Original article

Scand J Work Environ Health 1999;25(3):255-263

doi:10.5271/sjweh.432

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The following articles refer to this text: 2002;28(1):18-24; 2012;38(3):193-208

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This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/10450777

Scand J Work Environ Health 1999;25(3):255—263

Effects of an ergonomic training program on workers with video display units

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Brisson C, Montreuil S, Punnett L. Effects of an ergonomic training program on workers with video display units. *Scand J Work Environ Health* 1999;25(3):255—263.

Objectives This study evaluated the effect of an ergonomic training program on workstation changes and on the prevalence of musculoskeletal disorders among video display unit (VDU) users at a large university.
Methods A pretest-posttest design with a reference group was used with random allocation of administrative and geographic units. In each group, the measurements involved direct observation of the workstations, a self-administered questionnaire, and a physical examination. The measurements were performed 2 weeks before and 6 months after the training in parallel in both groups. The study population was composed of 627 workers (81% of those eligible).
Results The prevalence of all 3 of the postural stressors evaluated decreased in the experimental group after the training. In the reference group, 2 of the 3 stressors decreased in frequency but to a less extent. Some of these beneficial changes were more frequent in workers under 40 years of age. The prevalence of musculoskeletal disorders decreased among the workers under 40 years of age in the experimental group, from 29% to 13% determined by questionnaire and from 19% to 3% determined by physical examination. In other groups, there was no significant change in the prevalence of musculoskeletal disorders.
Conclusions Improvements in postural stressors occurred more frequently in the experimental group, and these beneficial changes tended to be more frequent in workers under 40 years of age. Improvements in musculoskeletal disorders occurred in the experimental group among the workers under 40 years of age.

Key terms age, clerical work, intervention study, musculoskeletal disorders, physical examination, static postural load, work station components.

Musculoskeletal disorders include conditions that affect muscles, tendons and tendon sheaths, peripheral nerves, joints, and other soft tissues. The reported incidence of such disorders in the upper extremities has increased dramatically in the past 15 years; since 1989 they have accounted for over one-half of all work-related illnesses in the United States (1). Several epidemiologic studies have linked these neck and upper extremity disorders to exposure to ergonomic stressors in work with a video display unit (VDU), especially such factors as rapid and repetitive keying in data entry tasks and poor workstation design leading to anatomically nonneutral body postures (2).

VDU use with computers has increased dramatically since their introduction in the early 1980s. At the end of the last decade, estimates of the number of units in use ranged from 40 to 70 million in the United States alone (3). VDU use is not limited to 1 economic sector; increasing numbers of people have seen changes in the content of their jobs, with consequences for both mental and physical work demands. Office workers who are intensive users of a VDU now represent about 15% of the

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entire working population in Canada, and women comprise about 80% of all office workers (4).

A limited number of formal intervention studies has been published to date to evaluate the effectiveness of ergonomic intervention in the office environment. This trend suggests that changes in workstations and work content may reduce morbidity and disability (5—10). On the other hand, there is a clear consensus in the literature that the effect of intervention aimed at reducing musculoskeletal disorders among workers has too rarely been evaluated formally and that most available evaluation studies have serious methodological limitations (11—13).

At a large university in Canada, work involving a VDU was recognized as presenting a potential hazard to employees in both administrative and academic departments. An ergonomic training program was developed to enable clerical workers to identify postural stressors in their job and make appropriate changes in VDU equipment, furniture, and work activities to reduce such stressors. The objective of this study was to evaluate the effect of this training program on the prevalence of postural stressors and appropriate features of workstations and the prevalence of musculoskeletal disorders among VDU users at the university.

Methods

Design

A pretest-posttest study design was used. Administrative and geographic units of the university were randomly allocated to the experimental and reference groups. The experimental group received the training in the first year, while the reference group, composed of workers employed in similar jobs, did not receive the training until the following year (after the formal study was concluded). The prevalence of musculoskeletal disorders and other relevant variables was measured using identical methods 2 weeks before and 6 months after the training in both groups. In the text, the expression "before and after the training" is used without distinction for the experimental and the reference group, given that, in the latter, measurements were taken within the same time frame as in the former.

