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ORIGINAL ARTICLE

Reducing musculoskeletal burden through ergonomic program implementation in a large newspaper

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Abstract *Objectives:* To assess the impact of a workplace ergonomic program to reduce musculoskeletal burden among newspaper employees and to understand relationships among participation, risk factor changes and health status within an employee cohort. *Methods:* We conducted repeat cross-sectional surveys, with 1,003 employees from all major departments in 1996 and 813 in 2001, generating a cohort of 433 participants in both surveys. Elements of the ergonomic program included employee RSI (repetitive strain injury) training, proactive assessment of workstations and workstation modifications, and encouragement of early treatment through on-site physiotherapy. Potential risk factors included biomechanical and work organizational aspects of office work. Health status measures included pain intensity and the Work-Disability of the Arm, Shoulder, and Hand (DASH). Repeat cross-sectional analyses incorporated modifications for shared variance. For the cohort, a theory of change informed path analyses using M*PLUS*. *Results:* Among respondents in 2001, 69% reported participation in RSI training and 56% had workstation assessments. Among those with pain, 57% had consulted a health practitioner, including the on-site physiotherapist. In repeat cross-sectional analyses, the proportion reporting moderate pain or worse, at least once per month or for longer than 1 week, declined from 20 to 16% (p=0.01). Among the cohort, pain intensity and work disability in 1996 were the strongest predictors of 2001 health status (both $p < 0.001$). Stable or increased supervisor awareness and concern about RSI was associated with decreased pain in 2001($p < 0.01$). Participation in RSI training was associated with increases in decision latitude ($p < 0.05$), which themselves were associated with decreased work disability in 2001 ($p < 0.05$). Increased time mousing was associated with increases in work disability ($p < 0.05$). *Conclusions:* Implementation of a worksite ergonomics program was associated with a reduction in frequent and severe pain in the workforce. Changes in work disability were affected by multiple factors.

Keywords Repetitive strain injury/cumulative trauma disorders · Longitudinal study · Path models · Disability · Program evaluation

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Introduction

Repetitive Strain Injuries (RSI) (Health Council of the Netherlands 2000) or work-related Musculoskeletal

Disorders (MSD) (Kuorinka and Forcier 1995) constitute an important burden (Beaton et al. 2000) in workplaces worldwide. Neck, shoulder, and arm symptoms are widespread among European workers (Blatter and De Kraker 2004). Direct societal and employer costs attributed to RSI/MSD through workers' compensation claims are substantial in Canada (AWCBC 2004). Indirect costs through impaired work productivity and intangible costs such as worker home life impacts are estimated to be substantially greater, with evidence from Sweden that they are increasing (Liwing et al. 2004). Work causes are diverse, including biomechanical or physical aspects of tasks (Bernard 1997) and broader aspects of work organization, including psychosocial stressors (Houtman et al. 1994).

Workplace ergonomic policies and programs constitute important responses to this burden yet reviews of evaluations of workplace-based ergonomic interventions have commented on a number of weaknesses in the literature: lack of attention to evaluation research design; poor descriptions of populations, exposures, potential confounders and interventions; and inadequate reporting of uncontrolled co-interventions and limited analytic adjustment for such co-interventions (Westgaard and Winkel 1997; Norman and Wells 2000). A particular challenge of MSDs is their variation over time, even without interventions (Cole et al. 2002a; Luime et al. 2004). Calls for more rigorous intervention studies in occupational epidemiology abound (Kristensen 2005).

During a collaborative research project with workplace parties of a large newspaper, we documented substantial MSD morbidity in the workforce (Polanyi et al. 1997), assisted the development of an ergonomic program (Polanyi et al. 2005), and devised an evaluation framework to guide data collection activities (Cole et al. 2002b). Qualitative techniques were used to understand the challenges faced by the workplace parties during implementation (Polanyi et al. 2005). In the current paper, we use quantitative data on the entire workforce collected at two points in time (1996 and 2001) in a pre–post evaluation design (program implementation started in 1998).

Our analytic approaches are consistent with those used in field intervention evaluations (Atienza and King 2002). Our repeat cross-sectional analysis asked:

1. What changes in awareness of MSD, MSD risk factors, MSD burden and MSD-associated practices occurred with implementation of an ergonomic program?

For the cohort analysis, we focused on plausible pathways, which linked participation in the program to changes in risk factors that might be expected to bring about changes in health status within the workforce (see Fig. 1). Such an intervention-specific theory of change builds on approaches to evaluation, which argue for the clear articulation of hypotheses by which change likely occurs in complex social interventions (Weiss 1995). Hence our compound research question was:

2. Was individual 1996 MSD-related pain or work disability associated with individual participation in ergonomic program activities?; were participation and ongoing work changes associated with changes in self-reported biomechanical and psychosocial risk factors for MSD?; and were changes in risk factors associated with changes in MSD-related pain or disability, taking into account potential confounders?

