Workplace Changes Associated with a Reduction in Musculoskeletal Symptoms in Office Workers

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The purpose of this study was to identify factors associated with reductions observed in musculoskeletal symptoms when office workers were moved to a new building. A questionnaire including items regarding symptoms and aspects of the work environment was administered to 577 office workers before and after they were moved from nine buildings to a single new facility in 1992. Employees working in two reference buildings, where they remained throughout the study period, were also surveyed. Two musculoskeletal outcomes, hand/arm and neck/shoulder/back, were selected for study. In matched multivariate analyses, the reduction in hand/arm symptoms from 1992 to 1993 was associated with improved satisfaction with the physical workstation (odds ratio [*OR*] = 2.0); the reduction in neck/shoulder/back symptoms was associated with improved chair comfort (*OR* = 1.8), fewer housekeeping responsibilities (*OR* = 3.6), female gender (*OR* = 1.8), and low pay range (*OR* = 1.7). Longitudinal results suggested that changes in workstations resulted in decreased symptoms. Results of this investigation might be used to develop workplace changes that result in reductions of musculoskeletal disorders.

INTRODUCTION

Musculoskeletal symptoms have been shown to be associated with physical attributes of the work environment, psychosocial stressors, and personal characteristics of individuals employed in office buildings. Increases in back, neck, shoulder, arm, and hand pain have been shown to be related to intensive keyboard work, chair and workstation characteristics, job dissatisfaction, poor psychologic work environment, increased job demands, and female gender (Bammer, 1987; Bergqvist, Wolgast, Nilsson, & Voss, 1995; Bernard, Sauter, Fine, Petersen, & Hales, 1994; Bongers, De Winter, Kompier, & Hildebrandt, 1993; Hunting, Laubli, & Grandjean, 1981; Linton & Kamwendo, 1989; Punnett, 1994; Sauter, Gottlieb, Jones, Dodson, & Rohrer, 1983; Smith, Cohen, & Stammerjohn, 1981). Study populations have included newspaper reporters, computer programmers, clerical and administrative staff, and data and word processors, with particular emphasis on keying and use of computers.

Armstrong and colleagues suggested a dynamic cascading model for work-related musculoskeletal disorders, in which external exposures in the work environment (workstation configuration, work flow, supervisory support) contribute to an internal "dose" (e.g., biomechanical load on the shoulder girdle, frequency of finger extension, conflicting demands) that leads to a response (calcium ion accumulation in intracellular spaces, tendon creep, muscle contraction) that in turn becomes a new dose with cascading responses (Armstrong et al., 1993). This relationship is mediated by individual capacity (age, gender, health, endurance, and anthropometry).

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Depending on the intensity, frequency, and duration of exposures, the ultimate effect can be salubrious (training effect) or damaging (work-related musculoskeletal disorders). The expression of a disorder (reporting, disability) is often mediated by individual capacity and social climate. In this model, it is unlikely that a work-related musculoskeletal disorder would develop in the absence of physical overload. However, some have suggested that subjectively reported psychological risk factors can have physiological consequences that can lead to muscle pain in the absence of overt muscle activity (Bongers et al., 1993; Vasseljen & Westgaard, 1995).

The current study examines associations between musculoskeletal symptoms and individual and office workplace characteristics in an attempt to identify factors associated with lower rates of disorder. This study examines symptom rates in office workers at two points in time (before and after the group was moved from nine separate buildings to a single new facility). In the new building, employees were moved to workstations with adjustable chairs and keyboard trays that were specifically selected to improve comfort and reduce the likelihood of musculoskeletal disorders. The study hypothesis was that musculoskeletal symptom rates would decrease after employees were moved to the new facility. Two outcomes were selected: hand/arm and neck/shoulder/back symptom groups. Of particular interest were potential differences in risk factors identified for the two musculoskeletal outcomes and comparison of results for the relocated group of employees, who changed locations between surveys, with those for a reference group of employees, who remained in the same facilities over the study period. Few investigations have used a prospective study design to examine changes in musculoskeletal symptoms and their potential risk factors over time.

MATERIALS AND METHODS

Study Group

The relocated population consisted of 1452 Washington State Department of Labor and Industries employees working in nine buildings located in a single city. This group was moved from separate work facilities to a single new building in the summer of 1992.

Workstations in the former facilities varied in size, type, furnishings, and illumination level. In the new building, more than 90% of workstations were designed as modular units with uniform square footage, illumination level, wall partitions, furnishings, and adjustable work surface heights. Workstations were equipped with personal computers with adjustable-height keyboards and fully adjustable chairs. New chairs were available in three sizes with adjustable seat pan height and angle and seat back tilt. Chairs for employees whose major job responsibilities included data entry had additional features, including adjustable arm rests and a lumbar pump. Upon the move to the new building, all employees received 1 h of ergonomics awareness training, instruction in chair adjustment, and, if requested, a personal evaluation of their workstations and chair adjustments by an agency physical therapist.

