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Job demands, muscle activity and musculoskeletal symptoms in relation to work with the computer mouse

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Objectives This study assessed work postures, movements, psychosocial job demands, and shoulder and wrist extensor muscle activity and registered the prevalence of musculoskeletal symptoms of computer-aided design (CAD) operators.

Methods A questionnaire survey was used to study the use of the computer mouse, psychosocial work factors, and musculoskeletal symptoms among 149 CAD operators. A workplace study was performed using observations, electrogoniometers on the wrists, and electromyography to measure exposures and physiological responses during CAD work among a subgroup of the CAD operators.

Results Musculoskeletal symptoms were far more prevalent for the arm or hand operating the mouse than for the other arm or hand, and women were more affected than men. The symptoms may be related to such risk factors as repetitive movements, static postures (eg, ulnar-deviated and extended wrist on the mouse side), and static muscular activation patterns. The risk factors were present due to continuous mouse use and possibly also due to high demands for mental attentiveness, precision, and information processing.

Conclusions Exposure during work with a computer mouse may present a risk for developing musculoskeletal symptoms. Improvements should focus on introducing more variation.

Key terms exposure, mental demands, shoulder muscles, video display units, work posture, wrist, wrist extensor muscles.

The computer has become a necessary tool in many jobs, and people spend an increasing amount of work and leisure time using the computer. In a representative survey of Danish employees 11% reported working in front of a computer screen for at least three-fourths of their daily work time in 1995, whereas only 4% reported this amount of work with video display units (VDU) in 1990 (1). Developments in the software industry are leading to more computer mouse use and relatively less keyboard work than what is the case today. However, an increased prevalence of musculoskeletal disorders of the upper limb may be associated with computer mouse work (2—4). Intensive mouse work already exists in industries in which computer-aided design (CAD) is common. Traditionally, CAD work is performed with a puck (ie, a mouse-like input device with a cross-hair lens on front), which is used to draw or select icons on a digitizer. In

this report, the term “mouse” is used both for the puck and for the ordinary computer mouse to distinguish these from other types of input devices.

Risk factors for the development of musculoskeletal disorders when working with a visual display unit (VDU) include factors related to the workstation (5) and the psychosocial work environment, such as low decision latitude (6). Knowledge on specific risk factors associated with mouse use is scarce, although the duration of mouse use and a mouse location lateral to the mouse operator have been reported as risk factors for the development of upper-limb symptoms (3).

In our study a questionnaire survey was performed in a Danish company to quantify the use of computer input devices, the psychosocial work environment, and the prevalence of musculoskeletal symptoms among CAD operators. More specifically whether differences in

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symptom prevalence occurred between the hand operating the mouse versus the other hand and between genders was studied. Furthermore, work postures and movements, psychosocial demands, and muscular activity were more objectively measured or observed during CAD work.

Subjects and methods

Questionnaire survey

All the employees in a consultative engineering company who, according to company representatives, worked with CAD for at least 5 hours a day were given a questionnaire seeking information on individual characteristics, work technique, and duration of work with computer input devices. In addition the psychosocial work environment was assessed by 23 questions. The answers were combined into 5 indices reflecting the following dimensions: (i) psychological demands, (ii) decision latitude, (iii) social support from colleagues, (iv) social support from superiors, and (v) initiative and learning. The indices ranged from 0 (most "negative" answer) to 100 (most "positive" answer). Finally, musculoskeletal symptoms were reported according to the Nordic questionnaire (7). The questionnaire was answered by 149 CAD operators (62% response rate).

Workplace study

Twenty female CAD operators, who all participated in the questionnaire survey, volunteered to participate in the workplace study in which postures, movements, muscular activity, and psychosocial exposures were registered during the performance of normal work at a CAD station. Their mean age was 39 (SD 10) years, and their mean seniority was 13 (SD 9) years. Their mean body height and body mass were 170 (SD 5) cm and 65 (SD 7) kg, respectively.

