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Workplace intervention associated changes in office environment and worker-environment interface indicators at a large newspaper

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Abstract

Objectives: To track changes in office work environment characteristics and environment-worker interface measures during a workplace intervention at a large newspaper.
Methods: Among a cohort of 33 office workers, we obtained yearly measurements (1999-2001) of work environment (observed equipment dimensions, work organization) and interfaces (observed postures, perceived workstation optimality of equipment placement) and video-based analysis of office tasks). For assessing change across years, general linear mixed models were used for continuous measures and generalized estimating equations for categorical measures.
Results: Changes were noted in: some workstation dimensions e.g. decreases keyboard depth from table edge; some work organization factors e.g. fewer respondents sitting continuously >2 hours; many posture measures e.g. reduced wrist/ulnar deviation angles; and optimality e.g. keyboard placement. Increases were observed in keyboard to seat heights and in the number of employees mousing and the proportion of time spent mousing. Pain prevalence and intensity decreased but not significantly.
Conclusions: Improvements are possible in office work-environments but they must be closely monitored to assess heterogeneous impacts.
Significance: Changes in symptoms are less likely among long standing workers given the persistence of work-related musculoskeletal disorders.

Introduction

Office workers engaged in intensive computer work have been shown to be at increased risk of work-related musculoskeletal disorders (MSDs) associated with inadequate workplace design and inappropriate work organization (IJmker et al, 2007; Sandsjö and Kadefors 2001). Opportunities for a general improvement of working conditions can occur when workplaces undertake physical renovations, software upgrades, and new team-work approaches. Research on the impacts of such office workplace interventions is particularly important given the mixed state of evidence on effectiveness (Brewer et al. 2006). Documenting the nature of workplace changes and their impact on MSD risk factors requires a comprehensive approach where nested studies focus on more detailed measurements (Cole et al. 2002 & 2003).

Relevant combinations of measures used in workplace-based observational studies have included: questionnaire with workstation assessments/anthropometry (Aarås et al. 1998), and video recordings to synchronize tasks with postural and physiological measurements (Karlqvist et al. 1998). Some authors used multiple types of measures (questionnaire, observation, goniometry, and electromyography or EMG) while focused on particular equipment (mouse) and/or specific activities (computer-assisted design) (Jensen et al. 1998). Some researchers have applied combinations to assess the effects of specific changes: work organizational factors, e.g. questionnaire for different pause types (Sundelin and Hagberg 1989); workstation design features, e.g. observation for lowering and tilting of the work table permitting alternative postures (Westgaard and Aarås 1985); and questionnaire, anthropometry, observation and weekly diary for postural change and workstation adjustment (Gerr et al. 2005).

In collaborative research with a large newspaper, we had the opportunity to assess the impacts of new workstations on a previously empty floor (“move”) and a subsequent work reorganization (“team”), undertaken in conjunction with computer system changes (Polanyi et al. 2005). Embedded within the larger cohort experiencing the newspaper’s ergonomics program (Cole et al. 2006), a nested subset of volunteer employees agreed to undergo intensive exposure assessment to determine changes associated with the “move” (primarily 1999 to 2000) and “team” (primarily 2000 to 2001). In keeping with a framework of linkages between work environments, employee-workstation fit, and job tasks (Wells et al. 2004), we expected equipment and work organization changes would contribute to improvements in “postural” fit and greater task variation across years (see Figure 1). Specifically:

1. improved workstation equipment locations e.g. more keyboard support;
2. reduction in extremes of postural angles e.g. reduced wrist extension;
3. increased variation in tasks within comparable time periods;