Methods

Population

Newspaper employees included in both 1996 and 2001 were office workers employed at the head office, at zone offices and at external bureaus. Details of the 1996 survey are reported elsewhere, including the inclusion of non-permanent employees (Polanyi et al. 1997). In 2001, the workplace joint labor management RSI Committee members wanted to focus only on permanent employees (see Table 1). The RSI Committee recruited volunteers to distribute 1,186 surveys and collect the returned questionnaires. As per approval by the McMaster University Research Ethics Board, signed informed consents and questionnaires were collected in sealed envelopes and transferred to the research team for coding, data entry and analysis. Non-respondents received a second survey. The final proportion responding was 69% (n=813).

As a whole, participants in 2001 were significantly older, with fewer men and fewer part-time permanent staff. For employees present at both times, a participant identification number, assigned in 1996, was used to link the two waves of responses into a cohort (n=433). Compared to all 1996 participants, cohort members were younger and more commonly female, likely due to contracting out of the male-dominated Outside Circulation department in 2000 (Circulation proportions 37% in 1996 and 20% in 2001).

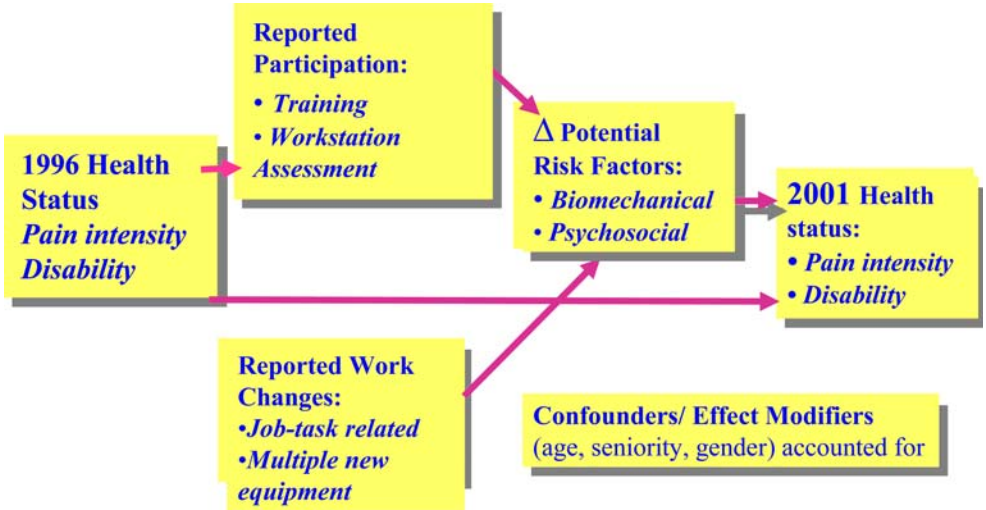


Fig. 1 Theory of change within cohort. Δ is difference of 2001 vs. 1996. Model depicts hypothesized pathways

Measures

For 2001, we used similar domains of interest and survey questions as in 1996 (Polanyi et al. 1997), including demographic variables that could be potential confounders, e.g., age, gender, and seniority. Sources of risk factor measures included: NIOSH questionnaires used in newspaper surveys (Bernard et al. 1994) for physical stressors including task demands, e.g., time keyboarding, and the physical variety of the job, e.g., time sitting continuously; adaptation of Karlqvist et al.'s (1996) diagrams to detect non-optimal positioning of workstation components, inside and outside a spatial box; and adapted Job Content Questionnaire items used in the Canadian National Population Health Survey (Wilkins and Beaudet 1998) for decision latitude, psychological demands, job security and work social support. IWH researchers developed questions on workers' role in decision making and the extent to which employees ideas were listened to by management. The RSI Committee developed questions on supervisor and management support around RSI.

For health status, we measured symptoms, pain intensity and work disability. We adapted a grid of questions (Kuorinka and Forcier 1995) regarding duration of their symptoms, frequency of episodes, and overall severity of their neck, shoulder and upper extremity symptoms during episodes. Von Korff et al.'s work (1992), including pain on average, over the past week and at its worst, enabled calculation of pain intensity (range 0–100) (Beaton et al. 2000). For both symptoms and pain intensity, we used the value of the body area with the greatest intensity. The Work-Disabilities of the Arm, Shoulder, and Hand (DASH) consists of four items designed to pick up difficulties experienced during a full day at work (McConnell et al. 1999) and scored from 0 (none) to 100 (maximum) work disability.