Measurements by observation. Through direct observations the posture of the arm operating the mouse was registered for 5 minutes (N=20). Data were continuously collected using a minicomputer. For the posture registrations, predefined keys were pressed each time a change in posture was observed between predefined position categories in the frontal and sagittal planes. In the sagittal plane the categories were upper-arm extension $>0^\circ$, flexion $>0-30^\circ$, $>30-60^\circ$, and $>60^\circ$. In the frontal plane the categories were upper-arm adduction, $>0^\circ$, and abduction, $>0-30^\circ$, $>30-60^\circ$, and $>60^\circ$. Zero degree was defined as vertical. A "pause" was defined and registered when the upper arm was hanging vertically along the side of the body or resting with support of the forearm or hand. Observations of arm, hand, and finger movements were performed on 6 subjects using video recordings,

from which the number of repetitive movements of the respective joints were counted.

Wrist postures and movement velocities. Wrist posture was measured for 20–25 minutes using a flexible biaxial electrogoniometer on the hand operating the mouse (N=16) and on the other hand (N=18). The goniometers were connected to a datalogger (M110, Penny and Giles Biometrics Ltd, United Kingdom). The method has been described in detail by Hansson et al (8). In short, the electrogoniometers recorded flexion and deviation angles of the wrists with a sampling frequency of 20 Hz. The reference values corresponding to 0° for flexion and deviation angles was defined as the position of the wrist, when the subject was standing, holding the arm and hand relaxed along the side of the body. Data were transferred from the dataloggers to a computer, where the distribution of angles and angular velocity were described by the percentiles of the cumulative angles and velocities. The total duration with "low velocity" pauses was calculated, defining a pause as a period of at least 0.5 seconds' duration with an angular velocity below $1.0^\circ/\text{second}$.

Electromyography. Bipolar surface electrodes were used for electromyographic (EMG) recordings of the trapezius descendens muscle on the side operating the mouse (N=14) and on the other side (N=7) and of the extensor digitorum communis muscle (N=20) and extensor carpi ulnaris muscle (N=9) of the arm operating the mouse for 20–25 minutes (mercury-mercury chloride electrodes, Medicotest A/S, type 7 00 02-E, Denmark). The inter-electrode distance was 20 mm. The EMG signal was amplified, low-pass filtered (8th order Butterworth filter, cut-off 400 Hz), and sampled on dataloggers (Logger Teknologi HB, Lund, Sweden) with a sampling frequency of 1024 Hz. The signals were transferred to a computer, where they were visually checked and high-pass filtered (cut-off 10 Hz). The signals were full-wave rectified and root-mean-square (RMS) converted within moving windows of 100-millisecond duration. The resting signal level was quadratically subtracted from the EMG signal. For normalization the EMG amplitude recorded during maximal voluntary isometric contractions (reference contractions) were used. The maximal EMG amplitude (EMG_{\max}) during the reference contractions was calculated as the highest mean RMS amplitude obtained with a 1-second window moving in steps of 100 milliseconds. The reference contraction for the trapezius muscle was 90° arm abduction with resistance just proximal to the elbow; for the forearm muscles the references were wrist extension with a fixed forearm and hand grip using a Jamar dynamometer, all in a seated posture. Each reference contraction was performed 3 times. The EMG activity levels recorded during CAD work were calculated according to the amplitude probability distribution function (9).