and

4. reduction in pain intensity

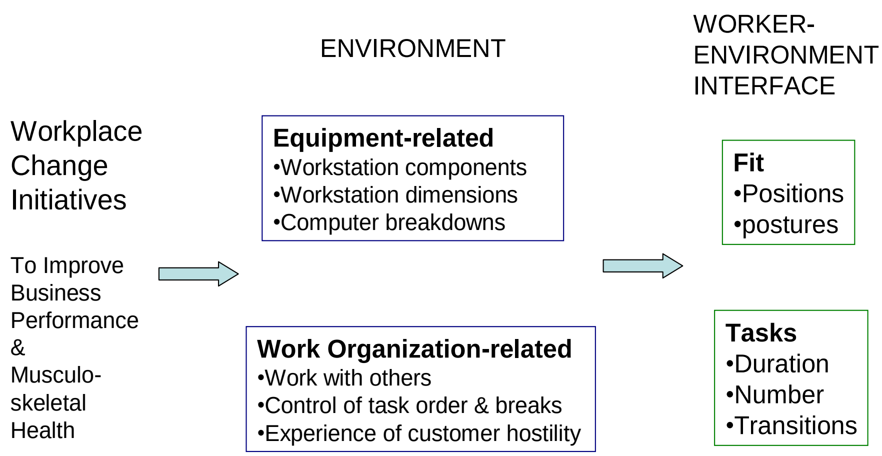

Figure1 Links between workplace change initiatives, environment indicators (equipment & work-organization related), and worker-environment interface indicators (fit & tasks).

Methods

Design

Longitudinal follow-up with repeated measures.

Setting

Large newspaper with approximately 1200 employees, primarily in one large office building in an intensely competitive newspaper market of a metropolitan area of southern Canada.

Intervention

Within a broader business development process and a "Repetitive Strain Injury" (RSI) [MSD] program/ergonomic policy (Polanyi et al. 2005), initiatives of particular importance here were efforts around workstation design and work organization.
As a part of the program, workstation assessment protocol and form were designed, including notes on the layout and conditions of the workstation, with assessments conducted both on requests from area management or union and periodically every two years (Swift et al., 2004). Guidelines were developed for the purchasing or reassignment of workstations and computer equipment, with the formation of a joint labour and management committee

for furniture selection. For the "move" workers were encouraged to view a set of workstation options and provide input prior to full scale purchase. The ergonomic policy included both work demands e.g., duration, postures, and characteristics of work organization e.g. schedules, task variability, and deadlines among risk factors for RSI [MSD]. Guidelines were developed for modifications of the work environment e.g. engineering, administration, staffing, workflow. The company Health and Safety Manager was consulted on software decisions which might impact on workflow. Finally, work organization factors were included on a workstation assessment form (Swift et al., 2004).

Population

After starting the wider study, we learned of imminent changes with both the 'move' and 'team' formation, we decided to recruit a smaller group of employees who would undergo intensive more intensive observation. Among the 85 initial volunteers, forty-one office workers agreed to assessment of workstation dimensions (winter 1999), followed by postural assessments, and intensive task observation. The reduction in the number of participants was due to a combination of staff re-assignment, appropriateness of jobs to direct observation e.g. those in meetings much of the time could not be observed adequately at their desks, and unwillingness to engage in the additional burden of documentation during a stressful period of workplace change. The 41 participants worked in the advertising, circulation and finance departments performing a wide variety of clerical, administration, sales, customer accounts and call centre jobs. All participants provided written informed consent in keeping with approval by the Research Ethics Boards of McMaster University and the University of Waterloo.

Mean age of the group was 41 years (SD=9.6), and 71% were female. They had a mean height of 168 cm. (SD=10) and a mean weight of 74 kg. (SD=19). Participation in repeated measures (2000, 2001) varied because of vacation schedules, particularly during the summer, and for a few participants, job changes or retirement. Numbers available for analyses varied from 25 (61%) to 33 (80%) across years.

Measures

Workstation Equipment and Dimensions. Trained observers noted equipment available for each employee. Measurements of workstation setup were taken at the worker's usual workstation with the worker present (details in Appendix A). Dimension measures were recorded with an estimated accuracy of within 5mm. The orientation of workstation equipment was determined relative to the J key (center of the keyboard) using a calibrated "bubble" level as a reference when needed.

Work Organization. Items on work organization factors focused on those that we anticipated would undergo change with the transition to teams e.g. coordination of work with others, which we had previously found associated with meeting deadlines (Beech-Hawley et al. 2004). Sources included prior questionnaires in this population (Polanyi et al. 1997), Carayon and colleagues (1998) research on office work re-organization, and our own with time dimensions of work (Beech-Hawley et al. 2004). Nature of the variables can be inferred from Table 2 of questionnaire measures, administered each summer over three years. We also asked about computer malfunctions, as one potential remediable equipment related risk factor (Carayon et al. 1998).