To document work changes in the 3 years since the ergonomic program was initiated in 1998 and participation in ergonomic program activities, e.g., RSI training and workstation assessment, we worked out new questions with RSI Committee members.

Analyses

Repeat cross-sectional analyses included frequency distributions and means for the prevalence of key risk

Table 1 Newspaper survey respondent characteristics

Variables	1996 (*n*=1,007)	2001 (*n*=813)	Difference 1996–2001 (95% CI)	1996 values for cohort (*n*=433)
Age in years, mean (SD)	42.1(9.3)	42.9 (10.1)	Δ=0.8 (0.1, 1.6)	41.1 (8.1)
Gender (male)	54%	47%	Δ=-0.07 (-0.04, -0.11)	42%
Tenure in years, mean (SD)	15.8 (8.8)	15.0 (11.0)	Δ=-0.8 (-1.6, -0.05)	15.7 (8.0)
Work status				
Full-time/permanent	75%	87%		82%
Part-time/permanent	21%	12%	Part-time Δ=-0.10 (–0.13, –0.07)	16%
Temporary	3%	–		1%
Missing	1%	1%		1%

SD standard deviation, Δ difference of 2001 minus 1996 factor and health status measures (research question 1), as commonly done in community intervention trials (Atienza and King 2002). We modified test statistics to account for the lack of independence (shared variance) brought about by respondents common to the two time periods (details available from authors).

For the cohort analyses, we grouped the work changes based upon the frequency of stated changes and polychoric correlations among changes into: job task changes, e.g., greater scope of work; and multiple workstation equipment changes, e.g., new monitor, chair, and desk. We examined relationships between 1996 health-status variables and participation in ergonomics program activities using chi-square for dichotomous and ordinal variables and *t*-tests for continuous variables. For changes in risk factors, a test of symmetry for paired ordinal data was used (Agresti 1990) to determine whether the overall distribution of factors remained the same over time. We dropped single-item, ordinal variables with non-significant (p>0.15) tests, meaning no substantial change had occurred. For dichotomous and ordinal variables that were mediating variables, we had to use values that would make sense in interpreting the overall path model. Hence a value of +1 was assigned if the persistence or worsening of the mediating risk factor was likely to lead to increasing pain or disability, 0 if no change in the risk factor occurred, and -1 if the change in the risk factor was likely to lead to less pain or disability over time. For continuous variables we constructed difference scores (2001–1996). We dealt with the skewness of the health-status variable distributions by re-categorizing pain intensity as terciles and WorkDASH as a dichotomous outcome, given that 70% of 2001 values for the latter were zero.

Given sample size limitations, we had to limit the number of explanatory variables to be used in multivariable modeling. We checked intra-domain variable associations, by using cross-tabs for ordinal variables and correlations for continuous variables. We examined bivariate relationships among health status, participation, work changes, and risk factor changes (as per Fig. 1), retaining those with $p < 0.2$. Multivariable polytomous and logistic models were done sequentially backward, i.e., change in potential risk factors as predictors of 2001 health status first, and then program participation and work change variables as predictors of risk factors. Model reductions were achieved by manually removing those with the highest p-value until all remaining variables in each model had a $p < 0.2$. Although we sometimes noted changes in variable coefficients through this process, sample size restrictions prevented us from carrying forward all potentially relevant variables to path analysis.

With the reduced set of variables, we conducted separate path analyses to predict each of 2001 pain intensity and 2001 work disability (research question 2). We used M*PLUS* software Version 3.11 (Muthen and Muthen 2002), which accommodates combinations of continuous and categorical mediating and outcome variables. We used a weighted least squares method (WLSMV) that produces robust standard errors and chi-squared statistics. We reduced the path models by sequentially removing variables whose z-score was less than 1.6, roughly equivalent to p=0.1, while maintaining model goodness of fit. The latter was assessed using the overall chi-square test, the Comparative Fit Index (CFI) and Tucker Lewis Index (TLI) (for both high (>0.8) is good), and the Root Mean Square Error of Approximation (RMSEA, low (< 0.05) is good).