Study population

The study population was composed of workers employed in a large university (90%) and in other institutions involved in university services (10%). Eligible workers were those working 5 hours or more per week with a VDU. The list of eligible workers was provided by the employer. Workers were assigned to the experimental or reference group on the basis of the units in which they worked. Forty administrative and geographic units were randomized to receive training in either the first (experimental group) or second (reference group) year of the program. The units were stratified before randomization on the basis of the number of clerical workers (<20 and ≥20) and type of services (administrative and teaching) in order to insure equal distribution of these features in each group. The workers belonging to the experimental group usually worked in different buildings and were employed in different administrative units than the workers belonging to the reference group. The units in which the ergonomic program was pretested (N=104 workers) were excluded from the study. The 627 workers who participated in both the base line and the 6-month measurements represented 81% of the persons eligible at the base line. The reasons for nonparticipation were refusals (11% for the first measure and 4% for the 6-month follow-up measure), long-term leave (2.5%) and not being traced (1.5%). The experimental and reference groups were composed of 284 and 343 workers, respectively. The proportion of nonparticipants in each step was comparable in the 2 groups.

The study population was composed of 80% women, the mean age being 43 years; 50% were involved in leisure-time physical activity less than 2 times per week; 12% had a body mass index of >27; and less than 10% had diabetes or thyroid disease. Over 75% of the study population was composed of clerical workers, and the mean number of years worked in the current job was 8 years. The mean number of hours worked on a VDU per week was 20; close to 85% had at least 1 postural stressor at the time of the baseline; and 20% had a job involving both high demands and low latitude. The 2 groups were comparable on all these factors. Smoking was more prevalent in the reference group (22%) than in the experimental group (13%).

Ergonomic training program

The ergonomic training program was developed according to the PRECEDE (predisposing, reinforcing and enabling causes in educational diagnosis evaluation) model (14). The objective of the program was to act on characteristics of the work environment and the workers that determine behavior in order to motivate and enable employees to improve the ergonomic features of their workstation. *Predisposing* factors relate to knowledge, beliefs, attitudes and values; *enabling* factors relate to skills and material resources; and *reinforcing* factors relate to support provided by the environment. The program targeted the following 3 types of behavior: (i) adjusting the postural components of the workstation correctly; (ii) adjusting the visual components of the workstation correctly; and (iii) organizing work activities in a preventive manner (15).

The program was composed of 2 sessions of 3 hours each at a 2-week interval. A training guide was given to each participant (16). The sessions involved demonstrations, simulations, discussions, and lectures. In addition, each worker had to do a self-diagnosis of his (her) workstation using a photograph taken of him (her) at work before the program started. Each session was presented to about 15 workers with their supervisor at one time. The presence of the supervisor aimed at providing an organizational environment which was supportive of actions taken by the workers. The 2-week interval allowed the workers to apply knowledge and skills learned at the first session and to return to the second training session with questions and experiences to discuss. The trainers were 4 occupational health and safety professionals working for the employer and 1 occupational health and safety union representative, as mandated by the Quebec legislation on occupational health and safety. All the trainers were specially trained by one of the authors (SM), who met with them regularly to maintain the quality of the training throughout the program.

Data collection

Data were collected over 30 months (1994—1996). The measurements made in each group involved direct observation of components of the workstation and postural stressors, a self-administered questionnaire on musculoskeletal symptoms and other relevant variables, and a physical examination. These measurements were performed 2 weeks before and 6 months after the training in parallel in both groups.