Postures and Fit. Trained observers took bilateral upper-extremity *postural* measures of the workers while they performed keyboarding tasks at their workstation in their usual keying position (Appendix A). As appropriate, hand-held goniometers located on standard anatomical landmarks were used for some body segments. The postural measures had an estimated accuracy of within two degrees and were categorized into three bands (0-10, 10-20, >20 degrees). Workers' perceptions of the placement of their keyboard, mouse and monitor compared to a diagram designed by newspaper graphics employees (details in Polanyi et al. 1997). The diagram depicted placements that are in agreement with current standards e.g. Canadian Standards Association, ANSI, and peer-reviewed literature findings (Gerr et al. 2005). Hands-free phone use was considered to be better than the use of a regular hand-held phone, a cell phone or a phone with shoulder rest.

Tasks. We collected direct, real time measures of tasks performed by workers, reflecting work on accuracy of estimates of time spent performing tasks (Engström and Medbo 1997; Homan and Armstrong 2003). A two hour video recording was taken of the worker at her/his own workstation. The video camera was focused on the worker and included the keyboard, mouse, monitor and as much desk space as possible. A 30 minute video recording segment was coded by a trained analyst (Observer Pro 4.0, Noldus Information Technology, Netherlands). The software allowed the analyst to slow down or rewind the video and estimate task start and end times to the nearest tenth of a second. Measures created included percent (%) time in each task, number of tasks extrapolated to a shift, and the number of task transitions during the observation period.[23]

Symptoms. For symptoms, we asked the 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). Responses also permitted the construction of a case level, based on initial NIOSH work, but adapted to our newspaper population (see Beaton et al. 2000 for details). For both intensity and case level, we used the value of the body area with the greatest intensity.

Statistical analysis

For all direct measurements from workstation, equipment dimensions, postures, optimality of positions, work organization and tasks, preliminary analyses were used to describe changes in distributions across years. The data of continuous measures was normally distributed and hence the distributions were described by mean and standard deviation. For categorical data, frequency distributions were calculated. Box-plots, line plots and scatter plots were also used to assess the shape of the distribution.

To test our expected changes across years, we used statistical techniques appropriate to each measure. Generalized Estimating Equation (GEE) models were used for binary measures e.g. better self-reported fit, and multinomial measures e.g. reduced extreme postural angles. General linear mixed (GLM) models were used for continuous measures e.g. reduced %age of time at desk work, less pain intensity. To cast another light on changes in exposure that might be associated both with less pronounced extremes of posture e.g. decreased required head rotation, or with greater task flexibility e.g. greater variability in transitions between tasks, we used Levene's test (1960) to assess equality of variance across years. All analyses used the SAS statistical package V9.1 (2002-3).

RESULTS

Changes in equipment and work organization

All participants in 2001 reported having some new *equipment* over the period of the study, with 27 indicating a new computer, monitor or keyboard. Fifteen reported also having new computer programs or a new computer and mouse, the gateway into the editorial process at the newspaper. Observers documented an increase in the presence of bilateral wrist and elbow support for keyboards with the new equipment - 18% in 1999 to 86% in winter 2000 (see table 1). Significant decreases in keyboard depth from table edge were also observed (14.6 cm in 1999 to 7.4 cm in winter 2000) i.e., the keyboard was closer to the table edge. Monitor height above the seat pan increased (63.6 cm in winter 1999 to 69.9 cm in winter 2000). Variance seemed to decrease for continuous measures, though only table edge to center pad of mouse (see box plots in Figure 2) and height of monitor adjusted to seat were significant.

