

A multivariate evaluation of an office ergonomic intervention using longitudinal data

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The present study used longitudinal data from an alternative keyboard intervention study to test pathways between physical, work organization/psychosocial, stress and musculoskeletal symptom factors postulated by Sauter and Swanson in their ecological model of musculoskeletal disorders in office work. Data on work organization, stress and musculoskeletal symptoms were collected from 189 office workers at baseline and 1 year later. After baseline, an alternative keyboard was provided to half of the participants, while the remaining participants continued using a conventional keyboard. Regression analyses on the Year 1–baseline difference scores revealed significant relationships for keyboard condition and musculoskeletal symptoms, keyboard condition and work organization and work organization and stress. However, the relationships between work organization and musculoskeletal symptoms, keyboard condition and stress and stress and musculoskeletal symptoms were not significant. Thus, the analyses provided partial support for the tested pathways.

Keywords: Alternative keyboards; Psychological variables; Musculoskeletal symptoms

1. Background

Multiple studies have demonstrated a relationship between psychosocial (or work organization) factors and musculoskeletal symptoms within the computerized office environment (e.g. see reviews by Sauter and Swanson 1996 and Carayon *et al.* 1999). However, despite the growing evidence of the relationship between psychosocial factors and musculoskeletal outcomes, little is yet empirically known about the mechanisms and pathways by which psychosocial factors alone and in combination with physical factors may influence musculoskeletal symptoms. A number of models have been proposed to explain these relationships (Bongers *et al.* 1993, Sauter and Swanson 1996, Smith and Carayon 1996). These models are very similar in that they all have physical, biomechanical, psychosocial/work organization and stress components and propose similar, multiple pathways connecting these components to musculoskeletal symptoms. However, the Sauter and Swanson (1996) ecological model postulates additional mechanisms not found in the other two models (Huang *et al.* 2002) and is the model used to guide the present analyses. This model is depicted in figure 1 and is discussed in some detail below.

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As mentioned above, the model has physical, biomechanical, psychosocial/work organization and stress components that are linked through multiple pathways. The pathways of primary interest for the present study are as follows.

The first pathway lies between VDT or office technology, physical job demands and musculoskeletal outcomes. The interpretation is that changes in VDT or office technology may change the physical demands of the job, which may lead to biomechanical strain and to musculoskeletal symptoms. For example, changes in office technology/furniture/equipment may result in changes in posture or force, which may translate into changes in musculoskeletal symptoms. A recent example which supports this pathway is a study by Tittiranonda *et al.* (1999) in which symptomatic keyboard users experienced reduced musculoskeletal symptoms when using certain alternative keyboard designs. Such keyboards have been shown to alter hand and arm postures (Marklin *et al.* 1999) and other biomechanical risk factors (Treaster and Marras 2000).

The second pathway illustrates that changes in VDT or office technology may change the way that work is organized, which may lead to psychological strain, which in turn may lead to biomechanical strain and to musculoskeletal symptoms. For example, Lundberg *et al.* (1993) have shown that work-related psychosocial factors, such as boring and repetitive tasks, are related to physiological strain and Westgaard and Bjorkland (1987) and Waersted *et al.* (1991) have found low-level sustained muscle tension related to cognitive task demands. Waersted *et al.* (1991) and Lundberg and Melin (1995) hypothesize that psychologically stressful jobs may create risk for musculoskeletal symptoms due to the sustained muscle tension caused by the psychological demands.

The third pathway lies between work organization, physical demands and musculoskeletal outcomes. Here, changes in work organization may change the physical demands of the job, which may lead to symptoms. Early studies by Smith *et al.* (1981) and Sauter *et al.* (1983) comparing computer users to non-computer users found that computer users reported significantly greater work pressure and supervisory control and less autonomy, role clarity and support from co-workers. Lim and Carayon (1993) provide evidence from a field study of office workers that psychosocial/work organization variables can change the physical demands of the job. For example, psychosocial/work organization factors such as control over work and production standards can influence repetitiveness and work postures. In the Smith *et al.* (1981) and Sauter *et al.* (1983) studies, computer users reported more musculoskeletal symptoms than non-computer users. Additionally, more recent studies indicate that increasing the frequency of rest breaks (i.e. a work organization factor) in repetitive work provides relief from repetitive motions and static postures and can result in a significant reduction in musculoskeletal symptoms (Galinsky *et al.*, 2000, Dababneh *et al.* 2001).