Results

Repeat cross-sectional analyses

Fifty-eight percent of 2001 survey respondents remembered the special RSI training sessions held in all departments and another 11%, primarily new employees, indicated that they received training on RSI as part of their orientation. Compared to the 1996 survey, significantly more 2001 respondents endorsed relevant responses on potential causes of RSI, e.g., poorly designed workstation (68% in 1996 to 78% in 2001, 10% improvement, 95% confidence interval (CI) on improvement 8–16%), too much keyboarding (5–62%, +8%, 95% CI 4–13%), working without breaks (40–52%, +12%, 95% CI 8–17%), excessive workload (27–40%, +13%, 95% CI 11–19%), and poor posture (68–73%, +5%, 95% CI 3–11%). At the same time "lack of training" was mentioned less frequently (37–23%, -14%, 95% CI -17 to -9%).

Overall, the proportion reporting equipment in a more optimal location at their workstation increased from 1996 to 2001: 56–72% for the keyboard and 17–61% for the mouse (Table 2), though much of the latter was due to the greater proportion of employees reporting mouse use (36–91%). The mean daily hours of use of the keyboard (extra 40 min) and mouse (extra 56 min among mouse users, approximately 2 h across non-users and users) also increased. "Time sitting for more than 2 h continuously" increased to 3% of 2001 respondents. Social support at work (not RSI related) improved but other work organizational risk factors remained unchanged.

Table 2 Changes in risk factors—repeat x-sectional analyses

Measure	1996 (n=1,007)	2001 (n=813)	Δ, p, 95% CI and interpretation
Keyboard in box			
Inside	564 (56%)	585 (72%)	Δ=0.14 p= < 0.0001 CI (0.10, 0.18) larger percentage inside box in 2001
Outside	370 (37%)	203 (25%)	
Not use/missing	73 (7%)	28 (3%)	
Mouse in box			
Inside	163 (17%)	498 (61%)	Δ=0.22 p < 0.0001 CI (0.16, 0.28) larger percentage inside box (larger no reporting mouse use in 2001, majority have mouse in good position)
Outside	200 (20%)	247 (30%)	
Not use/missing	644 (64%)	68 (8%)	
Sitting continuously			
< 0.5 h	121 (12%)	68 (8%)	>2 vs. < 2 Δ=0.09 p < 0.0001 CI (0.05, 0.13), i.e., significantly more people sitting for longer than 2 h
0.5–1 h	301 (30%)	204 (25%)	
1–2 h	318 (32%)	260 (32%)	
>2 h	239 (24%)	270 (33%)	
Invalid/missing	28 (3%)	11 (1%)	
Time keyboarding h/day, mean (SD)	3.1 (2.2) (n=968)	3.8 (2.1) (n=749)	Δ=0.66 p < 0.0001 CI (0.48, 0.85), i.e., significantly more time ~40 min/day
Time mousing h/day, mean (SD) including mouse and non-mouse users	0.7 (1.5) (n=983)	3.0 (2.3) (n=717)	Δ=2.28 p < 0.0001 CI (2.11, 2.45) significantly more time spent mousing per day (~2 h/day), due to both increased proportion using mouse and longer time on mouse
Time on phone h/day, mean (SD)	2.4 (2.1) (n=971)	2.6 (2.2) (n=708)	Δ=0.29 p=0.0014 CI (0.11, 0.46) significantly more time telephoning per day (~20 min)
Psychological demands (JCQ, range 0, low, to 8, high)	5.3 (1.6) (n=981)	5.4 (1.5) (n=795)	Δ=0.11 p=0.089 CI (-0.02, 0.24) non-significantly greater psychological demands in 2001
Decision latitude (JCQ, range 0, low, to 20, high)	12.1 (3.5) (n=972)	12.0 (3.1) (n=778)	Δ=-0.07 p=0.61 CI (-0.34, 0.20) very similar
Social support at work (JCQ, range 0, low, to 12, high)	7.8 (2.1) (n=977)	8.0 (2.0) (n=788)	Δ=0.28 p=0.0020 CI (0.10, 0.45), i.e., significantly higher work social support in 2001

SD standard deviation, Δ difference of 2001 minus 1996, *JCQ* job content questionnaire

The vast majority said that their pain and discomfort were caused or aggravated by work: yes=308 (57%) and "to some extent"=183 (34%) versus no=54 (10%) (invalid/missing=18). Overall, the prevalence of pain and discomfort during the past year increased from 59% in 1996 to 68% in 2001 (+9%, 95% CI 5–13%). Significant increases in prevalence of pain in the neck and shoulder were observed with decreases in wrist/hand pain (see Table 3) Overall, there was a reduction in frequency and duration of episodes. Combined, the proportion reporting moderate pain or worse, at least once per month or for longer than 1 week, declined from 20 to 16% (p=0.01). The increase in work-related disability among those with pain may be due to greater awareness of impact, but other potential causes, such as increased task demands seen above, are also of concern.