There were 287 department employees working in two reference buildings who were also included in the study; these workers remained in the same facilities over the study period.

One reference building was an older facility (built in 1958); many employees working in this facility were out of the building for at least part of the work week. Furnishings and workstations were highly variable, but most had not been changed in 10 years or more. The other reference building, built in 1990, was more similar to the new facility: Workstations were modular, and new furnishings had been installed when the building was constructed. Work spaces in both buildings included private offices, shared rooms, and open spaces with and without partitions.

Functions carried out in agency buildings included administration of the state workers' compensation claim system and the workplace inspection program. Employee job responsibilities included clerical, administrative, and professional support.

Questionnaire

Potential study participants were invited to complete a self-administered questionnaire in March 1992, three to six months before the

move took place. Participation in the survey was encouraged but voluntary. The study was approved by the State of Washington's Department of Social and Health Services Human Subjects Research Review Board.

An identical questionnaire was administered in March 1993, one year after the first survey was conducted and seven months after the move to the new building was completed. Questionnaire responses from 1992 and 1993 were individually linked using a unique code created by respondents in order to preserve their anonymity. Individuals had to complete a questionnaire in both 1992 and 1993 in order to be included in the study group.

The questionnaire was adapted from a variety of instruments used by other researchers, including the U.S. Environmental Protection Agency (EPA) Indoor Environmental Quality Survey, the National Institute for Occupational Safety and Health (NIOSH) National Center for Health Statistics building and Library of Congress building study questionnaires, and the NIOSH Job Stress Instrument (Hurrell & McLaney, 1988; Hurrell, Sauter, Fidler, Wilcox, & Hornung, 1990; National Institute for Occupational Safety and Health, 1991). Questionnaire items included questions regarding demographic characteristics, physical and psychosocial attributes of the work environment, job satisfaction, work pace, influence over responsibilities, and stressors unrelated to work. The original NIOSH/EPA instrument, which was used in a number of indoor air quality investigations, included questions regarding respiratory, mucosal, dermal, and central nervous system symptoms (Malkin, Wilcox, & Sieber, 1996). Questions on musculoskeletal symptoms were developed following the same format. A copy of the full questionnaire is available from the authors upon request.

Statistical Methods

A large number of questions regarding environmental characteristics and psychosocial aspects of the workplace were included in the questionnaire. Given that many independent variables measured similar phenomena and were highly correlated, factor analyses (varimax rotation) were carried out to determine which variables could be combined to create fewer and unique dimensions. Factor analyses were completed using the 1992 questionnaire responses; analyses of potential risk factors were conducted separately for the physical environment and for psychosocial aspects of the workplace. Some variable scales were reversed as necessary to ensure that all included in any particular factor were in the same direction.

Similarly, questionnaire responses for musculoskeletal symptoms were highly correlated for several anatomic regions; factor analysis techniques were used to create fewer and unique outcome measures. Two dependent variables were created: hand/arm symptoms (numbness in hands or wrists, pain in hands or wrists, waking up at night because of hand pain, arm pain or numbness), and neck/shoulder/back symptoms (pain or stiffness in neck or shoulder, pain or stiffness in back). A *case* was defined as a report from any individual of at least one of the symptoms in each group for one to three days per week in the previous four weeks (or more), with symptom improvement when away from work.

Cross-sectional relationships between health outcome and potential risk factors were examined for the 1992 data set. Potential risk factors examined in analyses consisted of gender, year of birth, education level, history of rheumatoid arthritis, hours worked per week, times leaving the work building per day, pay scale, hours working at a video display terminal per day, factors for physical and psychosocial workplace characteristics, and outside responsibilities (child care, elder care, housekeeping, course work, or volunteer activities). For continuous or scored variables, dichotomous variables were created using median values as cut points. Potential risk factors that were statistically significantly related to health outcomes ($p < .05$) in two-way analyses were included in subsequent multivariate analyses. Relationships among independent variables were examined to identify potential colinearity to ensure that no risk factors included in multivariate models were strongly associated with one another.

The multivariate statistical approach used a logistic model, where the logit transform of the outcome probability in each risk category

is expressed as a linear function of regression variables for which the values correspond to levels of exposure to the risk factors, as follows (Breslow & Day, 1980):

$$\ln [P/(1 - P)] = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k.$$

P denotes the probability of the health outcome, and calculated coefficients correspond to odds ratios (OR), which estimate the relative risk of a particular factor or exposure. The relative risk for presence of a dichotomous factor is estimated by exponentiating the coefficient for that variable; for continuous variables, exponentiating the coefficient calculates the increase in risk for an increment of 1 on whatever scale is used. An OR greater than 1 indicates increased risk; an OR less than 1 indicates decreased risk.