Although evidence from prior studies can be used to substantiate the proposed pathways in the ecological model, there has been only one study to date that has tested the actual validity of these pathways. Amick *et al.* (1999) used data from a study of nearly 1800 aerospace manufacturing workers and found effects of work organization on both psychological strain and musculoskeletal symptoms. However this study was cross-sectional in nature and a stronger test of the model and its predicted relationships is provided by longitudinal data. With longitudinal data changes in one or more components of the model can be examined for their impact on other components of the model to see if relationships occur (or change

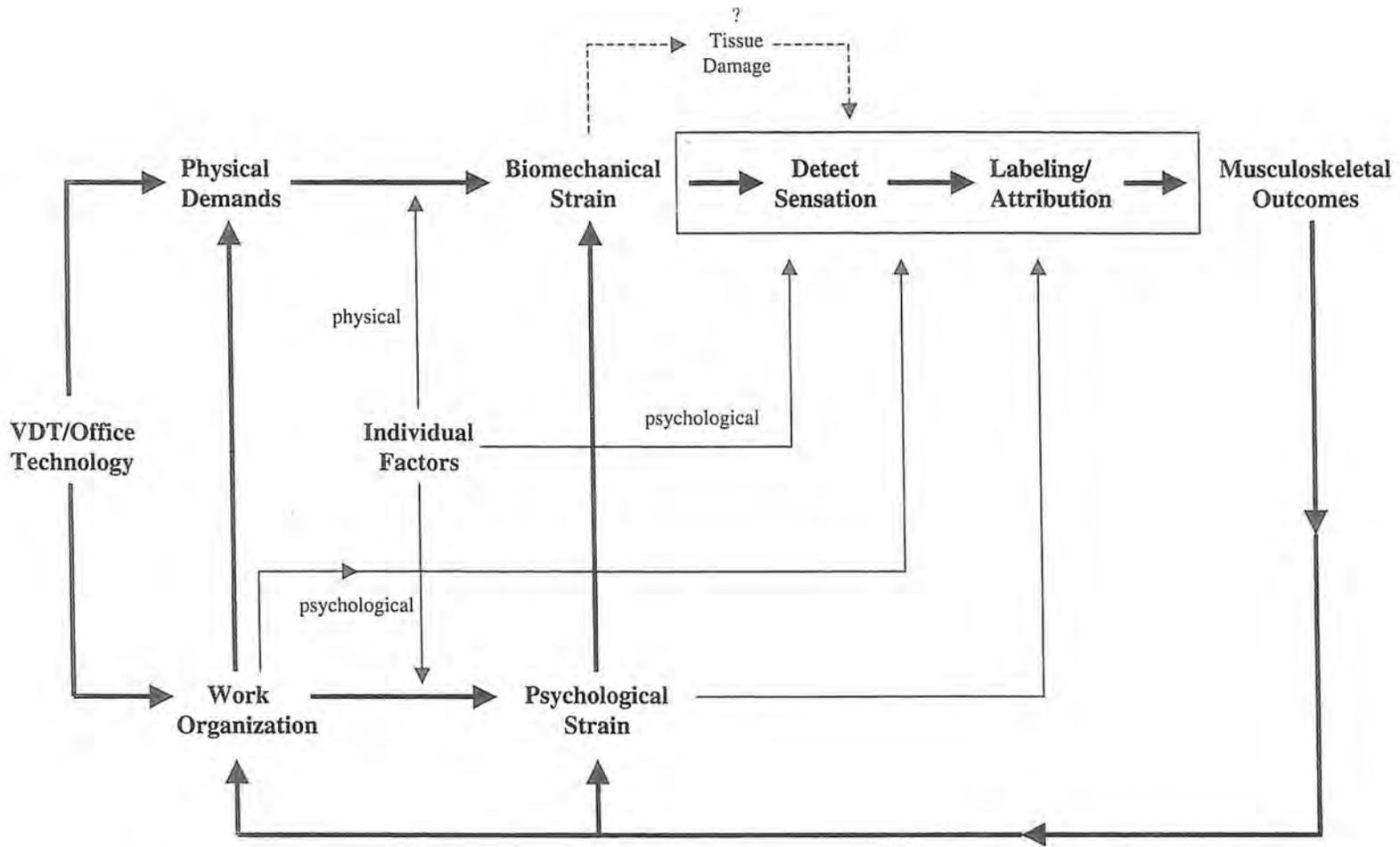


Figure 1. An ecological model of musculoskeletal disorders in VDT work (Sauter and Swanson 1996).

as predicted. The present multivariate analyses utilize data from the first year of a 2-year longitudinal alternative keyboard study, which is a follow-on to an earlier National Institute for Occupational Safety and Health (NIOSH) laboratory study of alternative keyboards (Swanson *et al.* 1997). This intervention study involved only a change in keyboards for some of the participants: study participants were randomly assigned to either a control (conventional keyboard) group or to an alternative keyboard condition for the duration of the study. Data are drawn from musculoskeletal symptom surveys and psychosocial/work organization surveys administered to two of the keyboard groups at baseline and at year 1 of the study and the analyses are guided by the Sauter and Swanson (1996) model, as depicted in figure 2.

As can be seen, aspects of the model which are tested include VDT technology (i.e. keyboard condition—alternative or conventional), work organization, psychological strain (i.e. stress) and musculoskeletal symptoms. Physical demands and measures of biomechanical strain and cognitive processes were not included in these analyses. The following relationships were examined using Year 1–baseline difference scores. Since the analyses are exploratory in nature, directionality is not specified.