Psychosocial exposures. Job demands and job control were assessed using a semiquantitative observational method based on the studies of Hackmann (10), Warr (11), and Kern & Schumann (12). Eleven CAD

Table 1. Percentage of CAD (computer-aided design) operators reporting different amounts of worktime with computer input devices. (Approx = approximately)

Input device	Worktime				
	Almost all	Approx 75%	Approx 50%	Approx 25%	Little or none
Puck in hand	41	28	9	11	11
Ordinary computer mouse in hand	11	14	4	32	39
Keyboard	10	6	15	55	14
Other input device in hand (pen, trackball, etc)	2	0	1	1	96

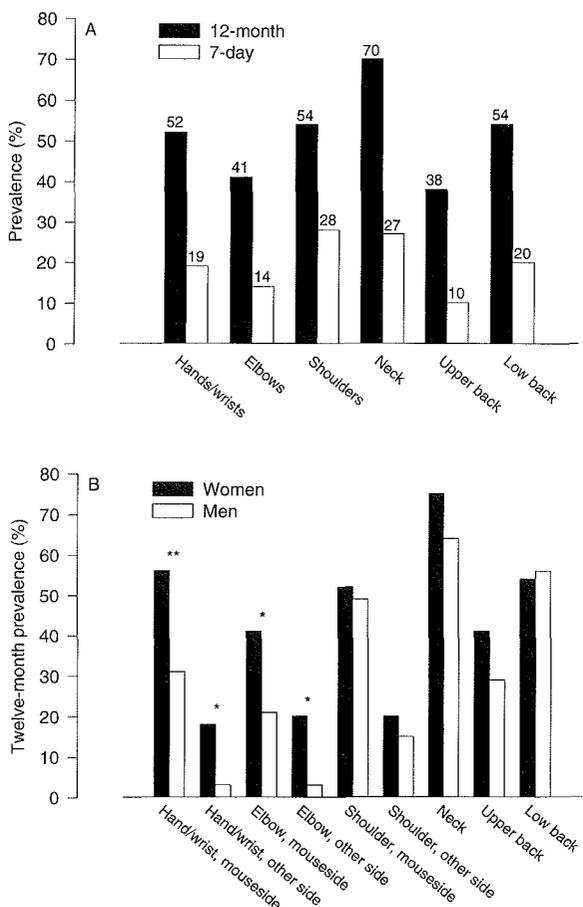


Figure 1. Prevalence of musculoskeletal symptoms among all the respondents (A) and the 12-month prevalence of musculoskeletal symptoms for CAD operators who always used the same hand to operate the mouse (B). The differences between the women and men were tested with the chi-square test: * $P < 0.05$, ** $P < 0.01$.

operators were observed for 2–3 hours each at their workplace. The observations were supplemented with questions to the CAD operators about specific worktask operations. Six items related to job demands and 5 items related to job control were assessed. Each item was given a score from 0 (no demands or no control) to 4 (constant presence of demands or control) on a categorical scale. The mean score of the 6 items related to demands represented the overall demand score for each subject. Correspondingly, an overall control score was calculated.

Statistics

The sign test (equivalent to McNemar’s test) was used to test whether upper-limb symptoms were more frequent on the side operating the mouse than on the other side. The differences in the prevalences of musculoskeletal symptoms between the female and male CAD operators were tested with the chi-square test. The differences in wrist postures and angular velocities between the side operating the mouse and the other side were tested with the paired t-test. A Wilcoxon signed rank test was used to test the differences between the EMG activity levels of the upper trapezius muscles. The level of significance was 0.05.

Results

Questionnaire survey

The questionnaire was answered by 149 CAD operators (71% women and 29% men). The mean age of the respondents was 38 (SD 9) years. Their mean seniority was 11 (SD 8) years, and 86% worked at least 32 hours a week.

Pucks and ordinary computer mice were the most used input devices (table 1). The dominant hand was used to operate the mouse by 66% of the respondents, 25% used their nondominant hand exclusively, while both hands were used intermittently by 9% of the workers. Work was performed entirely while seated by 75% of the CAD operators.

The mean scores of the dimensions describing the psychosocial work environment on indices from 0 to 100 were all above 60 [ie, it was 68 (SD 14) for psychological demands, 62 (SD 14) for decision latitude, 72 (SD 14) for social support from colleagues, 66 (SD 25) for social support from superiors, and 73 (SD 17) for initiative or learning].