In response to their pain, many participants (49%) actively did something: exercises n=259 (65%), changing posture n=237 (59%), self education n=151 (38%), heat or ice n=148 (37%), relaxation n=122 (31%), adjusting their workstation n=116 (29%), medication n=92 (23%), and a range of other less frequent options [changed job description n=10 (3%), splints/braces n=37 (9%), injections n=7 (2%), surgery n=7 (2%), and other n=36 (9%)]. In 2001 they were more likely to see a health care practitioner, most commonly a family physician (42%) or on-site physiotherapist (37%). Further, they were somewhat more likely to report their symptoms to the workplace (36–40%, +4%, 95% CI -2 to 9%, p=0.18), in keeping with the RSI Committee's emphasis on reporting in RSI training sessions and posters on bulletin boards in the workplace.

Cohort analyses

Cohort members, compared to 1996-only respondents (n=574), were more likely to experience musculoskeletal pain in the neck and upper extremities (68% vs. 53%; mean intensity 29.8 [standard deviation (SD) 26.5] versus mean=22.3 (SD 25.4), both $p < 0.0001$) and to have higher levels of disability (WorkDASH mean 6.2 (SD14.9) n=424 versus mean 3.4 (SD 9.5) n=567; both $p < 0.001$). Hence, it appears that rather than a "healthy worker" selection effect, those with more problems were still at the workplace and responded to the questionnaire in 2001 (note there were 373 non-responders in 2001). Correlations between pain intensity and work disability were 0.54 in 1996 and 0.63 in 2001. Those with greater pain or disability did not undergo more work changes but did preferentially participate in RSI training (pain intensity mean 30.8 (SD 26.4) versus mean 25.1 (SD 26.7), p=0.07). Among cohort members, RSI training was most common (324/410), followed by job task changes (273/428), ergonomic assessment (262/433) and multiple new equipment (255/428).

Mean continuous risk factor values paralleled those in repeat cross-sectional analyses. Distributions of changes in ordinal risk factors demonstrated an overall tendency to persist or become worse (8/11) rather than better (3/11) for health outcomes (Table 4).

Mean health outcome changes paralleled those in repeat cross-sectional analyses. In the final path analyses, the strongest effects ($p < 0.001$) were for 1996 health status as a predictor of 2001 health status (parameter to standard error or z-score equivalents of 8.9 for pain and 6.1 for WorkDASH), indicating persistence of pain and disability over time within individuals. Age was also positively associated with worse 2001 health status though with small effects, e.g., pain intensity increase of 0.2 points on 0–100 scale for every increase in age of 10 years. For pain intensity, no intermediate paths went from participation and work changes to changes in risk factors but better or no change (versus change for worse) in supervisor awareness or concern was associated with reductions in pain intensity (see Table 5).

Multiple influences on both change in risk factors and 2001 WorkDASH are apparent, perhaps commensurate with the complexity of determinants of work disability (see Fig. 2). Men were more likely than women to report decreases in decision latitude ($p < 0.05$) but increases in management support for RSI ($p < 0.05$). Multiple equipment change was associated with decreased types of risky telephones, i.e., hand-held or shoulder rest ($p < 0.01$), but such telephones were paradoxically associated with reduced work disability, indicating that those with problems after 1996 may have been provided better types of telephones, e.g., headsets. The fact that greater decision latitude was associated with decreased work disability ($p < 0.05$), makes sense if employees have greater ability to adjust their work demands to their current condition. Greater time spent mousing was associated with greater levels of 2001 work disability (ten-point increase for every additional daily hour of mousing, $p < 0.05$), though those with greater seniority experienced less increase in mousing ($p < 0.05$). The fact that improved management support for RSI was associated with increased disability may seen counter-intuitive, unless those that develop work disability required more assistance and so discovered that management was supportive.