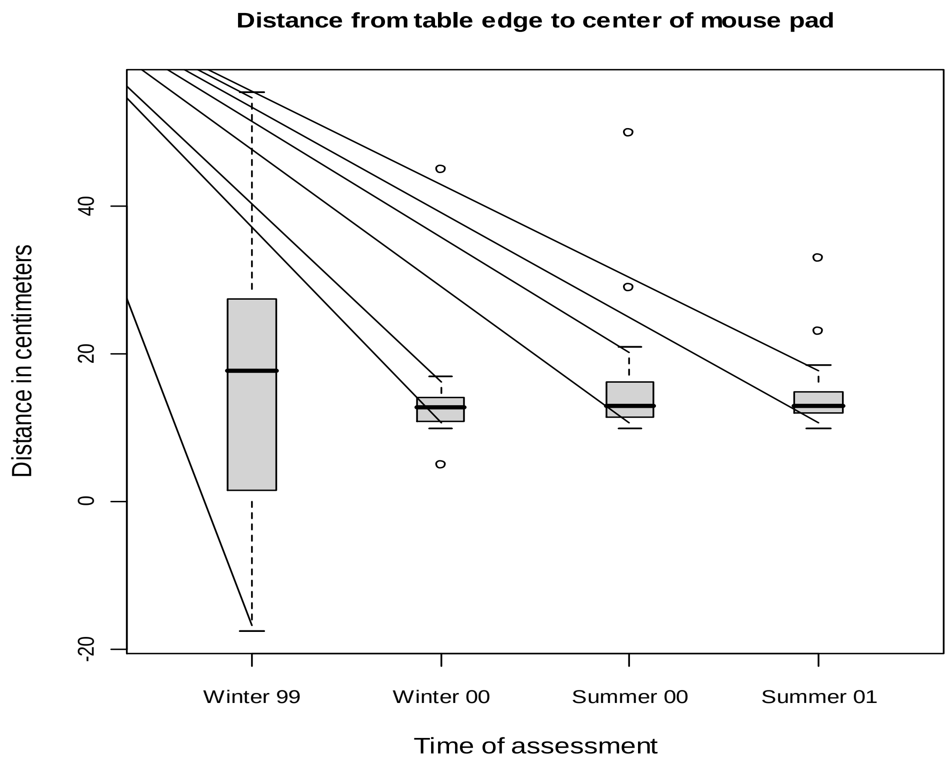

Figure 2. Distance from the table edge to the centre of the mouse pad in centimeters across the different data collection periods.

> Negative values indicate that mouse pads were closer to the worker than the table edge, located on another surface than the keyboard tray. Thick line represents median, box ends 25 and 75%iles, bars outside boxes represent 5 and 95%iles, and circles represent most extreme values (outside figure for winter 99).

For aspects of *work organization*, significantly fewer respondents reported sitting continuously for more than two hours (34% in 1999 to 17% in 2001). More frequent computer breakdowns, freezes, crashes or slowdowns were apparent between 1999 and 2000. In keeping with team work, there was greater agreement that employees worked with others to get their jobs done in later years. However, neither of these latter changes were significant.

Table 1. Equipment, dimension and posture measures (through direct observation), across years

Equipment-relationship & construct	Indicators		Winter 1999 (N=25)	Summer 1999 (N=25)	Winter 2000 (N=32)	Summer 2000 (N=30)	Summer 2001 (N=29)	Time Effect on Mean (p-value)	Equality of Variance (p-value)
Mouse-related									
- Dimensions [1]	J key to center of mouse pad (cm)		34.50 (20.1)	-	40.50 (4.7)	38.22 (12.9)	40.69 (3.2)	0.46	0.12
	Table Edge to Centre Pad (cm)		15.69 (20.2)	-	13.65 (6.4)	15.52 (7.6)	14.32 (4.6)	0.23	<.0001
Keyboard-related									
- Equipment [2]	Keyboard Support	Unsupported	-	14 (63.6%)	4 (13.8%)	6 (21.4%)	7 (26.9%)	0.0004	
		Partially supported (one side)	-	4 (18.2%)	0 (0%)	0 (0%)	2 (7.7%)		
		Fully supported (both sides)	-	4 (18.2%)	25 (86.2%)	22 (78.6%)	17 (65.4%)		
- Dimensions[1]	Depth from table edge (cm)		**14.60 (4.1)**	-	7.44 (6.1)	6.23 (4.0)	5.35 (3.7)	<.0001	0.44
	Height adjusted to seat (cm)		**18.17 (3.6) †**	-	**18.99 (3.1)**	22.64 (5.4)	22.12 (4.0)	<.0001	0.19
- Postures [2]	Wrist/Ulnar Deviation at left (degrees)	-- Angle in [0,10]	-	6 (26.1%)	21 (72.4%)	22 (75.9%)	13 (50.0%)	0.009	
		-- Angle in [>10,20]	-	17 (73.9%)	7 (24.1%)	6 (20.7%)	12 (46.2%)		
		-- Angle >20	-	0 (0%)	1 (3.5%)	1 (3.4%)	1 (3.9%)		
	Wrist/Ulnar Deviation at right (degrees)	-- Angle in [0,10]	-	6 (26.1%)	21 (84.0%)	21 (72.4%)	17 (65.4%)	0.003	
		-- Angle in [>10,20]	-	17 (73.9%)	4 (16.0%)	7 (24.1%)	9 (34.6%)		
		-- Angle >20	-	0 (0%)	0 (0%)	1 (3.5%)	0 (0%)		
	Wrist Extension at left (degrees)	-- Angle in [0,10]	-	7 (30.4%)	8 (27.6%)	12 (41.4%)	10 (38.5%)	0.16	
		-- Angle in [>10,20]	-	14 (60.9%)	8 (27.6%)	10 (34.5%)	12 (46.2%)		
		-- Angle >20	-	2 (8.2%)	13 (44.8%)	7 (24.1%)	4 (15.4%)		
	Wrist Extension at right (degrees)	-- Angle in [0,10]	-	8 (34.8%)	4 (13.8%)	12 (41.4%)	12 (46.2%)	0.001	
		-- Angle in [>10,20]	-	14 (60.9%)	6 (20.7%)	10 (34.5%)	12 (46.2%)		
		-- Angle >20	-	1 (4.3%)	19 (65.5%)	7 (24.1%)	2 (7.7%)		
	Head Tilt Angle (cm)		-	0.43 (12.4)	**-5.86 (7.2)**	-2.07 (9.45)	0.81 (5.0)	0.004	0.02