The 12-month and 7-day prevalences of musculoskeletal symptoms are shown in figure 1A. For the CAD operators who always used the same hand to operate the mouse, the 12-month prevalence of symptoms from this hand or wrist, elbow, and shoulder were 49%, 35%, and

52%, respectively. The 12-month prevalence of symptoms in the other hand or wrist, elbow, and shoulder were 13%, 15% and 19%, respectively. When only subjects who operated the mouse with the nondominant hand were included, the 12-month prevalence of hand or wrist symptoms was higher on the mouse side (44%) than on the dominant side (28%). For the hand or wrist, elbow, and shoulder regions, unilateral symptoms were experienced by 44%, 36%, and 41% of the CAD operators always using the same hand to operate the mouse; bilateral symptoms were reported by 9%, 7%, and 15%, respectively. Among those with unilateral symptoms, there was a significantly larger proportion with symptoms on the mouse-operating side than on the other side ($P<0.001$ for all 3 regions). A larger proportion of women than men reported symptoms in the hands or wrists and elbows, but not in any of the other body regions (figure 1B). When only the CAD operators who reported working most intensively with a puck (ie, for at least one-half of the worktime) were included, the female CAD operators ($N=89$) had a 12-month prevalence of 52% for hand or wrist symptoms on the mouse side, while the prevalence of male CAD operators ($N=25$) was 20% ($P<0.05$). No significant difference was found between the men and women regarding mean age (women 38 years, men 37 years), seniority (women 12 years, men 9 years), or mean score for of psychological demands (women 67, men 70).

Workplace study

For the upper limb operating the mouse, the mean number of repetitive movements of the upper arm, the forearm, the hand, and the fingers was 12 (range 9–16)/min, 12 (range 9–15)/min, 13 (range 11–16)/min, and 48 (range 42–57)/min, respectively.

The upper arm operating the mouse was flexed and abducted from 0° to 30° for most of the time (table 2).

The wrist on the side operating the mouse was extended and ulnar-deviated for more than 90% of the worktime (table 3, figure 2). The mean central positions (50th percentile) of extension for the 2 wrists were similar, but the mean 10th percentiles of extension differed significantly ($P=0.002$). The range of motion, defined as the 95th-5th percentiles, for the wrist operating the mouse was significantly smaller than for the other wrist ($P<0.001$). In the plane of deviation, all the mean values of the angular positions and the range of motion for the wrist or hand operating the mouse were significantly different from the values of the other hand ($P<0.05$). The wrist-movement velocities of the hand operating the mouse were below $2^\circ/s$ for half of the worktime. The 90th percentile of the angular velocity in the plane of deviation for the hand operating the mouse was significantly higher than the velocity of the other wrist ($P<0.001$). Velocities lower than $1^\circ/s$ (pause) were registered for

Table 2. Upper-arm positions (shoulder joint position) for the arm operating the mouse, as registered by observations during CAD work ($N=20$). (CAD = computer-aided design)

Position	Percentage of time	
	Mean	SD
Flexion or extension		
Extension $>0^\circ$	10	20
Pause	16	16
Flexion 0° - 30°	68	24
Flexion 30° - 60°	5	5
Flexion $>60^\circ$	0	0
Abduction or adduction		
Adduction $>0^\circ$	1	3
Pause	14	19
Abduction 0° - 30°	81	20
Abduction 30° - 60°	4	9
Abduction $>60^\circ$	0	0

Table 3. Wrist positions, angular velocities, and pauses for the hand operating the mouse ($N=16$) and for the other hand ($N=18$), as recorded by electrogoniometry during CAD work. Positive values of the wrist positions denote extension or deviation in the ulnar direction; negative values denote flexion or deviation in the radial direction. The percentiles refer to the percentage of recording time (eg, for 10% of the time the mean hand extension on the mouse side was less than 150). (CAD = computer-aided design)