Multivariate logistic regression (including stepwise logistic regression) was used for developing final models. In stepwise logistic regression analyses, criteria used to determine variables that would remain in final models

TABLE 1: Factors Representing Environmental and Psychosocial Characteristics of the Workplace Created by Grouping Questionnaire Variables

Factor Name	Direction	Cronbach's Alpha	Variables Included
Environmental factors			
Desk comfort	+	.87	Satisfaction with desk, arm rests, computer monitor or keyboard, telephone handset
Physical Satisfaction	+	.87	Satisfaction with workstation, privacy, amount of space, overall physical environment, problems with distraction
Glare	–	.76	Problems with glare related to lights, computer screens, windows
Chair comfort	+	.86	Satisfaction with chair adjustment or comfort
Psychosocial factors			
Good supervision	+	.85	Satisfaction with supervisory treatment, competence, praise, and policies
Clear expectations	+	.88	Clearness of job responsibilities, work objectives, and expectations
Work hard/fast	–	.79	Having to work hard or fast frequently, having a lot of work to do and little time
Job satisfaction	+	.76	Overall satisfaction with job, would take same job again, recommend it to others
Influence workplace	+	.68	Amount of influence over amount of work, work materials, policies, equipment
Conflicting demands	–	.78	Often given work projects to do by multiple supervisors that conflict with one another
High concentration	+/–	.64	Job requires a great deal of concentration
Salary satisfaction	+	.55	Satisfaction with salary and opportunities for advancement

Notes Cronbach's alphas represent correlations among variables combined to create factors (using 1992 questionnaire responses for relocated group, n = 577).

TABLE 2. Response Rates, 1992–1993

	Reference Group		Relocated Group	
	1992	1993	1992	1993
No. in building	287	187	1452	1616
No. respondents	179	110	998	1239
% response	62.4	58.8	68.7	76.7
Total no. matched questionnaires	55		577	
% of respondents	30.7	50.0	57.8	46.6
% of target population	19.2	29.4	39.7	35.7

included significance levels of .05 for entry into and removal from models. SAS statistical software was used (SAS Institute, Inc., 1996).

To compare results for the two years, matched statistical testing was carried out by linking individuals' 1992 and 1993 questionnaire responses. Logistic regression models examined the relationships between dichotomous health outcomes (symptom improvement vs. no improvement from 1992 to 1993) and potential risk factors. Longitudinal analyses included the same potential risk factors used in cross-sectional analyses (listed previously); however, independent variables might have remained the same from one year to the next (e.g., gender) or might have changed from 1992 to 1993. The latter were expressed by subtracting 1992 values from 1993 values. Unconditional logistic regression procedures were identical to those employed in cross-sectional analyses (described previously).

RESULTS

Factor Analyses

Four physical-environment risk factors were identified, which explained 60.4% of the variance of the 17 individual variables included in the analysis (Table 1). Eight psychosocial factors were identified, which explained 62.9% of the variance of the 29 individual variables included in the analysis (Table 1). Cronbach alpha coefficients ranged from .55 to .88 for the standardized variables that were created.

Study Participants

Table 2 shows questionnaire response rates by year for the relocated and reference groups (which ranged from 59% to 77%). In both survey years, response rates were higher for the relocated group than for the reference group. Because matching rates were particularly low for the two reference buildings, results for these two facilities were combined.

TABLE 3: Comparison of Matched Respondents to Total Population in Relocated and Reference Groups, 1993

	Reference Group		Relocated Group	
	Target	Matched	Target	Matched
n	187	55	1616	577
% female	55.1	65.5	66.6	71.4
% age 20–29	5.3	1.9	12.3	8.7
30–39	25.7	29.6	31.6	29.8
40–49	40.6	35.2	37.5	39.6
50–59	23.0	29.6	15.7	19.2
60+	5.3	3.7	2.9	2.7

TABLE 4: Matched Questionnaire Responses, 1992–1993: Physical Characteristics of the Work Environment

	Reference Group (n = 55)			Relocated Group (n = 557)		
	% Yes Response			% Yes Response		
Characteristic	1992	1993	p value	1992	1993	p value
Desk comfort	59	64	.44	49	63	<.0001
Physical satisfaction	78	78	1.0	49	74	<.0001
Chair comfort	56	64	.35	55	74	<.0001
Problems with glare	31	42	.083	46	54	.003
Work at VDT > 6 h/day	39	36	.62	49	46	.43
Work ≥ 40 h/week	69	62	.16	86	92	<.0001

Notes: Definitions for first four characteristics appear in Table 1. For continuous or scored variables, dichotomous variables were created using median values as cut points. p values compare responses for 1992 and 1993 (using matched analytical methods).