Direct observations of the workstation were performed using a standardized grid developed especially for the study. The grid was used to evaluate and record workstation components potentially related to postural stressors (table 1) and the following 3 specific postural stressors: (i) twisted neck, (ii) inappropriate height of visual target, and (iii) broken (bent) hand-wrist line (17—21). The grid was first pretested at 30 workstations by 4 observers specially trained to make direct observations. Adjustments were made after the pretest to insure the validity of the observation and interobserver reliability. In addition, interobserver reliability was evaluated for 150 VDU workstations during the course of the study. The interobserver agreement was found to be higher than 95% for all the items presented in table 1 (22). The interobserver reliability could not be evaluated for the 3 postural stressors presented in figure 1.

The questionnaire evaluated musculoskeletal symptoms of the neck-shoulder, hand-wrist, and lower back regions (23—25). The prevalent musculoskeletal disorders on the questionnaire were defined as those which were present on 3 days or more during the last 7 days and for which the intensity of pain was greater than half the visual analogue scale (VAS) among the subjects with no history of inflammatory disease or acute injury at the relevant anatomic site. Duration was evaluated by the question "When did you first note this problem or pain?", and scales measuring psychological job demands, job-decision latitude (26), control over work pace and duration of continuous work on a VDU, other job characteristics, and life-style factors were included. Each worker completed the questionnaire at his or her desk on the same day that the observations of the workstation were made.

The physical examination was performed on workers who reported symptoms meeting the case definition. It was performed by a trained occupational therapist blinded to the subject's assigned group according to a standard protocol used in previous studies (23, 25, 27). The examination was performed 2 to 5 weeks after the

Table 1. Prevalence of workstations with appropriate components before (T1) and after (T2) the training in the experimental and reference groups by age.

Appropriate components at the workstation	Subjects <40 years				Subjects ≥40 years			
	Experimental (N=97)		Reference (N=110)		Experimental (N=187)		Reference (N=233)	
	T1 (%)	T2 (%)	T1 (%)	T2 (%)	T1 (%)	T2 (%)	T1 (%)	T2 (%)
1. Utilization of a copy holder	54	63*	48	46	60	65	49	51
2. Copy holder at same height as screen	7	29*	19	15	19	32*	15	16
3. Copy holder at same angle as screen	5	27*	16	17	17	20	11	13
4. Keyboard table adjustable in height	46	51	25	26	31	35	27	28
5. Rotation of the keyboard in neutral position	55	66*	40	40	53	59	43	46
6. Utilization of hand support	38	49*	27	32*	30	47*	29	32*
Regular use of mouse[a]	71	74	65	73*	67	74*	71	75
7. Mouse at same level as keyboard	61	67	66	77*	66	70	77	78
8. All levers for adjustments of chair usable when sitting	81	91*	92	89	90	94*	86	85
9. Possible extension of legs under table	92	98*	86	92	89	93	91	89
10. Utilization of foot support	31	57*	40	42	41	53*	36	38

[a] This information is presented to better understand item 7. The regular use of a mouse was not associated with an effect of training.
* $P<0.05$ for the difference between T1 and T2 within an assignation group.

