.49-1.13) 2. RR (crude) = 1.32 (CI 0.95-1.82) 3. RR = 0.82 (CI 0.54-1.22) 3. RR (crude) = 1.30 (CI 0.95-1.78) - Computer work: D ≥4h per day 1. RR = 1.19 (CI 0.79-1.81) 1. RR (crude) = 1.73 (CI 1.30-2.30) 2. RR = 0.66 (CI 0.41-1.07) 2. RR (crude) = 1.35 (CI 0.99-1.84) 3. RR = 0.87 (CI 0.55-1.38) 3. RR (crude) = 1.56 (CI 1.16-2.09) - Continuous computer work without breaks > 10min: D 2-3h per day or >3h <few times per week 1. RR = 1.14 (CI 0.89-1.46) 1. RR (crude) = 1.28 (CI 1.04-1.57) 2. RR = 0.91 (CI 0.68-1.21) 2. RR (crude) = 1.08 (CI 0.85-1.37) 3. RR = 0.94 (CI 0.72-1.23) 3. RR (crude) = 1.16 (CI 0.93-1.45) - Continuous computer work without breaks > 10min: D >3h at least a few times per week 1. RR = 1.34 (CI 0.95-1.88) 1. RR (crude) = 1.43 (CI 1.08-1.89) 2. RR = 1.30 (CI 0.89-1.90) 2. RR (crude) = 1.55 (CI 1.15-2.08) 3. RR = 1.06 (CI 0.73-1.55) 3. RR (crude) = 1.51 (CI 1.13-2.01) - Data/text entry work: D 0.5-<3h per day 1. RR = 0.88 (CI 0.67-1.15) 1. RR (crude) = 1.19 (CI 0.94-1.49) 2. RR = 0.87 (CI 0.63-1.19) 2. RR (crude) = 1.02 (CI 0.78-1.33) 3. RR = 0.87 (CI 0.64-1.18) 3. RR (crude) = 0.95 (CI 0.74-1.22) - Data/text entry work: D ≥3h per day 1. RR = 0.97 (CI 0.66-1.43) 1. RR (crude) = 1.36 (CI 1.02-1.83) 2. RR = 1.17 (CI 0.75-1.83) 2. RR (crude) = 1.33 (CI 0.96-1.85) 3. RR = 1.03 (CI 0.68-1.58) 3. RR (crude) = 1.12 (CI 0.81-1.56)

					- Mouse use: D 0.5-<3h per day 1. RR = 1.08 (CI 0.80-1.45) 1. RR (crude) = 1.24 (CI 0.99-1.57) 2. RR = 1.62 (CI 1.12-2.34) 2. RR (crude) = 1.41 (CI 1.07-1.85) 3. RR = 1.44 (CI 1.01-2.05) 3. RR (crude) = 1.41 (CI 1.09-1.84) - Mouse use: D ≥3h per day 1. RR = 0.88 (CI 0.58-1.33) 1. RR (crude) = 1.28 (CI 0.93-1.76) 2. RR = 1.30 (CI 0.77-2.19) 2. RR (crude) = 1.31 (CI 0.90-1.90) 3. RR = 1.70 (CI 1.07-2.70) 3. RR (crude) = 1.74 (CI 1.24-2.43)
Walker-Bone et al. 2006[34]	N = 4170 G = men and women A = 25-64 y O = various C = England	Cross-sectional study Ref = minimal exposed group (<1h per day; N = 1.149) Conf = age, sex, smoking, occupational facotrs	Exp = self-reported questionnaire (exposure history; 3 categories, from <1h per day to >4h per day) HEf = self-reported questionnaire based on the Standardized Nordic Questionnaire and clinical examination	1. Tenosynovitis of the wrist 2. Osteoarthritis of the wrist 3. Non- specific disorder of the wrist.	- Keyboard use: D ≥1h per day 1. OR = 3.1 (CI 1.3-7.8) 2. OR = 0.9 (CI 0.5-1.9) 3. OR = 1.3 (CI 0.8-2.1)