When age and gender distributions were compared for the matched respondents and the target population, matched respondents were slightly more likely to be female (Table 3). For the reference buildings, age distributions were similar for the matched and target groups; for the relocated group, matched respondents tended to be slightly older than the target population.

Questionnaire Findings

The majority of study participants were female; in 1992 the average ages were 41 and 44 for the relocated and reference groups, respectively. Both groups had an average of two years of college education.

Table 4 shows questionnaire responses regarding physical characteristics of the work environment for the relocated and reference groups for 1992 and 1993. In general, employees who were moved to the new building reported significantly more comfort and fewer problems with their physical work environments after the move. Similar but less marked changes were seen from 1992 to 1993 for reference building respondents (except for overall satisfaction with the physical workstation). No differences were statistically significant for the reference group because numbers were small. Table 5 shows responses regarding psychosocial aspects of the workplace. Most psychosocial workplace characteristics remained stable from 1992 to 1993 for both groups.

Musculoskeletal symptom rates are reported in Table 6. For relocated employees, symptom

TABLE 5: Matched Questionnaire Responses, 1992–1993: Psychosocial Aspects of the Work Environment

	Reference Group (n = 55)			Relocated Group (n = 557)		
	% Yes Response			% Yes Response		
Characteristic	1992	1993	p value	1992	1993	p value
Good supervision	46	45	1.0	56	56	.94
Clear expectations	49	53	.62	42	45	.19
Work hard/fast	36	50	.035	54	57	.20
Job satisfaction	67	55	.034	51	54	.13
Influence workplace	52	54	.76	53	48	.010
Conflicting demands	31	29	.80	40	41	.49
High concentration	71	73	.80	64	69	.007
Salary satisfaction	60	51	.32	61	61	.93

Notes: Definitions for characteristics appear in Table 1. For continuous or scored variables, dichotomous variables were created using median values as cut points. p values compare responses for 1992 and 1993 (using matched analytical methods).

rates decreased from 1992 to 1993 for nearly all anatomic regions, but particularly for the neck/shoulder/back. Overall symptom rates were lower for the reference group than for the relocated group. Neck/shoulder/back symptoms rates also decreased substantially from 1992 to 1993 for the reference group, but changes were not statistically significant because numbers were small. Reports of leg symptoms increased for this group.

1992 Cross-Sectional Multivariate Analyses

Table 7 shows Spearman correlation coefficients for relationships among independent variables (expressed as scores) included in 1992 cross-sectional multivariate logistic analyses. Correlations were not strong. Risk factors for hand/arm and neck/shoulder/back symptoms identified in multivariate analyses are shown in Table 8 (using dichotomous expressions for all independent variables). Hand/arm symptoms were negatively associated with desk comfort and overall satisfaction with the physical workstation and positively associated with number of times out of the workplace per day and using a visual display terminal for more than 6 h/day. Neck/shoulder/back symptoms were negatively associated with desk and chair comfort and positively associated with taking college courses outside of work, female gender, and perception of having to work hard or fast (Table 8).

1992–1993 Matched Analyses

Table 9 shows Spearman correlation coefficients for relationships among independent variables included in 1992–1993 matched multivariate logistic analyses. Correlations were weak.

For 11.5% of relocated respondents, hand/arm symptoms improved from 1992 to 1993 (7.9% reported symptom worsening, whereas 80.6% remained the same). In two-way analyses, improvement in hand/arm symptoms was associated with changes in three factors (from 1992 to 1993): improvement in desk comfort, improvement in overall satisfaction with the physical workstation, and having fewer housekeeping responsibilities in the home (Table 10). In multivariate analyses, only overall satisfaction with the physical workstation remained statistically significantly associated with improvement in hand/arm symptoms, with an *OR* of 2.0.