	Flexion or extension				Ulnar or radial deviation			
	With mouse		Without mouse		With mouse		Without mouse	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Positions (percentile)								
10th ($^\circ$)	15	11	3	15	4	7	-13	8
50th ($^\circ$)	26	10	24	12	14	6	-4	8
90th ($^\circ$)	34	10	41	12	21	5	9	10
95th-5th ($^\circ$)	27	9	50	21	23	5	31	12
Velocities (percentile)								
50th ($^\circ/s$)	2	1	0	0	2	1	0	0
90th ($^\circ/s$)	26	7	22	8	21	5	15	4
Pause								
Below $1^\circ/s$ (% time)	28	8	56	11	31	7	61	9

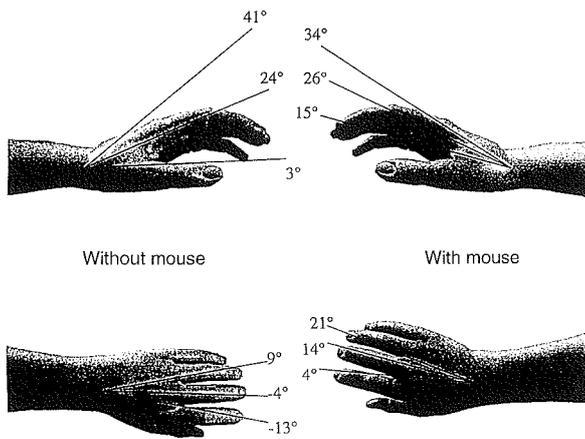


Figure 2. Wrist positions of the hand operating the mouse (N=16) to the right and of the other hand (N=18) to the left. Top half shows positions in the flexion-extension direction and the bottom half shows the wrist deviation. The mean values of the 10th, 50th, and 90th percentiles from the distributions of wrist angles recorded during CAD work are shown. (See table 3 for further details.)

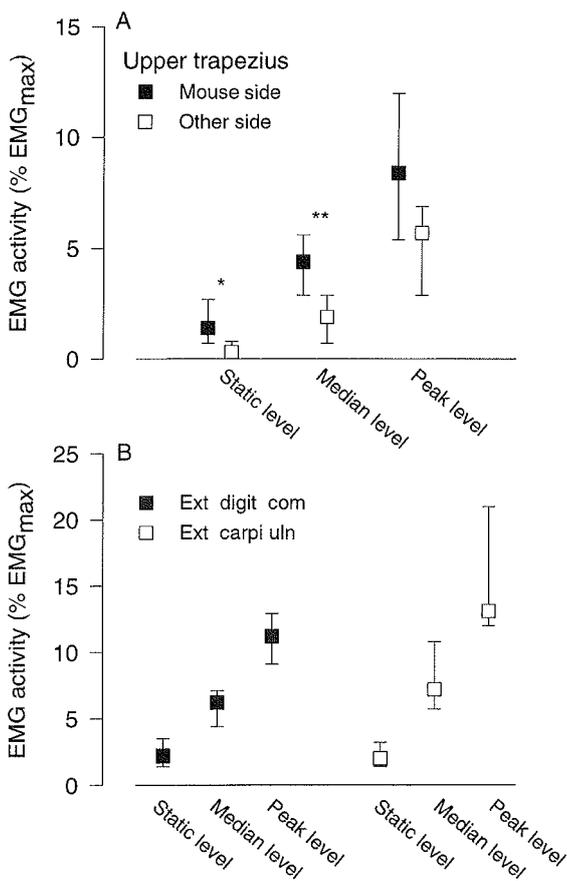


Figure 3. Median values of the electromyographic (EMG) activity levels recorded on shoulder (A) and forearm (B) muscles. Bars indicate 1st and 3rd quartiles. The differences between the EMG levels recorded on the upper trapezius muscles on the side operating the mouse and on the side not operating the mouse were tested with the Wilcoxon signed rank test: * $P < 0.05$, ** $P < 0.01$. (Ext digit com = extensor digitorum communis, Ext carpi uln = extensor carpi ulnaris)

about 30% of the worktime in both directions for the hand operating the mouse, whereas the duration of pauses for the other hand were twice as long ($P < 0.001$).