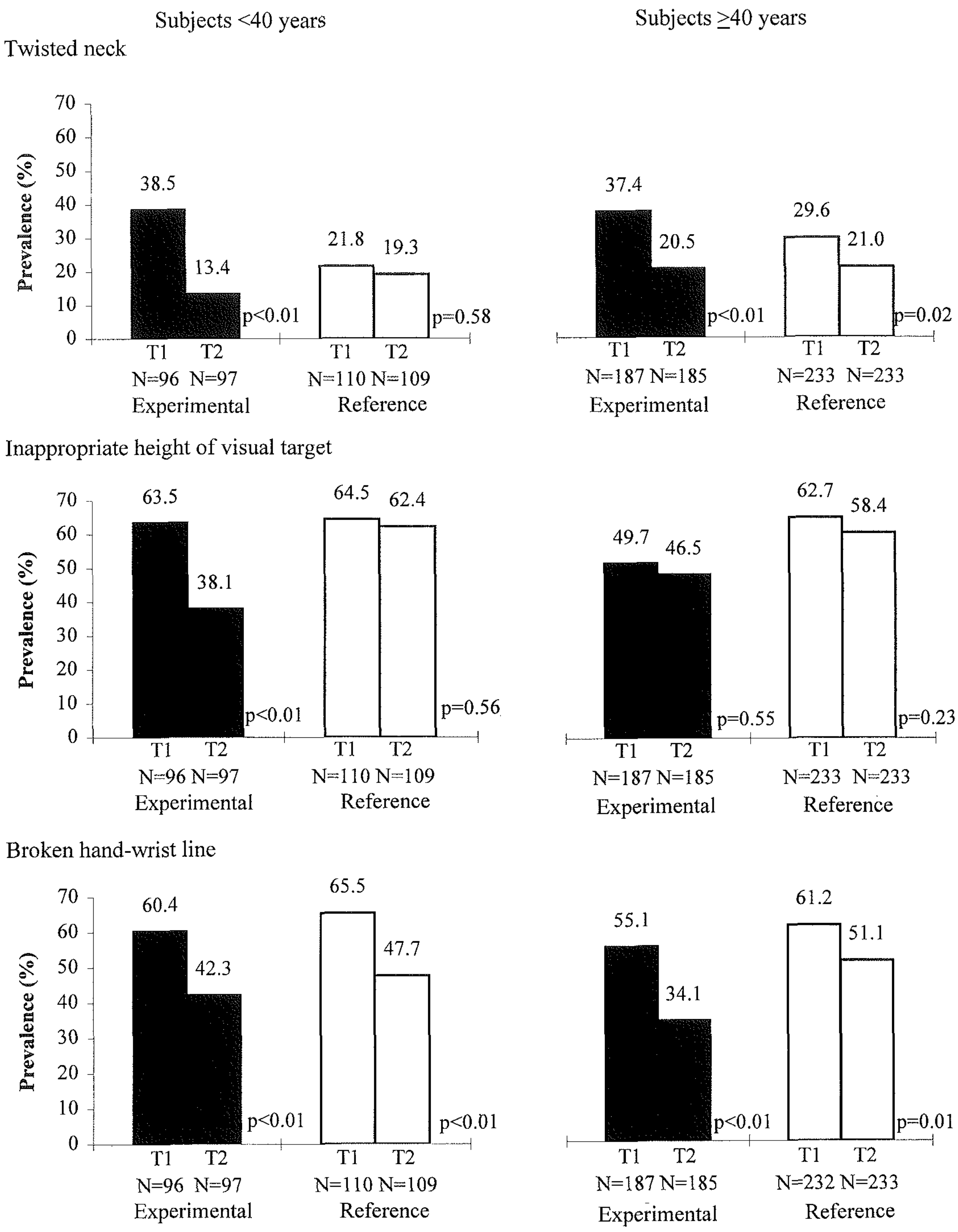

Figure 1. Prevalence (%) of 3 postural stressors before (T1) and after (T2) the training in the experimental group and in the reference group by age.

questionnaire was filled out. This time interval was evenly distributed among the groups and pre-post situations. Prevalent musculoskeletal disorders were defined in the physical examination as those that met the questionnaire definition and had one of the following findings: (i) a positive Phalen's test (carpal tunnel syndrome), (ii) a positive Finkelstein's test (de Quervain's disease), (iii) a positive straight leg raising test (low-back pain) (28), (iv) a diminution of 30% or more of the normal range of motion (ROM), (v) a diminution of normal muscular strength (MS) scored 4 on the Lovett scale, a scale ranging from 0 to 5 (29), (vi) a pain of intensity 3 on the numerical VAS scale (a scale ranging from 0 to 10) produced at the relevant anatomic site during maneuvers iv or v. Items iv, v and vi were assessed for all 3 anatomic areas as follows: (i) wrists (ROM: flexion, extension; MS: flexion, extension); (ii) hands [ROM: fingers metacarpal phalangeal (MCP) flexion and extension, thumb flexion and extension; MS: index MCP extension and pinky abduction]; (iii) neck-shoulders (ROM: abduction, flexion, external rotation; MS: abduction, lateral rotation, medial rotation); (iv) lower back (ROM: flexion, extension, lateral flexion, trunk rotations).