For 20.0% of relocated participants, neck/shoulder/back symptoms improved from 1992 to 1993 (10.3% reported symptom worsening, whereas 69.7% remained the same). Improvement in neck/shoulder/back symptoms from 1992 to 1993 was associated with five factors in two-way analyses: gender, lower pay range, improvement in chair comfort (from 1992 to 1993), an increase in perception of having influence over one's job, and decreased housekeeping responsibilities in the

TABLE 6: Matched Questionnaire Responses, 1992–1993: Musculoskeletal Symptom Reports

	Reference Group (n = 55)			Relocated Group (n = 557)		
	% Yes Response			% Yes Response		
Characteristic	1992	1993	p value	1992	1993	p value
All hand/arm pain	11	7	.32	18	14	.052
Hand/wrist numbness	7	7	1.0	8	5	.022
Hand/wrist pain	6	4	.56	13	11	.20
Woke up at night with hand pain	2	2	1.0	3	2	.41
Arm pain	4	4	1.0	6	6	1.0
Leg pain	4	6	.66	6	5	.45
All neck/shoulder/back pain	31	20	.13	38	28	<.0001
Neck/shoulder pain	27	20	.29	33	23	<.0001
Back pain	20	13	.29	20	15	.005

Notes: Definition for symptom (dichotomous): Individual reported symptom 1–3 days per week in last 4 weeks (or more) with symptom improvement when away from work. p values compare responses for 1992 and 1993 (using matched analytical methods).

TABLE 7. Spearman Correlation Coefficients for Relationships Among Independent Variables Included in 1992 Cross-Sectional Stepwise Multivariate Analyses

Variable	1	2	3	4	5	6	7	8	9	10
				Hand/Arm Analyses						
1. Times outside/day	1.0									
2. Physical satisfaction	-.06	1.0								
3. Chair comfort	.03	.20	1.0							
4. Desk comfort	.04	.36	.52	1.0						
5. VDT use (h/day)	.04	-.23	-.07	-.16	1.0					
6. Good supervision	-.08	.32	.05	.25	-.06	1.0				
7. Work hard/fast	.05	-.24	-.07	-.22	.15	-.23	1.0			
8. Job satisfaction	-.04	.24	.05	.14	-.09	.47	-.18	1.0		
9. Influence workplace	-.08	.36	.12	.18	-.20	.35	-.21	.32	1.0	
10. High concentration	.01	-.15	-.08	-.15	.14	-.10	.48	-.08	-.12	1.0
				Neck/Shoulder/Back Analyses						
1. Gender	1.0									
2. Physical satisfaction	-.05	1.0								
3. Chair comfort	-.13	.20	1.0							
4. Desk comfort	-.16	.36	.52	1.0						
5. VDT use (h/day)	.07	-.23	-.07	-.16	1.0					
6. Good supervision	.07	.32	.05	.25	-.06	1.0				
7. Work hard/fast	.05	-.24	-.07	-.22	.15	-.23	1.0			
8. Influence workplace	-.05	.36	.12	.18	-.20	.35	-.21	1.0		
9. High concentration	.02	-.15	-.08	-.15	.14	-.10	.48	-.12	1.0	
10. College course work	.06	-.09	-.07	-.16	.03	-.04	-.05	-.07	-.04	1.0

Notes: Gender and college course work are dichotomous variables (for gender, code 0 = male, code 1 = female). The remaining variables are scored variables.

home (from 1992 to 1993) (Table 10). In multivariate analyses, more chair comfort, female gender, lower pay range, and fewer housekeeping responsibilities remained statistically significantly associated with improvement in symptoms.

DISCUSSION

We were fortunate to be able to take advantage of the planned move of employees to determine if workplace changes were associated with reductions in musculoskeletal symptom rates. For many employees, the new workplace represented an improvement over the old, with increased square footage per person, better lighting, partitions separating workstations, and adjustable chairs and computer keyboards. These changes were perhaps reflected in the relocated group's increased overall satisfaction with physical characteristics of the workstation (from 49% to 74% from 1992 to 1993). Unfortunately, it was not possible to study effects of specific changes, as all changes in the physical work environment occurred simultaneously at the time of the move.

A notable exception to the general increase in satisfaction with the physical work environment was the increased perception of glare problems. For relocated employees, a possible reason for this was that most workers were moved from interior office spaces without windows or direct natural light to cubicles that were close to windows that caused glare problems. The reason for the increased perception of glare reported by the reference group is not apparent, however.

On average, employees had worked in the new building for seven months when the second survey was conducted. A potential limitation of the study is that although a reduction in symptoms was noted from March 1992 to March 1993, it is possible that if participants had been followed for a longer period of time, symptom reporting might have changed. For example, in a prospective study of office workers carried out over seven years, Bergqvist (1995) observed increased hand/wrist symp-

TABLE 8: Cross-Sectional Multivariate Logistic Regression Analyses, 1992: Factors Associated with Hand/Arm and Neck/Shoulder/Back Symptoms in Relocated Employees (n = 577)

Factor	Odds Ratio	p value
Hand/arm symptoms		
Desk comfort[a]	0.38	.0002
Physical satisfaction[a]	0.49	.0049
Times outside/day	1.8	.0117
VDT use > 6 h/day	1.8	.0194
Neck/shoulder/back symptoms		
College course work	2.5	.0077
Desk comfort[a]	0.48	.0003
Chair comfort[a]	0.49	.0003
Female gender	1.9	.0048
Work hard/fast[a]	1.8	.0017