N, number; G, gender; A, age; O, occupation (sector); C, country; Ref, reference group; Exp, exposure; HEf, health effect; Conf = confounder taken into account; D, duration; I, intensity; F, frequency; m, mean; sd, standard deviation; %, percentage; h, hour; min, minute; s, second; OR, *odds ratio*; HR, hazard ratio; PRR, prevalence proportion ratio; RR, relative risk; CI, confidence interval; *,p<.05; **, p<.01; ***, p<.001

Annex **G**

Extraction table computer use by students

Author	Study population	Study design	Measurement methods	Health effect	Degree of association
Brink et al. 2009[38]	N = 93 G = 48 men; 45 women A = 16.0 y (sd=0.7) S = high school C = South Africa	Prospective cohort study (6 months) Ref = unexposed or minimal exposed group Conf = sex	Exp = valid self-reported Computer Usage Questionnaire and measurement of postural alignment; at baseline, three and six months follow-up HEf = valid self-reported Computer Usage Questionnaire (pain component; binary outcome); at baseline, three and six months follow-up	Upper quadrant musculoskeletal pain *Symptom*: UQMP during preceding month Incidence rate: 5 cases per 6 months per 100 students	- Computer use: D ≥ 1h45 per day OR = 1.7 (CI 0.7-4.2) OR (boys) = 1.0 (CI 0.3-3.4) OR (girls) = 0.5 (CI 0.1-4.3) - Computer use: D ≥ 6h per week OR = 1.6 (CI 0.7-3.8) OR (boys) = 0.9 (CI 0.3-2.8) OR (girls) = 1.8 (CI 0.4-8.7)
Chang et al. 2007[39]	N = 27 G = 13 men;14 women A = 20.6 y (sd=1.5) S = undergraduate C = USA	Prospective cohort study (three weeks; pilot) Ref = unexposed or minimal exposed group Conf = unclear	Exp = computer usage monitor software (continuous transformed in binary outcomes: less or high exposed); daily HEf = self-reported questionnaire (five categories: none, mild, moderate, severe and very severe); four daily reports	Musculoskeletal symptoms (13 body parts) *Symptom:* current pain or discomfort Prevalence of moderate or severe neck pain 48%	- Computer use: D >2h per day OR = 1.43 (CI 0.92-2.24) OR (male) = 2.01 (CI 0.91-4.44) OR (female) = 1.23 (CI 0.72-2.10) - Computer use: D >2.5h per day OR = 1.44 (CI 0.98-2.09) OR (male) = 1.96 (CI 1.12-3.42) OR (female) = 1.25 (CI 0.78-1.98)