The physical examination began 3 months after the data collection had started. It was thus restricted to 496 subjects (79% of the study population) who were enrolled from that time to the end of the study.

Analysis

The prevalence of workstation components, postural stressors, musculoskeletal disorders evaluated by the questionnaire, and those evaluated by the physical examination was compared before and after the training in each group using the McNemar test (30). Age, number of hours of VDU use per week, seniority in the current job, and the combination of high demands and low latitude were evaluated as potential effect modifiers in all the analyses using a stratified analysis (31). In addition, leisure-time physical activity, smoking, and body mass index were evaluated as potential effect modifiers for the effect of training on musculoskeletal disorders. A P-value of 0.05 was defined as the criterion for statistical significance.

Results

In the experimental group, the prevalence of all 3 postural stressors (twisted neck, inappropriate height of visual target, and broken hand-wrist line) decreased after the training. In the reference group, it did not decrease for the inappropriate height of the visual target, and the decreases observed for the 2 other stressors were smaller than those observed in the experimental group. There was a modifying effect of age for some of these changes (figure 1). In the experimental group, the prevalence of an inappropriate height for the visual target decreased only in workers less than 40 years of age. For a twisted neck, the decrease was larger for these workers.

There was also some evidence of a modifying effect of age on improvements of the appropriate workstation components (table 1). For the workers less than 40 years of age, the prevalence increased significantly for 8 out of 10 items evaluated in the experimental group and for 3 out of 10 items in the reference group. For the workers 40 years or older, the prevalence increased significantly for 5 out of 10 items in the experimental group and for 1 item in the reference group.

The prevalences of musculoskeletal disorders measured before the training, for the 3 anatomic areas combined, was 21% by questionnaire and 12% by physical examination (figure 2). Neck-shoulder disorders were the most frequent, followed by lower back disorders, while wrist-hand disorders were the least frequent. For each anatomic area, the prevalence measured using the questionnaire definition was about twice as high as that evaluated by the physical examination.

In the experimental group, the prevalence of musculoskeletal disorders of all 3 anatomic areas, by questionnaire, was similar before and 6 months after the training program. In the reference group, similar results were also observed before and after the training. However, age had a modifying effect. The results were similar for each of the 3 anatomic areas with both the questionnaire and the physical examination. Therefore, the results are presented for all 3 anatomic areas combined (figure 3). In the experimental group, the prevalence of musculoskeletal disorders decreased significantly among the subjects under 40 years of age. For these workers, the prevalence of

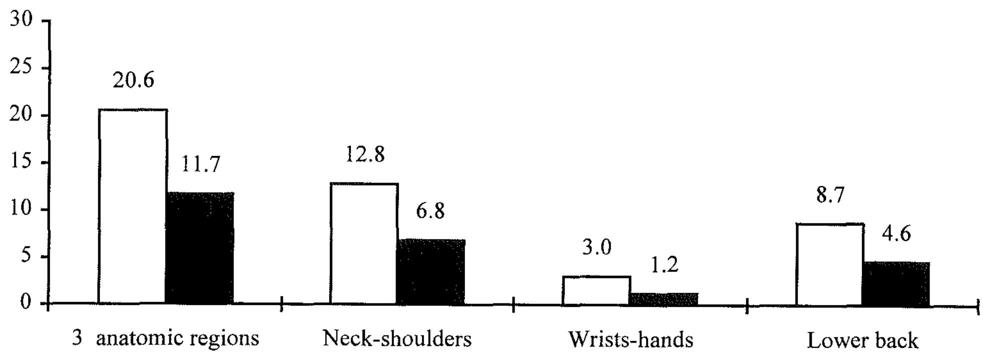

Figure 2. Prevalence of musculoskeletal disorders according to the questionnaire and the physical examination of all the subjects 2 weeks before the training (N=627).(open column = questionnaire definition: symptoms 3 days or more during the last week for which the intensity of pain was greater than half of the visual analogue scale among the subjects with no history of inflammatory disease or acute injury at the relevant anatomic site; solid column = physical examination: musculoskeletal problem which met the questionnaire definition and had a positive result in the physical examination)

29% observed before the training had decreased to 13% 6 months after. In the reference group, there was also a decrease among the subjects under 40 years of age, but it was less marked and did not reach statistical significance. For the subjects 40 years or older, the prevalence of musculoskeletal disorders determined by the questionnaire had increased slightly after the training in both groups. However, neither of these changes was significant.