The static and median EMG activity levels recorded for the upper trapezius muscle on the side operating the mouse were significantly higher than on the other side (figure 3A). The EMG levels recorded for the forearm extensor muscles were similar to or slightly higher than the EMG levels recorded for the upper trapezius on the same side (figure 3B).

The mean level of job demands associated with CAD work was assigned a score of 2.3 on a scale from 0 to 4. For most of the CAD operators many sources of information imposed a constant perceptive demand and high mental demands of processing this information, which was sometimes interrupted by other sources of input. Demands for fast reaction times were never observed. On a similar scale the mean score of job control was 2.0. The CAD operators had some influence on the planning and organization of the tasks between workers. They had low influence on the work methods used, but each CAD operator could determine his or her own work pace.

Discussion

The computer mouse (ie, puck or ordinary mouse) was reported to be the most frequently used input device among the CAD operators both in terms of the number of workers choosing the mouse instead of alternative input devices such as pen and trackball and in terms of daily worktime as compared with the time performing keyboard operations. While answers relating to the type of input device used are probably valid, self-reported estimates of duration of specific work demands may be highly inaccurate (13). This is also the case for computer tasks, where overestimates of the duration of data entry have been reported, partly because interruptions (eg, telephone calls, desk work, etc) may be included in such estimates (14). However, the estimates of mouse use duration were probably just as valid as the estimates of the duration of work with other input devices such as the keyboard. Thus it can be concluded that CAD work with a mouse was the main task of the respondents in our study. The higher prevalences of musculoskeletal problems for the hand, wrist, elbow, and shoulder operating the mouse than for the contralateral side were probably due to the mouse use per se, even though the causal relationship cannot be verified with a cross-sectional study design. Thus the difference did not appear to be an effect of dominant versus nondominant sides, which was supported by data from a study of 5940 Danish employees (1), where 16% and 13% of the women reported symptoms within the last year in the right and left hand or wrist, respectively (unpublished data). The prevalences

of musculoskeletal symptoms in the hands or wrists, elbows, and possibly the neck among the respondents were higher than reported for some groups of workers exposed to highly repetitive worktasks (eg, sewing machine operators, for whom reported 12-month prevalences in the hand or wrists, elbows (one or both sides), and neck were 32%, 7% and 56%, respectively (15). The prevalences were still high if the nonrespondents, (ie, 38% of the CAD operators) would have been free of symptoms. Thus the most conservative estimate of the true 12-month prevalences for the hand or wrists, elbows (one or both sides), and neck of the CAD operators were 32%, 25%, and 43%, respectively.

Previously Karlqvist et al (3) reported that musculoskeletal symptoms were more prevalent among female than male CAD operators. In our study this was only the case for the hand or wrist and elbow regions, whereas the prevalences of shoulder and neck symptoms were similar for the women and men. We cannot explain the gender differences from our present data, but we chose to focus our workplace study on female CAD operators due to their frequent reports of musculoskeletal symptoms.

The workplace study showed that CAD work was performed with repetitive movements of the upper arm, elbow, wrist, and fingers on the side operating the mouse. The number of movements of the arm, elbow, and wrist exceeded the limits of 2.5/min, 10/min and 10/min, as suggested by Kilbom (16), to indicate highly repetitive work that is a risk factor for developing musculoskeletal disorders. The movements were, in general, small, as indicated by the posture analyses. The wrist of the hand operating the mouse was in a relatively fixed, extended and ulnar-deviated posture, which was similar to wrist postures recorded during text editing with an ordinary mouse and suggested as a risk factor for musculoskeletal discomfort (17). The wrist movement velocities were low if compared with the corresponding velocities of other types of repetitive work (8, 18).