Monitor-related									
- Dimensions [1]	J key to center screen (cm)	Overall	6.85 (8.1)	-	6.38 (7.8)	5.01 (4.6)	6.21 (10.0)	0.15	0.41
		14" Monitor	-	-	7.08 (8.5)	4.74 (5.2)	3.85 (2.5)		
		15" Monitor	-	-	4.38 (6.6)	3.96 (3.1)	6.63 (13.1)		
		19" Monitor	-	-	7.5 (2.1)	9.67 (3.4)	22.0 (.)		
	Table edge to center screen (cm)		**27.39 (12.7)**	-	37.12 (10.8)	34.57 (8.2)	37.41 (11.4)	0.001	0.71
		14" Monitor	-	-	37.2 (12.0)	32.59 (8.1)	35.30 (10.4)		
		15" Monitor	-	-	35.00 (7.7)	33.78 (1.7)	37.60 (11.75)		
		19" Monitor	-	-	44 50(10.6)	48.17 (9.5)	39.0 (.)		
	Height adjusted to seat (cm)		**63.65 (10.0)**	-	69.87(4.3)	69.67 (6.5)	72.05 (5.2)	0.0002	0.006
		14" Monitor	-	-	69.5 (3.7)	69.18 (7.1)	72.95 (3.4)		
		15" Monitor	-	-	72.00 (5.0)	71.89 (5.2)	73.00 (4.71)		
		19" Monitor	-	-	64.75 (1.1)	65.83 (6.6)	65.0 (.)		
- Postures [1]	Head rotation angle (degrees)		-	**48.18 (24.5)**	4.29 (7.7)	5.00 (7.5)	7.69 (9.0)	<.0001	<.0001

[1] For continuous measures, mean (SD) is shown
[2] For categorical measures, frequency (percentage) is shown
[†] Bold text indicates the most different average values from other years

Table 2. Self-reported fit/optimality, work organization measures and symptoms (from questionnaire), across years

Domains	**Indicators/values**		**1999 N=32**	**2000 N=33**	**2001 N=30**	**p-value**
Self-reported fit	Keyboard-related Optimal Position		22 (68.8%)	22 (66.7%)	26 (86.7%)	0.03
	Monitor-related Optimal Position		24 (75%)	24 (75%) (n=32)	17 (60.7%) (n=28)	0.51
	Phone-related Optimal Position [1]		18 (43.8%)	13 (39.4%)	9 (30.0%)	0.18
	Mouse-related Optimal Position		13 (54.2%) (n=24)	17 (54.8%) (n=31)	22 (75.9%) (n=29)	0.09
Work organization, & experiences	Sitting continuously	< ½ hour	4 (12.5%)	10 (30.3%)	5 (16.7%)	0.01
		½ to 1 hour	10 (31.2%)	13 (39.4%)	12 (40.0%)	
		>1 - 2 hours	7 (21.9%)	4 (12.1)	8 (26.7%)	
		> 2 hours	11 (34.4%)	6 (18.2%)	5 (16.7%)	
	Computer breakdown (1=rarely, 10=very often) [2]		4.69(1.45)	5.27 (1.75)	5.27 (1.34)	0.07
	Work with others (1=strongly disagree, 10=strongly agree) [3]		6.56 (2.24)	7.15 (2.24)	6.90 (2.17)	0.22
	Control of task order & breaks (1=strongly disagree, 10=strongly agree)		6.00 (1.39)	6.13 (1.39)	5.77 (1.61)	0.64
	Experience of customer hostility	Often	14 (43.7%)	17 (51.5%)	15 (50%)	0.68
		Rarely/Occasionally	18 (56.3%)	16 (48.5%)	15 (50%)	
Symptoms	Pain in last year	Yes	23 (37.1%)		23 (37.1%)	0.65[4]
	Pain intensity		33.33(28.87)		30.00(24.13)	0.24[5]
	Case level	Mild	14 (43.8%)		14 (46.7%)	0.98[4]
		Moderate-severe	7 (21.9%)		7 (23.3%)	