Notes: Odds ratios refer to dichotomized variables (for continuous and scored variables, median values were used as cut points)

[a] Definitions for these factors appear in Table 1.

toms that were associated with increased use of visual display terminals. For some individuals, however, new keyboards that were purchased during the study period appeared to alleviate other (neck, shoulder, and upper arm) symptoms. In another prospective study of electronics workers in which participants were examined three times over two years, cervicobrachial symptoms decreased after one year; participants who were moved to more varied tasks showed improvement over the following year (Jonsson, Persson, & Kilbom, 1988). The current study was similar to the latter investigation in that it could detect differences in symptom reports over only the short term; it is hoped, however, that the health outcome that was studied represented the lower end of the severity continuum and consequently could be reversible in a short period of time.

In fact, the health outcome measures used in the current study were perhaps too restrictive, in that it was required that symptoms improve when away from work. In this attempt to exclude disorders unrelated to work, participants with long-standing work-related disorders that may have shown little or no improvement upon leaving the workplace at the end of the day might have been eliminated from the case group. Even so, the symptom definition that was utilized represented discomfort that was frequent and persistent.

A second limitation of the study relates to the fact that information on health outcomes and potential risk factors was obtained by self-report. Several independent comparisons were carried out to examine the validity of questionnaire responses. In a separate evaluation of employees working in the agency's workers' compensation claims initiation area, which was carried out at the same time as the current study (1993), ergonomists observed that workers spent 54% of their workday engaged

TABLE 9: Spearman Correlation Coefficients for Relationships among Independent Variables Included in Matched 1992–1993 Stepwise Multivariate Analyses

Variable	1	2	3	4	5
	Hand/Arm Analyses				
1. Increased desk comfort[a]	1.0				
2. Increased satisfaction with physical work environment[a]	.22	1.0			
3. Decrease in housekeeping responsibilities[a]	-.02	-.03	1.0		
	Neck/Shoulder/Back Analyses				
1. Female gender	1.0				
2. Increased chair comfort[a]	.08	1.0			
3. Increase in influence over job[a]	.04	.10	1.0		
4. Lower pay range	-.23	-.07	-.08	1.0	
5. Decrease in housekeeping responsibilities[a]	-.04	-.02	-.04	-.02	1.0

Notes: Gender and housekeeping variables are dichotomous. The remainder are scored variables.

[a] Variable refers to perceived change from 1992 to 1993.

TABLE 10: Relocated Group Matched Analyses: Factors Associated with Improvement in Hand/Arm and Neck/Shoulder/Back Symptoms from 1992 to 1993 (n = 577)

	Univariate Analysis		Multivariate Analysis	
	Odds Ratio	p value	Odds Ratio	p value
	Hand/Arm Symptom Improvement			
Decrease in housekeeping responsibilities[a]	7.1	.028		
Increased satisfaction with physical environment[a]	2.0	.017	2.0	.019
Increased desk comfort[a]	1.8	.050		
	Neck/Shoulder/Back Symptom Improvement			
Decrease in housekeeping responsibilities[a]	3.1	.025	3.6	.036
Female gender	2.1	.005	1.8	.047
Increased chair comfort[a]	1.9	.003	1.8	.014
Lower pay range	1.9	.005	1.7	.022
Increase in influence over job[a]	1.6	.018		

[a] Factor refers to perceived change from 1992 to 1993

in keying activities (Washington State Department of Labor and Industries, 1993). Self-reported questionnaire data for the same group suggested that approximately 75% of their total time was spent working at video display terminals. Given that keying may represent only a portion of time spent working at a visual display terminal, these results appear consistent. They may also demonstrate that self-reports overstate keying time: Bernard et al. (1994) observed similar results in which employees appeared to over-report time spent in typing activities. In that study, over-report was nondifferential with regard to symptom reporting and thus did not appear to bias results. If keying time was indeed over-reported in the current study, then its relationship with musculoskeletal symptoms was underestimated.

In another comparison – an independent measure of musculoskeletal injury and illness for agency employees – the workers' compensation claim rate decreased from 1992 to 1993 (from 3.8 to 3.3 per 100 employees), which is consistent with the decrease in reported symptoms.

Other limitations of the study relate to response rates and difficulty in matching the 1992 and 1993 questionnaires, particularly for the two reference buildings. The proportion of linkable questionnaires was low because of incomplete or missing record identification numbers, differing respondents from one year to the next, and, perhaps, differing reporting of encoded identification numbers from one year to the next. However, responses to questionnaire items did not statistically significantly differ for linkable and nonlinkable questionnaires; thus it appears that the matching failure did not bias results.