Table 3 Changes in symptoms and responses—repeat cross-sectional analyses

Measure	1996 (n=1,007)	2001 (n=813)	Δ, p, 95% ±CI and interpretation
Locations of pain			
Neck	379 (63%)	405(75%)	Δ=0.12 $p<0.0001$
Shoulder	323 (54%)	328(61%)	Δ=0.07 p=0.0122
Elbow/forearm	221 (37%)	192 (36%)	Δ=-0.01 p=0.6365
Wrist/hand	380 (63%)	308 (57%)	Δ=-0.06 p=0.0202
Invalid/missing	16	23	Significant increases in neck, shoulder and decrease in wrist/hand by 2001
Pain intensity (ranges from 0, low, to 100, high) (0 imputed for those without pain) mean (SD)	25.5 (26.1)	26.1 (22.6) (n=804 invalid/missing=9)	Δ=0.61 p=0.5509 CI (-1.39, 2.60) not significantly different
Pain and discomfort—frequency of episodes (#, %)			
Constant	55 (10%)	31 (6%)	Δ=-0.1091 $p<0.0001$ CI (-0.16, -0.06) decreased frequency of episodes, comparing less frequent than 1/month to as frequent or more frequent than 1/month
Daily	86 (16%)	69 (13%)	
1/week	175 (32%)	168 (31%)	
1/month	141 (26%)	135 (25%)	
Every 2–3 months	73 (13%)	94 (17%)	
Every 6 months	12 (2%)	52 (9%)	
Invalid/missing	74	14	
Pain and discomfort—length of episodes (#, %)			
<1 h	92 (18%)	96 (18%)	Δ=0.04 p=0.0645 CI (-0.003, 0.09) small reduction in long episodes (>6 months), for episodes of a week or more compared to no more than 1 week, the reduction is marginally significant
1 h–1 day	181 (36%)	218 (41%)	
1 day–1 week	123 (24%)	124 (23%)	
1 week–1 month	45 (9%)	33 (6%)	
1–6 months	16 (3%)	30 (6%)	
>6 months	51 (10%)	31 (6%)	
Invalid/missing	108	31	
WorkDASH	7.9 (15.1)	10.1 (16.5)	Δ=2.21 p=0.0105 CI (0.52, 3.90) significantly higher work related disability
Mean (SD), higher more disability	Range (0, 83.3) n=578	Range (0, 100) n=534	
Invalid/missing	38	29	
Consulted a health care practitioner (#, % of those reporting pain)			
Yes	271 (46%)	316 (57%)	Δ=0.11 $p\leq0.0001$ CI (0.06, 0.17) significantly more
No	324 (54%)	240 (43%)	
Invalid/missing	26		

SD standard deviation, Δ difference of 2001 minus 1996

Discussion

As one component of evaluation of the implementation of a workplace ergonomic program (Cole et al. 2002b), our 2001 survey was able to document participation at the employee level and demonstrate substantial coverage among the workforce. Further, we were able to elucidate the greater tendency for those with MSD symptoms and disability to participate, similar to findings in worksite health promotion activities (Davis et al. 1987). Coverage or reach, particularly among those in greatest need, is an important measure of the intensity of an intervention, without which judgments about effectiveness are exceedingly difficult (Bull et al. 2003). Such coverage resulted in both improved knowledge, as other educational interventions among computer users have demonstrated (Rizzo et al. 1997), and improved positioning of workstation elements, as was more conclusively shown in a randomized controlled trial in an office setting (Ketola et al. 2002).

At the same time, the majority of participants experienced changes in their jobs. These can be considered co-interventions for either individual purposes, e.g., career objectives, or business purposes, if company wide. The latter included major changes in the newspapers' computer systems, and renovation and move of the advertising department (Polanyi et al. 2005). So more time was spent sitting engaged in computer related tasks even though workstation setups were better, as corroborated among a subset of employees for whom intensive exposure measures were carried out (Cole et al. 2003a). Such mixed effects have been observed in other workplace computerization efforts with adverse musculoskeletal impacts (Jhun et al. 2004). Substantial employee turnover also

Table 4 Ordinal risk factor changes among cohort members (#) (*n*=433)

Variable (# missing)	Better=-1	No change=0	Persist/ worse=+1
Biomechanical risk factors			
Keyboard position (35)	**104**	213	81
Mouse position (100)	55	182	96
Telephone type (29)	52	75	277
Screen position (52)	64	230	87
Sitting continuously (16)	48	246	123
Physical effort (14)	**44**	339	36
Psychosocial risk factors			
Employees' ideas listened to (14)	65	274	80
Frequency workers take part in decisions (19)	79	222	113
Management supportive re RSI (14)	**24**	375	20
Supervisor aware and concerned about RSI (17)	28	342	46
Job security (14)	47	301	71

Bolded indicates that # better is greater than # persist/worse for that row

occurred between surveys but those who remained tended to have more MSD problems than those who left, discounting potential selection out of the workforce of those with greater problems.

The mix of intentional and unintentional changes, combined with care for those with symptoms, was associated with a reduced frequency and duration of pain periods, consistent with the reduction of lost-time, compensable MSD claims to zero by 2001 (Cole et al. 2003a). The overall positive impacts, despite co-interventions, and turnover, are an important finding in the mixed workplace ergonomic intervention evaluation literature (Norman and Wells 2000).