Analyses on continuous variables used mixed model procedure and on discrete variable used the GEE method except for 4 McNemar test of symmetry and 5 Paired T-test. [1] Phone with headset is defined as optimal; [2] include computer breakdown/freezes/crashes, and slow response of computer; [3] include working together with other people, and coordinating work with others

Changes in postures and fit/optimality

Concomitant with equipment changes, many mean *posture* measures improved (see table 1): reduced wrist/ulnar deviation angles (74% in range of 10 to 20 degrees in 1999 to 24% in winter 2000 on the left side), decreased head tilt angle (-5.9 degrees in winter 2000 to -2.1 degrees in summer 2000), and decreased head rotation angle (48.2 degrees in 1999 to 4.3 degrees in winter 2000). Variance appeared to be reduced in some cases, as graphically demonstrated in over-laid scatter plots of head rotation vs. monitor side/side by year (see Figure 3). The change towards a more central location in the latter is striking, with a highly significant reduction in variance. In parallel to the improvements observed, employees indicated significant improvements in perceived *optimality* of their workstation setups, particularly for the keyboard (69% in 1999 to 87% in 2001) and the mouse (54% of those with a mouse in 1999 to 76% in 2001) (see Table 2).

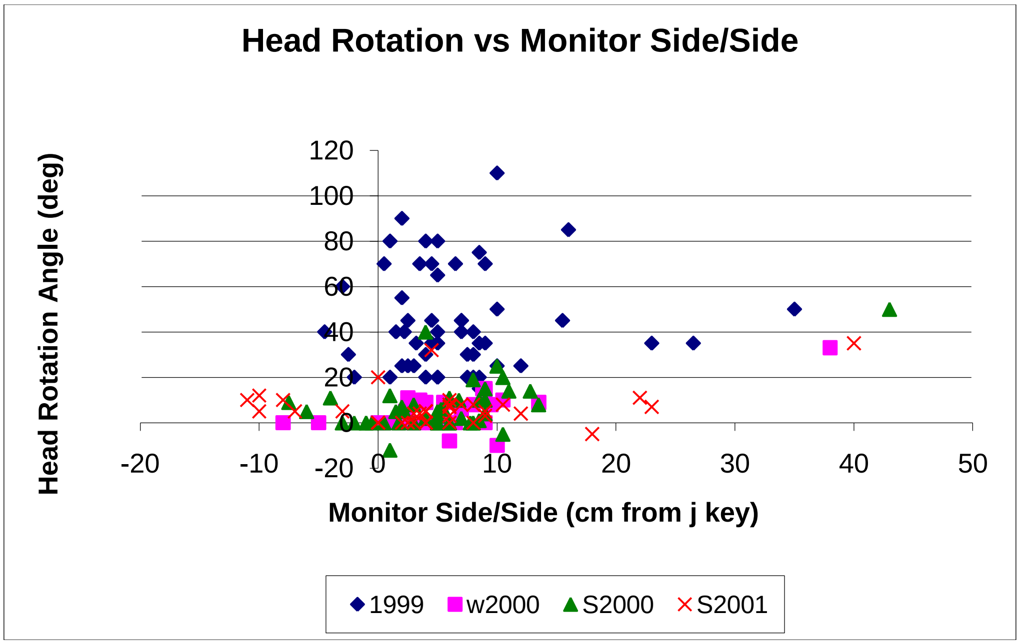

Figure 3. Maximum head rotation angle versus location of monitor side to side, across years