The major effect of the matching failure was to decrease the size of the study population and a reduction in statistical power. When respondents were compared with the target population, the two groups were similar: The individuals in the former group were slightly more likely to be female and slightly older. It was not possible to compare the two groups with regard to other characteristics.

An unfortunate consequence of the low response rates was that the reference group's results could not be examined in detail. However, in a general sense, it appeared that employees working in the reference buildings reported opinions similar to those of the relocated group with regard to the psychosocial aspects of the workplace. Overall satisfaction with the physical environment improved substantially for relocated employees; it did not change for those in reference buildings.

Musculoskeletal symptoms were reported frequently in both the relocated and reference groups (38% and 31% reported neck/shoulder/back symptoms, respectively) but were nearly always higher overall for relocated employees. Symptoms of the neck/shoulder/back were most frequent, occurring two to three times as often as hand/arm symptoms. Symptom rates decreased from 1992 to 1993 for most musculoskeletal symptoms for employees who moved; similar trends were observed for the reference group, although differences were not statistically significant because numbers were few.

More individuals' symptoms improved over time than worsened. For example, 20% of relocated employees experienced an improvement in neck/shoulder/back symptoms from 1992 to 1993, whereas 10.3% reported worsening. It might be argued that in matched analyses, those who worsened should not have been combined with the group that stayed the same; however, the former were few in number and perhaps only diluted the magnitude of observed results.

A possible explanation for the observed differences over time in reference buildings is the ergonomics awareness training received by agency supervisors in the summer of 1992, which was unanticipated by study investigators. Health and safety staff were concerned about conditions affecting agency employees and attempted to reduce perceived risk through supervisor training and individual job modifications for symptomatic workers. In one reference facility, supervisor training and job evaluations took place in the summer of 1992; in the other facility, training and workstation modifications were completed by February 1993. These activities might explain the similar downward trend in symptoms in the reference group. (Again, for the agency as a whole, the rate for workers' compensation claims for musculoskeletal disorders decreased from 1992 to 1993, which might suggest that the department's efforts were successful.)

The lower overall symptom prevalences in reference buildings might be explained by the fact that many employees spent at least part of the work week (an average of half a day) out of the building carrying out workplace inspections. It is also possible that results for the reference group reflected the fact that they reported spending less time working at a visual display terminal and perhaps also performed less intensive keying than the relocated group. Finally, it is possible that the observed reductions in symptoms in both groups were artifacts related to being included in a research investigation (the Hawthorne effect). It was for this reason that a reference group was included in the study, in the expectation that hypothesized improvements in symptoms in the relocated group would exceed baseline effects or Hawthorne-effect changes. Not all questionnaire responses changed over time, however (psychosocial variables in particular were stable over the study period), suggesting that results were not attributable to operation of a Hawthorne effect.

Risk factors identified in the cross-sectional analyses were similar to those observed by other investigators who studied office workers, including hours of visual display terminal use, chair and workstation comfort, psychosocial workplace factors, and individual factors such as gender (Bammer, 1987; Bernard et al., 1994; Bongers et al., 1993; Hunting et al., 1981; Linton & Kamwendo, 1989; Sauter et al., 1983; Smith et al., 1981). The cross-sectional analyses identified four factors associated with hand/arm symptoms and five factors associated with neck/shoulder/back symptoms in 1992 and 1993. One factor – desk discomfort – was shared by both health outcomes. Risk factors identified for hand/arm symptoms were largely related to physical aspects of the work environment. Risk factors for neck/shoulder/back symptoms were mixed, including factors related to physical and psychosocial workplace characteristics and other factors (i.e., gender and taking outside course work). These results might be interpreted as similar to those of Bernard et al. (1994), who found that psychosocial risk factors appeared to be more related to disorders of the neck and shoulder region than those of the hand or wrist. In a study of neck, shoulder, and back symptoms in salespeople, Skov, Borg, and Orhede (1996) found that both psychosocial and physical risk factors were associated with symptoms. In

particular, neck symptoms were associated with factors related to job demands.

A number of recent studies have examined relationships between musculoskeletal disorders and the use of video display terminals (VDTs). In a cross-sectional study of VDT operators (who used VDTs more than 4 h/week) in the editorial department of a large newspaper, Faucett and Rempel (1994) reported that potential upper torso disorders increased with greater daily VDT use (*OR* = 1.43) and less decision latitude (*OR* = 1.07). The risk of potential upper extremity disorders increased with increased daily hours of VDT use (*OR* = 1.49).