The upper trapezius EMG levels were similar to EMG levels recorded during keyboard work, office work, and light assembly line work (19, 20), but they were low when compared with EMG levels recorded during other types of highly repetitive work; for example, the mean EMG levels of the upper trapezius muscle recorded during electronic assembly work or sewing machine work were 15% of the EMG_{max} (21, 22). The median value of the static EMG level of the upper trapezius operating the mouse (1.4% EMG_{max}) was higher than that of the upper trapezius on the other side (0.3% EMG_{max}), indicating that the muscle on the side operating the mouse was active for a longer period of the recording time. The difference between the static and peak levels of EMG activity was less than 10% EMG_{max} (ie, in 80% of the time the EMG activity varied within 10% EMG_{max}),

indicating that little variation in the level of muscular activity was present. Similar conclusions can be drawn for the forearm muscles, for which the EMG levels were considerably lower than the EMG levels recorded during repetitive work with other hand tools, for example, during meat cutting, in which the mean EMG levels recorded on wrist extensor muscles was higher than 20% EMG_{max} (23). For the meat cutters the 12-month prevalence of hand symptoms was 60%. Thus for the CAD operators the actual level of muscular activity does not seem to explain the high prevalence of musculoskeletal symptoms. More likely, repetitive movements without notable postural variation may require prolonged activation of shoulder and forearm muscles and thereby present a risk for developing musculoskeletal symptoms (16, 24). CAD work with a puck and digitizer differs from ordinary mouse work in some respects; for example, the digitizer is usually placed in front of the CAD operator, implying that a lateral location of the mouse suggested as a risk factor for upper limb discomfort (3) cannot explain the high prevalences of symptoms found in our study. Repetitive work in any static posture probably induces musculoskeletal discomfort.

Both the self-reported and observed mental job demands were found to be relatively high for the CAD operators. This finding may contribute to provoke undesired physiological responses, as mental demands and high precision demands can induce static muscular activation patterns, at least in the upper trapezius muscle (25, 26). On the other hand, the CAD operators also had relatively high observed and self-reported levels of decision latitude and relatively high levels of self-reported support from colleagues and superiors. Whether such support reduces the risk of developing musculoskeletal symptoms is difficult to assess; however, it may have beneficial effects on the mental state and well-being of CAD operators.

In conclusion, exposure during CAD work involved repetitive movements, fixed work postures, and high cognitive demands. Thus intervention aiming at improving the exposure should limit the length of time CAD work is performed with a mouse by introducing other tasks, preferably without computer work. The use of alternative input devices during computer work can also be considered. However, it is not known whether this type of intervention would lead to a variation in exposure that would reduce the risk of developing musculoskeletal symptoms.