Table 3. Task measures (from video analysis), across years

	Years and N overall			Years effect on mean (p-value) #	Equality of Variance across years §
	1999 (N=25)	2000 (N=32)	2001 (N=27)		
Task Duration as percent of observation period, Mean (SD)					
Away from desk	15.5 (10.9) (n=19)	15.1 (13.3) (n=25)	17.7 (25.1) (n=23)	0.999	0.211
Desk work	45.5 (27.1) (n=25)	41.5 (23.3) (n=32)	28.5 (19.2) (n=26)	0.004	0.116
Keyboarding	21.4 (21.8) (n=21)	25.2 (19.0) (n=30)	28.9 (21.8) (n=26)	0.152	0.774
Mousing	11.5 (15.9) (n=14)	9.0 (8.3) (n=24)	18.4 (21.1) (n=23)	0.002	0.073
Phone	20.2 (19.6) (n=17)	16.9 (16.2) (n=18)	14.4 (13.3) (n=17)	0.515	0.340
Number during observation period, Mean (SD)					
Tasks in a shift	5.68 (1.11)	5.97 (1.18)	6.07 (1.38)	0.192	0.609
Transitions	123.64 (57.08)	143.97 (47.94)	149.89 (77.30)	0.122	0.121

Analyses used mixed model procedure
§ Due to the small sample size in 1999, the test has limited power

Changes in tasks

Few changes were observed in the mean percent duration of tasks, except for substantial increases in the number of employees mousing from 1999 to 2000 and a significant increase in the proportion of time mousing from 2000 to 2001 (see Table 3). In parallel, desk work alone i.e. doing no computer work, for example writing or reading documents significantly decreased. The mean number of tasks and task transitions steadily increased over three years, with greater variation (SD) in the number of transitions in the final year, though neither was significant.

Period prevalence of pain remained constant. Though a small decrease in pain intensity was reported the change was not statistically significant in this small population.

Discussion

Similar to changes in "ergonomic" adequacy associated with interventions in office workplaces (Ketola et al. 2002), we observed improvement in specific workstation configurations and associated equipment dimensions. The major new purchase opportunity (of new workstation furniture) associated with the "move" facilitated such changes (Polanyi et al. 2005). These in turn were associated with improvements in postures, greater than was observed in at least one office postural intervention (Gerr et al. 2005) and improvements in workers' perceived optimality of equipment locations.

Work organization and task indicators also showed some change, though less than the workplace parties had hoped for in the move to teams. Elsewhere (Polanyi et al. 2005), we have argued that both the nature of newspaper work and the technology and a variety of contextual characteristics of the organization (drive for productivity, management control, organizational culture) and the broader economic climate affected program implementation in a way which inhibited dealing with more upstream determinants of MSDs. Nevertheless, significant reductions in prolonged sitting and corresponding steady increases in task transitions were consistent with some of the workplace aims and appropriate to the modest gains expected in work organization interventions (Lamontagne et al. 2007).

The limited change in symptoms may reflect the multifactorial nature of MSD etiology but most likely reflects the persistence of symptoms observed in the larger cohort (Cole et al. 2006). Longer-term follow-ups of workforces at risk of MSDs 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). 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).

The number of participants was smaller than necessary to have adequate power to assign significance to some of the work organization and task changes that we observed. For example, the magnitude of decreases observed in wrist extension on the left and increases in transitions between work tasks would both have been significant in larger samples. Further, the selection of our sample down to those with particular kinds of desk work that were feasible for observation and and respondent burden may reduce generalizability to office workforces in general (Van Eerd et al, 2009). Nevertheless the overall pattern of change parallels those seen in the larger cohort of newspaper workers from which this sample was drawn (Cole et al. 2006). Given the long period of interest, we were restricted to limited sampling durations, with less sophisticated equipment than might be ideal e.g. observer-held versus continuous digital goniometers (Forsman et al. 2002). Each of these limitations was largely related to the substantial participant burden and resource costs associated with intensive monitoring of multiple indicators over time in a field setting.