					- Computer use: D >3h per day OR = 1.50 (CI 1.01-2.25) OR (male) = 2.09 (CI 1.17-3.72) OR (female) = 1.29 (CI 0.76-2.20) - Computer use: D >3.5h per day OR = 1.51 (CI 1.01-2.25) OR (male) = 1.88 (CI 1.16-3.05) OR (female) = 1.36 (CI 0.78-2.34) - Computer use: D >4h per day OR = 1.28 (CI 0.85-1.93) OR (male) = 1.64 (CI 0.93-2.89) OR (female) = 1.13 (CI 0.65-1.98)
Grimby-Ekman et al. 2009[40]	N = 1204 G = 576 men;628 women A = ? S = university C = Sweden	Prospective cohort study (two years) Ref = less exposed group Conf = gender	Exp = valid self-reported questionnaire (number of times that computer was used for 4h without a break during the last 7 days); at baseline and yearly follow-up HEf = self-reported questionnaire (current pain, period of pain and years of pain); at baseline and yearly follow-up	Neck/upper back pain *Pain:* definition according to the Neck Pain Task Force Prevalence of pain 23%	- Computer use: one period of 4h per week OR (Marginal model) = 1.0 (CI 0.75-1.34) RR (Poisson model) = 1.1 (CI 0.95-1.36) OR (Markov model) = 1.7 (CI 0.94-2.94) - Computer use: ≥2 periods of 4h per week OR (Marginal model) = 1.4 (CI 1.11-1.71) RR (Poisson model) = 1.2 (CI 1.04-1.37) OR (Markov model) = 1.8 (CI 1.16-2.89)
Menendez 2008[41]	N = 30 G = 15 men;15 women A = ≥18 y S = undergraduate C = USA	Cross-sectional study Ref = unexposed group Conf = individual factors	Exp = valid self-reported questionnaire (daily computer use; 7categories: from 0 to >10h); three weekly periods, 5 times daily HEf = self-reported questionnaire (5 categories: none, mild, moderate, severe and very severe); three weekly periods, 5 times daily	Upper extremity symptoms 1. Any symptoms 2. Moderate or greater symptoms *Pain*: how much pain are you experiencing now	- Computer use: 1. OR = 1.1 (90% CI 1.1-1.2) 2. OR = 1.2 (90% CI 1.1-1.3) -Computer use 1-2 h per day 1. OR = 1.8 (90% CI 1.2-2.7) 2. OR = 0.9 (90% CI 0.5-1.5) -Computer use 3-5 h per day 1. OR = 2.6 (90% CI 1.7-4.0) 2. OR = 1.2 (90% CI 0.7-2.2) -Computer use 6-8 h per day 1. OR = 2.3 (90% CI 1.3-4.2) 2. OR = 1.0 (90% CI 0.4-2.3) -Computer use 9-14 h per day 1. OR = 5.5 (90% CI 2.7-11.4) 2. OR = 3.8 (90% CI 1.5-9.5)

Palm 2007[42]	N = 2826 G = 1251 men;1575 women A = 16-18 S = under-graduate C = Sweden	Cross-sectional study Ref = less exposed group (<14h per week) Conf = none	Exp = self-reported questionnaire (weekly computer use in hours and minutes) HEf = self-reported questionnaire (6 categories: from never to all the time).	1. Headache 2. Eyestrain 3. Neck or shoulders pain 4. Upper arms pain 5. Forearms pain *Pain:* number of days with pain, ache or symptoms during the previous month.	- Computer use: >14-56h per week 1. PR (female) = 1.07 (CI 0.96-1.20) 1. PR (male) = 1.47 (CI 1.06-2.05) 2. PR (female) = 1.29 (CI 1.03-1.63) 2. PR (male) = 1.07 (CI 0.68-1.67) 3. PR (female) = 1.08 (CI 0.94-1.25) 3. PR (male) = 1.32 (CI 0.89-1.94) 4. PR (female) = 1.30 (CI 0.97-1.74) 4. PR (male) = 0.99 (CI 0.58-1.67) 5. PR (female) = 1.56 (CI 1.17-2.06) 5. PR (male) = 1.06 (CI 0.71-1.60) - Computer use: >56h per week 1. PR (female) = 1.18 (CI 1.00-1.40) 1. PR (male) = 1.28 (CI 0.87-1.90) 2. PR (female) = 1.82 (CI 1.33-2.48) 2. PR (male) = 1.27 (CI 0.75-2.14) 3. PR (female) = 1.33 (CI 1.08-1.64) 3. PR (male) = 1.59 (CI 1.03-2.47) 4. PR (female) = 1.26 (CI 0.79-2.02) 4. PR (male) = 1.65 (CI 0.93-2.93) 5. PR (female) = 1.90 (CI 1.28-2.82) 5. PR (male) = 1.55 (CI 0.99-2.43)
Schloss-berg 2004[43]	N = 206 G = 176 men; 30 women A = >21 y S = graduate C = USA	Cross-sectional study Ref = less exposed group (<20h per week) Conf = unclear	Exp = self-reported questionnaire (number of years and number of hours per week; 5 categories) HEf = self-reported questionnaire (persistent or recurrent pain)	Upper extremity or neck pain	- Computer use: 20-29h per week OR = 4.32 (CI 1.29-14.48) - Computer use: 30-39h per week OR = 6.56 (CI 1.89-22.75) - Computer use: 40h per week OR = 3.76 (CI 1.17-12.06)