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References

1. Borg V, Burr H, editors. *Danske lønmodtageres arbejdsmiljø og helbred 1990—95* [Work environment and health among Danish employees 1990—1995]. Copenhagen: National Institute of Occupational Health, 1997. In Danish
2. Fogleman M, Brogmus G. Computer mouse use and cumulative trauma disorders of the upper extremities. *Ergonomics* 1995;38(12):2465—75.
3. Karlqvist L, Hagberg M, Köster M, Wenemark M, Ånell R. Musculoskeletal symptoms among computer-assisted design (CAD) operators and evaluation of a self-assessment questionnaire. *Int J Occup Environ Health* 1996;2:185—94.
4. Franzblau A, Flaschner D, Albers JW, Blitz S, Werner R, Armstrong T. Medical screening of office workers for upper extremity cumulative trauma disorders. *Arch Environ Health* 1993;48(3):164—70.
5. Carter JB, Banister EW. Musculoskeletal problems in VDT work: a review. *Ergonomics* 1994;37(10):1623—48.
6. Faucett J, Rempel D. VDT-related musculoskeletal symptoms: interactions between work posture and psychosocial work factors. *Am J Ind Med* 1994;26:597—612.
7. Kuorinka I, Jonsson B, Kilbom Å, Vinterberg H, Biering-Sørensen F, Andersson G, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl Ergon* 1987;18(3):233—7.
8. Hansson G-Å, Balogh I, Ohlsson K, Rylander L, Skerfving S. Goniometer measurement and computer analysis of wrist angles and movements applied to occupational repetitive work. *J Electromyographical Kinesiology* 1996;6(1):23—35.
9. Jonsson B. Measurement and evaluation of local muscular strain in the shoulder during constrained work. *J Hum Ergol* 1982;11:73—88.
10. Hackman JR. *Work redesign*. Reading (MA): Addison-Wesley, 1990.
11. Warr PB. *Work, unemployment and mental health*. London: Oxford University Press, 1991.
12. Kern H, Schumann M. *Industriearbeit und Arbeiterbewusstsein*. Frankfurt: Europäische Verlagsanstalt, 1970.
13. Viikari-Juntura E, Rauas S, Martikainen R, Kuosma E, Riihimäki H, Takala E-P, et al. Validity of self-reported physical work load in epidemiologic studies on musculoskeletal disorders. *Scand J Work Environ Health* 1996;22:251—9.
14. Fernström, E. *Physical load in computerised office work — with special reference to work tasks and equipment* [dissertation]. Stockholm: Institutionen för Miljöskydd och Arbetsvetenskap, Kungliga tekniska Högskolan, 1997.
15. Schibye B, Skov T, Ekner D, Christiansen JU, Sjøgaard G. Musculoskeletal symptoms among sewing machine operators. *Scand J Work Environ Health* 1995;21:427—34.
16. Kilbom Å. Repetitive work of the upper extremity: part II — the scientific basis (knowledge base) for the guide. *Int J Ind Ergon* 1994;14:59—86.
17. Karlqvist L, Hagberg M, Selin K. Variation in upper limb posture and movement during word processing with and without mouse use. *Ergonomics* 1994;37(7):1261—7.
18. Marras WS, Schoenmarklin RW. Wrist motions in industry. *Ergonomics* 1993;36(4):341—51.
19. Hagberg M, Sundelin G. Discomfort and load on the upper trapezius muscle when operating a wordprocessor. *Ergonomics* 1986;29(12):1637—45.
20. Jensen C, Nilsen K, Hansen K, Westgaard RH. Trapezius muscle load as a risk indicator for occupational shoulder-neck complaints. *Int Arch Occup Environ Health* 1993;64:415—23.
21. Christensen H. Muscle activity and fatigue in the shoulder muscles of assembly-plant employees. *Scand J Work Environ Health* 1986;12(6):582—7.
22. Jensen BR, Schibye B, Sjøgaard K, Simonsen EB, Sjøgaard G. Shoulder muscle load and muscle fatigue among industrial sewing-machine operators. *Eur J Appl Physiol* 1993;67:467—75.
23. Christensen H, Larsen J. Handgrip strength and forearm muscle activity during meat cutting. In: *PREMUS book of abstracts*. Montreal: IRSST, 1995:72—4.
24. Winkel J, Westgaard R. Occupational and individual risk factors for shoulder-neck complaints: part II — the scientific basis (literature review) for the guide. *Int J Ind Ergon* 1992;10:85—104.
25. Westgaard RH, Jensen C, Nilsen K. Muscle coordination and choice-reaction time tests as indicators of occupational muscle load and shoulder-neck complaints. *Eur J Appl Physiol* 1993;67:106—14.
26. Wærsted M, Eken T, Westgaard RH. Activity of single motor unit in attention-demanding tasks: firing pattern in the human trapezius muscle. *Eur J Appl Physiol* 1996;72:323—9.