Table 5 Final path model for prediction of pain intensity in 2001 among cohort members (*n*=357)[a]

Independent variables	Parameter estimate (P) (standard error, SE)	P/SE ratio significance[c]
1996 pain intensity (per ten points)	0.22 (0.003)	8.9***
Age (per 10 years)	0.18 (0.07)	2.4**
RSI training (yes versus no)	0.146 (0.078)	1.9*
Δ Supervisor awareness and concern:[b]		
Better versus worse	-0.356 (0.292)	-1.2 (ns)
No change versus worse	-0.512 (0.196)	-2.6**

NS not significant at 0.05 level, Δ difference of 2001 vs. 1996

$*p<0.05$;$**p<0.01$;$***p<0.001$

[a]CFI/TLI of 1.0/1.1, RMSEA 0.000, i.e., excellent fit

[b]Ordinal outcome so independent variables predictive of transitioning up (+ve coefficients), e.g., 0 (none) to 1 (mild) or 1–2 (moderate/severe), or down (-ve coefficients), e.g., 2–1 or 1–0

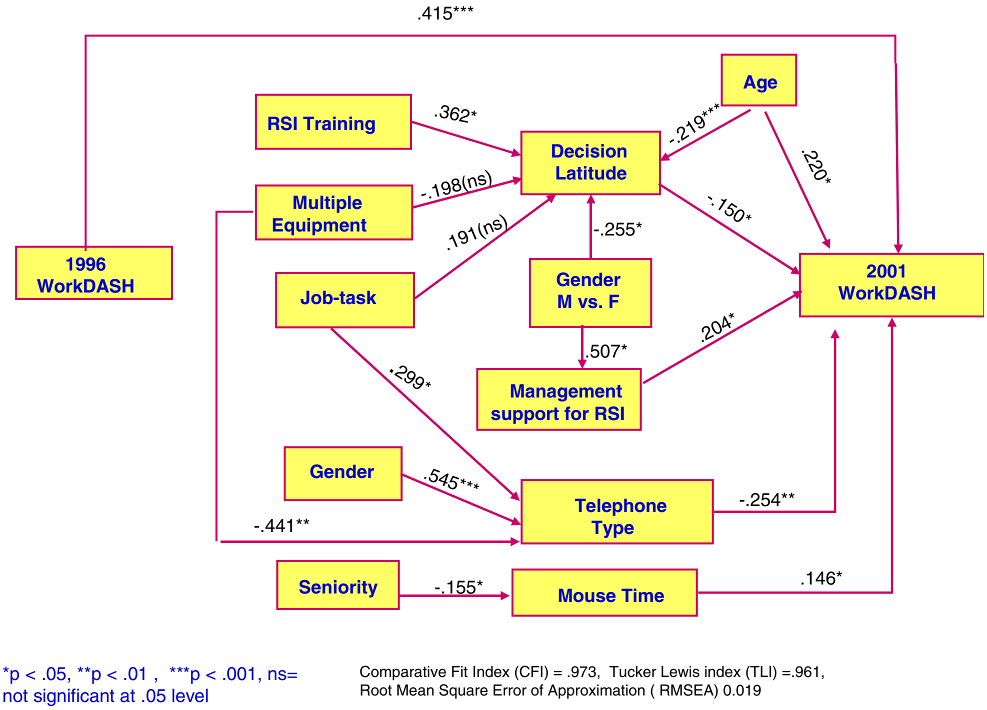
[c]Similar to *z*-score

Within the cohort, the combination of successive data reduction steps and sophisticated structural modeling advocated by other occupational health researchers (Engels et al. 1998; Amick et al. 1999), permitted analyses according to an evaluation based theory of change, within a longitudinal intervention evaluation design (Kompier 2002). We were able to track combined effects of RSI training and workstation assessment activities with changes in equipment and job tasks. We highlighted the heterogeneity of changes in both risk factors and health outcomes that can occur within a workforce, at the same time adjusting for confounders (age, gender, and seniority) and co-interventions.