Smith et al. 2008[44]	N = 1073 G = 35.1% men;64.9% women A = 16.3 (sd=1.1) S = under-graduate C = Australia	Cross-sectional study Ref = less exposed group (<8.5h per week) Conf = none	Exp = valid self-reported Computer Usage Questionnaire (number of times computer use per week and hours per day) HEf = valid self-reported Computer Usage Questionnaire (pain component; binary outcome; past month)	1.Headache 2.Neck pain 3. Headache and neck pain	- Computer use: ≥8.5h per week 1. OR = 0.7 (CI 0.5-1.1) 2. OR = 1.7 (CI 1.2-2.3) 3. OR = 1.4 (CI 0.8-2.3)

N, number; G, gender; A, age; S, type student; C, country; Ref, reference group; Exp, exposure; HEf, health effect; Conf = confounder taken into account; D, duration; I, intensity; F, frequency; m, mean;
sd, standard deviation; %, percentage; h, hour; min, minute; s, second; OR, *odds ratio*; HR, hazard ratio; RR, relative risk; CI, confidence interval; *,p<.05; **, p<.01; ***, p<.001

Annex **H**

The meta-analysis

The studies used for the meta-analysis are summarised in the figures below.

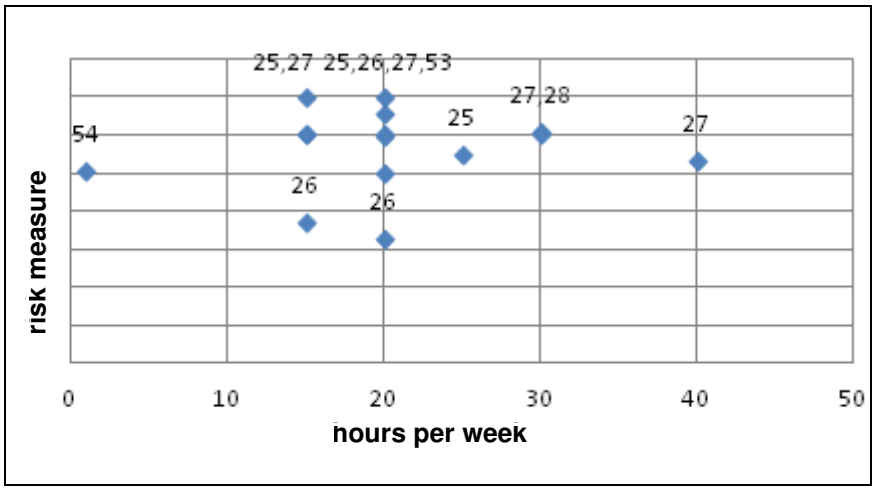

Figure 1 Associations found between computer use and neck/shoulder complaints based on six longitudinal studies.