The results of the physical examination showed a similar modifying effect for age (figure 3). In the experimental group, the prevalence of musculoskeletal disorders determined by the physical examination decreased dramatically among the subjects younger than 40 years, from 19% before the training to 3% 6 months after. In the reference group, there was also a decrease in the prevalence among the subjects younger than 40 years of age, but it was less marked and was not statistically significant. For the subjects 40 years or older, the prevalence of musculoskeletal disorders determined by the physical examination also seemed to increase after the training in both groups, but the changes were not significant.

Five other factors (hours of VDU use per week, the combination of high psychological demands and low latitude, leisure-time physical activity, smoking, and body mass index) were examined as potential effect modifiers of the change in the prevalence of musculoskeletal disorders between the 2 evaluations. In the stratified analyses, none of these factors showed a difference comparable with that observed between the older and younger workers.

We also evaluated potential confounding factors with respect to the effect found among the workers under 40 years of age. In this age group, the experimental and reference groups were comparable for all the personal, biomedical, and occupational factors measured for the baseline, except for smoking which, as for the entire population, was more frequent in the reference group (not

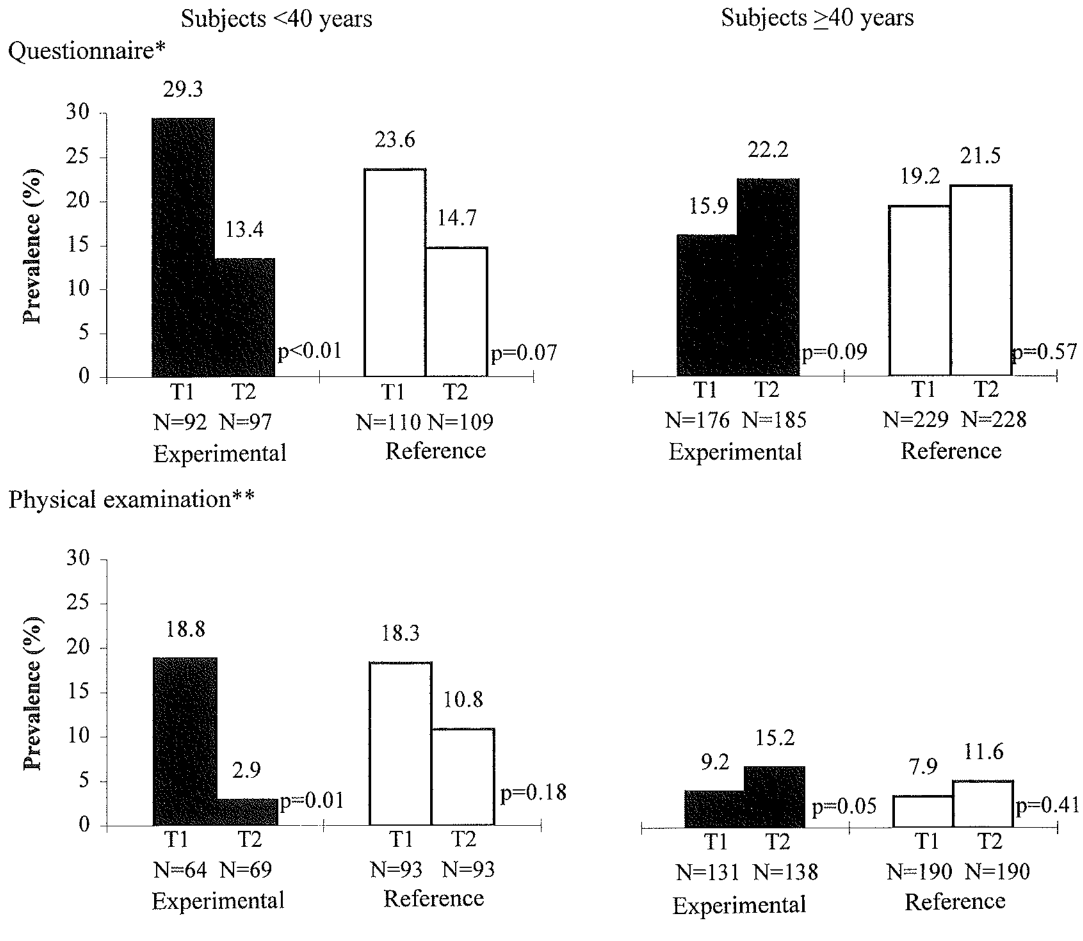

Figure 3. Prevalence of musculoskeletal problems as determined by the questionnaire and the physical examination for all 3 anatomic regions, before (T1) and after (T2) the training, in the experimental and reference groups by age. [* musculoskeletal symptoms present 3 days or more during the last 7 days, for which the intensity of pain was greater than half of the visual analogue scale among the subjects with no history of inflammatory disease or acute injury at the relevant anatomic site; ** musculoskeletal problem which met the questionnaire definition and had a positive result in the physical examination; the latter analysis was restricted to 496 subjects (79% of the study population) who received a physical examination]

shown). We also examined the variation in work load before and 6 months after the training according to the index of psychological demands. The prevalence of high psychological demands was comparable before and after the training (47% versus 43%) in the experimental group, while in the reference group it was higher before the training (59%) than 6 months after it (49%). If a lower work load is associated with smaller manifestations of musculoskeletal symptoms, our results might overestimate the decrease in the symptoms observed after the training in the reference group.