This is similar to our findings of increased risk of hand/arm symptoms with increased VDT use (more than 6 h/day, *OR* = 1.8). In the current study, psychosocial variables that increased risk of neck/shoulder/back symptoms included perception of having to work hard or fast (in cross-sectional analyses) and low influence over one's job (in longitudinal analyses). The latter might be considered to support Faucett and Rempel's observed association with low decision latitude. Physical risk factors identified in the Faucett study included having keyboard height above elbow height, which tends to increase load in the neck/shoulder region. In the present study, desk discomfort was associated with both hand/arm and neck/shoulder/back symptoms.

The current study design might have diluted the effect of intensive keyboard work by asking only about hours of use per day. It did not differentiate between data entry (intensive keying) and low-paced interactive keying. In a study of 353 VDT workers, Bergqvist et al. (1995) noted no difference in muscle-related disorders between participants doing VDT work and those not doing such work (less than 5 h/week). However, when VDT work was limited to intensive keying, as in data entry or word processing for more than 20 h/week, significant differences were observed. If additional factors such as limited rest breaks or low keyboard location were included, magnitude of risk increased (*OR*s = 2.8 to 4.8).

Of greatest interest in the current study was identification of risk factors associated with improvement of symptoms from 1992 to 1993. In univariate analyses, three factors related to changes in physical aspects of the work environment were associated with improvement in hand/arm symptoms. In multivariate analyses, only improvement (from 1992 to 1993) in overall satisfaction with the physical workstation remained associated with symptom improvement. Factors associated with improvement in neck/shoulder/back symptoms in univariate analyses included physical and psychosocial workplace characteristics, female gender, and housekeeping responsibilities. In multivariate analyses, improvement in chair comfort, female gender, low pay range, and perceived decrease in housekeeping responsibilities (from 1992 to 1993) were associated with symptom improvement. It should be noted that most associations observed in the current study were not strong (with *OR*s of 2.5 or less for work-related risk factors).

In comparison with cross-sectional multivariate analyses, longitudinal analyses identified fewer risk factors associated with symptoms. Variables identified by longitudinal multivariate analyses that did not appear as significant in cross-sectional analyses included low pay range and decrease in housekeeping responsibilities, both of which were associated with improvement in neck/shoulder/back symptoms. The former factor was fairly stable from 1992 to 1993 and was not associated with symptoms in 1992 or 1993 cross-sectional analyses. It might be that the move represented more of an improvement in the work environment (and lower symptom rates) for those with lower pay than those with higher pay. The association of symptom improvement with a decrease in housekeeping responsibilities might suggest that some physical activities unrelated to work affect the risk of work-related neck/shoulder/back symptoms.

Several other studies that examined effects of leisure time and sports activities showed no association with musculoskeletal symptoms or disorders (Ekberg, Karlsson, & Axelson, 1995; Holmstrom, Lindell, & Moritz, 1992; Houtman, Bongers, Smulders, & Kompier, 1994; Skov et al., 1996). Another study suggested that physical training in one's spare

time was related to improvement in cervicobrachial symptoms (Jonsson et al., 1988). Housekeeping responsibilities might represent more psychosocial than physical stress, which is consistent with our findings.

When the same relationships were examined for the reference group, improvement in hand/arm symptoms was associated with increased overall satisfaction with the physical workstation. Improvement in neck/shoulder/back symptoms was associated with improvement in chair comfort, female gender, and pay range. Thus, for both relocated and reference groups, neck/shoulder/back symptoms were associated with perceived workplace changes and other factors (including characteristics that did not change from one year to the next). Interpretation of results for the reference group is difficult, however, because numbers were small and differences were not statistically significant.

In a study such as this, in which the health outcomes of interest relate to self-report of symptoms and many potential causative factors are examined, it is sometimes difficult to determine relationships among them. Particularly in cross-sectional analyses, it is possible that observed associations might not represent cause-effect relationships but, rather, might be measures of the same perception. The fact that some variables remained significant in longitudinal analyses gives weight to their importance.

CONCLUSION

In cross-sectional analyses, hand/arm symptoms were associated with desk comfort, satisfaction with the physical workstation, and visual display terminal use. Neck/shoulder/back symptoms were associated with desk and chair comfort and perception of having to work hard or fast. In longitudinal analyses, a reduction in musculoskeletal symptoms in the relocated group appeared to be related to improvements in the physical work environment that came along with the move to the new building. Similar relationships were also observed for the reference group, which did not experience any location changes. The latter did experience unanticipated and somewhat less marked workstation changes, which were consistent with the observed reductions in symptoms. Results from both groups suggested that changes in workstations resulted in decreased symptoms. As psychosocial job characteristics remained fairly stable for both groups over the study period, it was not possible to assess their potential relationships with symptom changes over time.

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