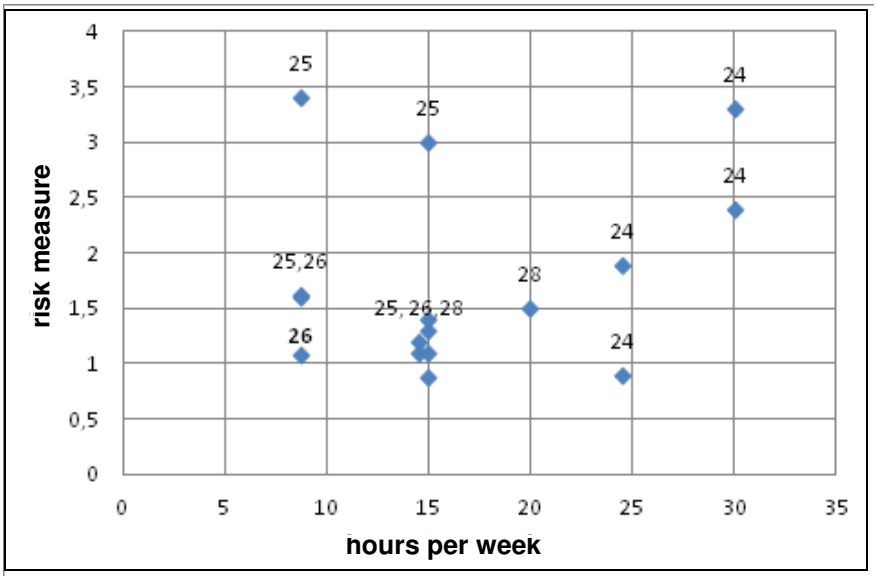

Figure 2 Associations found between mouse use and neck/shoulder complaints based on four longitudinal studies.

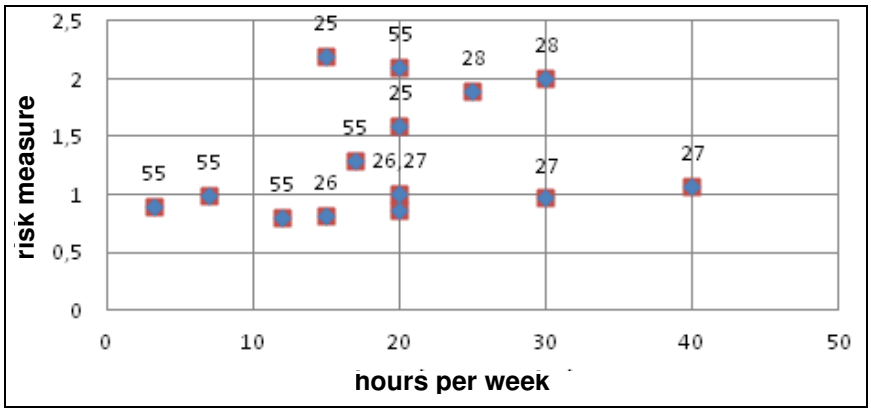

Figure 3 Associations found between computer use and arm/hand complaints based on five longitudinal studies.

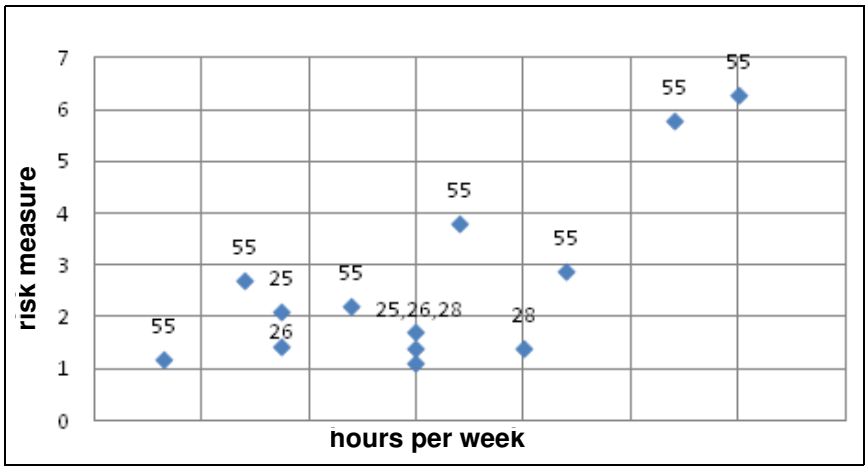

Figure 4 Associations found between mouse use and arm/hand complaints based on four longitudinal studies.

Health Council of the Netherlands

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