Nevertheless, an important strength of our work was the guidance in data collection provided by our explicit conceptual framework which recognized the multifactorial nature of causation of WMSD and complex nature of 'exposure'. Our methods may provide guidance to other researchers seeking to monitor impacts of workplace interventions to reduce the burden of MSDs among office workers. The important role played by some workstation dimensions e.g. monitor distance, and postures e.g. wrist extension, may provide support to practitioners faced with the need to more immediately reduce office workers' exposures, though they would be well advised to keep in mind results of more rigorous studies assessing effectiveness (Brewer et al. 2006) and the persistence of symptoms, which militate against over-inflated claims of likely improvement in the challenging environment of modern offices.

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Appendix A: Description of workstation and posture measurements

Physical environment

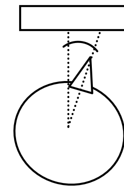
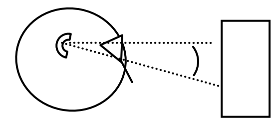
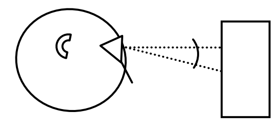
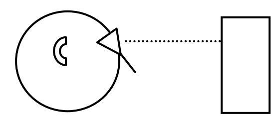
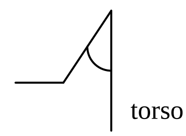
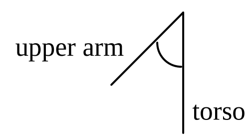
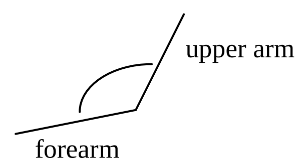
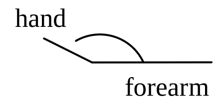
Workstation dimensions: Dimensions of the workstation were taken by trained observers while the worker was present at the workstation. Measures were taken consistently across various workstations (see Table D.1.1). The orientation of workstation equipment was determined relative to the J key of the keyboard. A calibrated "bubble" level was used as a reference as needed. It is estimated that the workstation dimensions were accurate to within 5 mm.

Table D.1.1 Examples of workstation dimension measurements

Workstation Dimension	Measurement
Keyboard Height	from floor to the height of the J key
Keyboard Width	from J key to left edge + J key to right edge
Keyboard Depth	from the table/desk edge to the front edge of the keyboard
Mouse Height	from floor to the height of the mouse pad/surface
Mouse Orientation	from the J key to the centre of the mouse pad/surface
Mouse Depth	from the table/desk edge to the centre of the mouse pad/surface
Monitor Size	diagonal measure from screen edge to screen edge
Monitor Height	from floor to top of screen
Monitor Orientation	from J key to centre of screen
Monitor Depth	from table/desk edge to centre of screen
Monitor Tilt Angle	number of degrees from perpendicular (-ve = facing downward)
Seatpan Height	from floor to top surface of seatpan
Seatpan Depth	from the lumbar support area of backrest to front of seatpan
Armrest Height	from floor to top surface of armrest
Armrest Width	from inside edge of one armrest to the inside edge of the other

Working postures: Worker postures were measured while they were at there workstations engaged in typical work situations. Postures were measured with hand-held goniometers using standard anatomical landmarks and body segments by trained observers. A calibrated "bubble" level was used to provide a reference for these measures. It is estimated that all posture measures were taken to within one to two degrees of accuracy. Worker heights were taken from self-reported questionnaire responses.

Table D.1.2 Examples of workstation posture measurements

Workstation Posture	Measurement (all taken while worker was working)	Diagrams
Head Rotation	Viewed from above the worker: angle between a line perpendicular from the centre of the monitor and a line from the worker's nose	
Head Tilt Angle	Viewed from the side: angle between a line parallel to the floor from the worker's ear to the monitor and a line from the worker's ear through the eye	
Gaze Angle	Viewed from the side: angle between a line from the worker's eyes parallel to the floor and a line from the worker's eyes to the middle of the screen of the monitor	
Viewing Distance	Viewed from the side: distance from the worker's eyes to the centre of the screen (note this could be considered a dimension but is included here because it includes the worker and the equipment)	
Shoulder Extension	Viewed from the side: angle between upper arm and torso	
Shoulder Abduction	Viewed from behind: angle between upper arm and torso	
Inner Elbow Angle	Viewed from the side: angle between the upper arm and the forearm	
Wrist Extension	Viewed from the side: angle between the dorsal surface of the hand and a line extending from the ulna	
Wrist Ulnar Deviation	Viewed from above: angle created from a line in the centre of the dorsal hand and a line extending from the centre of the dorsal forearm (between the ulna and radius)