The ergonomic program was not implemented in a new, young workforce without pre-existing conditions but rather in a workforce of all ages, with substantial numbers already having MSDs in 1996 (Polanyi et al. 1997). Pain and disability persisted for not only 1 year, as in our earlier study (Cole et al. 2002a), but up to 5 years as demonstrated here, with the highest P/SE ratio in the pain model and standardized coefficient in the disability model being for the 1996 health status measure. Longer-term follow-ups of workforces at risk of MSDs are gradually appearing in the literature. They also show persistence, e.g., Danish sewing machine operators (Kaergaard and Andersen 2000) and Dutch nursing home and elderly care workers (Luime et al. 2004). Among US industrial and clerical workers, baseline shoulder discomfort was an important predictor of subsequent upper extremity tendinitis (Werner et al. 2005). Such findings are consistent with the growing understanding of the chronic, fluctuating character of MSD, that has been best described for low-back pain (McGorry et al. 2000). Hence, ergonomic programs cannot aim only at primary prevention. Instead, workplace programs must simultaneously be engaged in ongoing rehabilitative initiatives (tertiary prevention), as well as MSD surveillance and treatment (secondary prevention) and risk factor reduction (primary prevention) to achieve control rather than elimination of MSD.

The important role of supervisor awareness and concern in reducing MSD-related pain is consistent with our earlier cross-sectional findings of lower MSD prevalence with higher social support (Polanyi et al. 1997) and other cross-sectional work among computer users (Jensen et al. 2002). More recent longitudinal work has shown the role of low versus high social support in predicting subsequent neck-shoulder symptoms among the general workforce (Feveille et al.

Fig. 2 Path model and standardized path coefficients for WorkDASH (cohort n=331). Δ is difference of 2001 vs. 1996. Path coefficients can be interpreted as z-scores, e.g., participation in RSI training is associated with a significantly greater likelihood of having greater decision latitude, which in turn is associated with decreased work disability in 2001



2002). Other cross-sectional work has shown the positive role of supervisor support in promoting safe working practices (Parker et al. 2001) and reducing absenteeism (Unden 1996). In the return-to-work literature, well-trained and supportive supervisors have been shown to play a positive role in reducing work-related disability (Shaw et al. 2003). Supervisors participation in the RSI training likely improved their understanding of MSD and provided them with problem-solving strategies, as exemplified by attitudinal and cultural changes around RSI documented in our qualitative research at this newspaper (Polanyi et al. 2005).

Decision latitude played a key role in the work disability path model. Although it was not a prime target of the ergonomic program, it was included in both the RSI training and the set of work organizational risk factors in the ergonomic policy (Cole et al. 2002b). Cross sectional research on computer users (Jensen et al. 2002) and longitudinal follow-up of the same cohort (Juul-Kristensen et al. 2004) have shown that low influence at work is a risk factor for neck, shoulder and hand-wrist pain. In a cross sectional survey, motor vehicle mechanics coping with MSD symptoms varied significantly by the extent of work demands, social support, and job control (Torp et al. 1999). In longitudinal designs, organizational psychologists have shown that job control, of which decision latitude is one component, is an important precursor for applying learning and reducing strain (Holman and Wall 2002) and mediates the impact of a work re-organization intervention on reducing sickness absence and improving self-rated job performance (Bond and Bunce 2001). Ergonomic education has been shown to improve psychosocial aspects of work among office workers while reducing body composite pain/discomfort scores (Bohr 2000). Our findings add to this literature by highlighting the important role of decision latitude in mediating the effects of RSI training on reductions in MSD-associated work disability.

The strength of our findings is weakened by a number of potential threats to internal validity, including the absence of a comparison group (Kristensen 2005). Participation in the 2001 survey was sub-optimal, partly due to persistent distrust in the workplace and partly due to changed requirements for explicit written consent (versus implied consent). Several of the associations with ergonomic program activities were relatively weak, perhaps due to inadequate capture of program components, low program intensity in comparison to other worksite changes occurring during the period (Polanyi et al. 2005) or low reversibility of long-standing MSD. Finally, measurement properties of questionnaire tools for risk factors, particularly more biomechanical ones, were likely less than desirable, given the difficulties individuals have in rating their demands, as exemplified by newer studies comparing recorded and self-reported durations of computer work (Andersen and Mikkelsen 2004; Heinrich et al. 2004; Toivonen and Takala 2004).

Conclusions

Through implementation of an ergonomic program, the workplace parties were able to bring about improvement in a number of physical and psychosocial risk factors, though business responses to intense competitive pressures and concomitant computerization brought about aggravation of others. In a workforce with substantial ongoing burden of MSD, they succeeded in reducing the frequency and duration of MSD pain episodes, although work disability increased. The important role played by supervisor support in reducing pain and decision latitude in reducing work disability needs to be more fully explored in evaluations of work organization interventions (Murphy and Sauter 2004). A continuing emphasis on care for those with MSD is needed given our demonstration of persistence and MSD impacts on work performance. At the same time, organizational leaders need to move ‘‘upstream’’ to influence decisions on new technology, organization of work and design of jobs (Polanyi et al. 2005) in the hopes of preventing occurrence of new MSD and controlling MSD burden.

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