The intensity of pain measured on the VAS, the number of days of symptoms during the last week, and the number of functional limitations were similar in both age groups. However, the time elapsed since the reported onset of symptoms tended to be shorter for the younger than the older workers in both groups [experimental group (EG)= 4.5 years versus 7.7 years; reference group (RG)= 3.6 years versus 5.8 years]. As expected, seniority in the current job was lower for the younger workers in both groups. The proportion of workers using a VDU over 25 hours per week tended to be higher for the younger workers in both groups (EG: 48% versus 38%; RG: 41% versus 32%). No other factors differed by age group. The number of subjects was not sufficient to evaluate whether changes in the prevalence of musculoskeletal disorders were greater specifically for the workers whose postural stressors were decreased when compared with the others.

For the workers under 40 years of age, the net decrease in the prevalence of musculoskeletal disorders due to the training can be estimated to be 16% for the prevalence evaluated by the questionnaire and 44% for that evaluated by the physical examination [ND = De – Dc, where ND = net decrease in prevalence due to the training, D = decrease in prevalence, e = experimental group, r = reference group, and D = (Pb - Pa)/Pb, where P = prevalence, b = before, a = after]. This is a conservative estimate, given that it assumes that no "contamination" occurred from the experimental to the reference group.

Discussion

This study had major methodological strengths that helped to minimize the likelihood of selection and information bias. The percentages of participants were reasonably high at each measurement (88% and 94%) and also overall (81%). The percentages and reasons for nonparticipation were comparable in the experimental and reference groups. Workers were assigned to the experimental and reference groups on the basis of the administrative and geographic units in which they worked. Random allocation of the units, instead of workers, was done to minimize transfer contamination of information from the experimental group to the reference group. It also made the condition of the intervention more closely resemble real workplace training programs in that the intervention took place among all the workers who performed similar tasks in a given unit and the workers had the opportunity to interact with their close fellow workers during and after the program.

The prevalence of musculoskeletal disorders was evaluated using both self-reported and objective measures. Both approaches gave consistent results, which provides strong support for the validity of each measure. The order in which the prevalence of the musculoskeletal disorders observed for each anatomic area ranked was comparable with what was observed in previous studies of VDU workers (32), and the proportion of disorders on the questionnaire and also confirmed by the physical examination (about 60%) was consistent with the results of other studies that have used similar methods (24, 25, 27). The experimental and reference groups were composed of workers employed in similar jobs in a single organization. Both groups were comparable on all the personal, biomedical, life-style (except smoking), and occupational factors measured in the base-line examination. In addition, for workers under 40 years of age, the experimental and reference groups were also comparable with regard to these factors. Given that the measurements were taken within the same time frame in the experimental and the reference groups, seasonal variations were evenly distributed in both groups. These results demonstrate that neither the global comparison between the 2 groups nor that among workers under 40 years of age was likely biased by confounding. If anything, the variations observed in work load before and after the training indicate that our results may have underestimated the true difference occurring between the experimental and reference groups of workers under 40 years of age.

One limitation of the study is that contamination probably occurred; therefore, the observed effect of the intervention was likely to be an underestimation of the true effect.

The modifying effect of age observed in the results is possibly consistent with the findings of Parenmark et al (33), who demonstrated a reduction in arm-neck-shoulder complaints after ergonomic training only among workers who were newly hired, although the authors did not examine the effect of age directly. Age could have had a modifying effect on the success of the intervention because of several factors. The proportion of workers who spent more than 25 hours working with a VDU was higher among the younger workers, and these workers also had less seniority. Thus younger workers may be more inclined to make changes in their workstation, since they spend more time at the VDU and, as they have worked in their jobs for shorter periods of time, their work habits might be more easily modified. These beneficial changes in postural stressors and workstation components could contribute to explain the modifying effect of age observed for musculoskeletal disorders. However, the difference between the younger and older workers in the effects on the disorders appears to be much greater than the differences in the frequency of ergonomic improvements, so it is not evident that changes in exposure explain all of the effect modification by age.

The data also suggest that the time elapsed since the beginning of symptoms could also contribute to a larger decrease of musculoskeletal disorders in younger workers. Indeed, the symptoms tended to have started more recently in the younger workers. Musculoskeletal disorders which are of recent onset could be more reversible than those which have lasted for a longer period of time. In this regard, it may also be that the ergonomic improvements reduced the onset of new disorders, but they were not sufficient to influence the recovery of longstanding cases. Along the same line, younger workers may have a higher capacity to recover or the period necessary for recovery could be shorter. A third factor that could contribute to the modifying effect of age on the decrease in musculoskeletal disorders is that the younger workers had a higher prevalence of musculoskeletal disorders before the training. Among these workers, the proportion of those who could benefit from the training was indeed twice as high as among the older workers. This situation left more room for a reduction of symptoms. This higher prevalence of symptoms in younger workers is consistent with the fact that they spent more time working on a VDU. It is also consistent with a healthy worker effect in that, among the older workers, those with musculoskeletal problems may have quit their job (34).

In conclusion, 6 months after the training program, improvements in postural stressors and workstation components occurred more frequently in the experimental group, and these beneficial changes tended to be more frequent among workers under 40 years of age. Improvements in musculoskeletal disorders were observed in workers under 40 years of age in the experimental group.

Acknowledgments

We thank the workers who participated in this study, their employer, and the union representatives. Special thanks are due to C Bélanger, who managed the training program. We also thank M Arial, S Bergeron, M Veilleux, and N Perreault for their help with the data collection; P Bernard, L Desgroseillers, and C Blanchette for the statistical analyses, and Céline Valin for the clerical work.

This study was funded by the Institut de Recherche en Santé et en Sécurité du Travail du Québec (IRSST), the Social Sciences and Humanities Research Council of Canada (SSHRC), and the Fonds pour la Formation de Chercheurs et l'Aide à la Recherche (FCAR). Chantal Brisson was a national health research scholar for Health Canada at the time of redaction.

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Received for publication: 9 January 1998