- (a) The effect of keyboard condition (alternative vs conventional) on musculoskeletal symptoms, with H_1 being that participants in the two keyboard conditions would show a differing pattern of musculoskeletal symptom reporting over the year.
- (b) The effect of keyboard condition on work organization/psychosocial factors. H_1 would predict an effect, as it is possible that an alternative keyboard may alter participants' perceptions of factors such as job control, workload or organizational climate.
- (c) The effect of keyboard condition on perceived stress. A relationship could exist if participants in the alternative keyboard condition, for example, perceive the alternative keyboard as more or less difficult (stressful) to use than the conventional keyboard.
- (d) The effect of changes in work organization/psychosocial factors on musculoskeletal symptoms, with H_1 being that substantial changes in

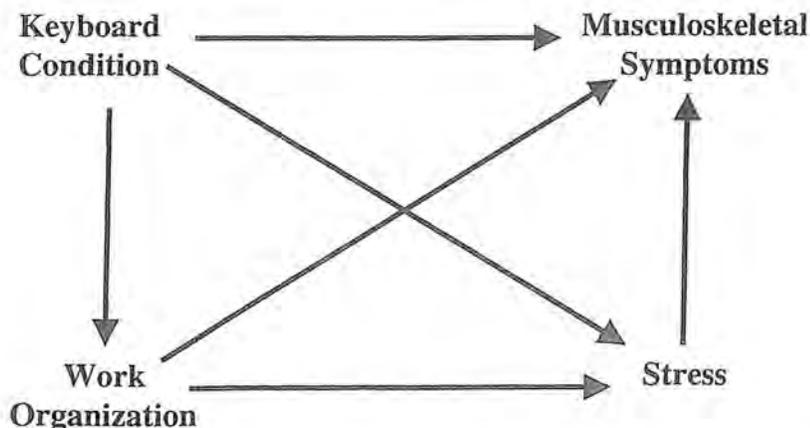


Figure 2. Derivative of the ecological model tested in the present study.

- work organization factors, such as job control, would be related to changes in reported musculoskeletal symptoms.
- (e) The effect of changes in work organization/psychosocial factors on perceived stress, with H_1 being that changes in work organization would be related to changes in perceived stress.
 - (f) The effect of changes in perceived stress on the reporting of musculoskeletal symptoms. H_1 would predict that substantial changes in reported stress would be related to changes in the reporting of musculoskeletal symptoms over the year.

A significant relationship between keyboard condition and musculoskeletal symptoms may partially operate through work organization or through perceived stress. For example, if changes in keyboards resulted in changes in perceived stress (e.g. alternative keyboard users reported less stress) and changes in perceived stress influenced symptom reporting (e.g. lower stress was related to fewer reports of symptoms), then these work organization or stress effects would need to be controlled for in order to examine the 'true' relationship between keyboard condition and musculoskeletal symptoms. Thus, if the relationship between work organization and musculoskeletal symptoms is significant, then work organization will be used as a control factor in the analysis examining the relationship between keyboard condition and musculoskeletal symptoms. Similarly, stress will serve as a control variable in analyses examining the relationship between work organization and musculoskeletal symptoms and keyboard design and musculoskeletal symptoms if the relationship between stress and musculoskeletal symptoms is significant.

2. Methods

2.1 Participants

The participants were 189 employees (163 women, 26 men) of a large insurance company who worked in a variety of jobs (e.g. claims representative, claims processor, word processing) and who typed on a computer keyboard for at least 3 hours per day. Software that was installed on participants' computers at baseline confirmed that participants typed on the keyboard for an average of 3.4 hours per day. Most participants had been in their jobs for 1 year or more (90%), were married (56%), were white (81%) and were 35 years of age or older (64%). Participant demographics are displayed in table 1.

2.2 Surveys

Two surveys were used to assess workplace psychosocial (work organization) factors and musculoskeletal symptoms.

2.2.1. Psychosocial survey. This survey contained a variety of psychosocial scales as well as demographic questions (e.g. age, sex, race/ethnicity, tenure, hours of

Table 1. Sample demographics.

Variable		Percentage*
Sex	Female	85
	Male	14
Age	<25	4
	25-34	31
	35-44	29
	45-54	28
	>54	7
Marital status	Married	56
	Single	43
Race/ethnicity	White	81
	African American	6
	Hispanic	8
	Other	4
Time in current job	< 1 year	10
	1-5 years	55
	6-10 years	16
	11-20 years	14
	> 20 years	5

*Percentages may not add up to 100% because of missing values.

work) and outcome measures (e.g. stress, general health). All but four of the scales selected for the present analyses (i.e. organizational climate, supervisory behaviours, innovation and communication, job hassles) were taken from the NIOSH Job Stress Questionnaire (JSQ) (Hurrell and McLaney 1988). The organizational climate and the innovation and communication scales were developed at NIOSH and have been used in numerous recent studies of office workers (e.g. Grubb *et al.* 2002). The supervisory behaviours questions and job hassles questions were taken from the University of Wisconsin Office Worker Survey (Sainfort 1990, Smith *et al.* 1992). Following is a description of the scales and items used in the present analyses.

- (1) *Organizational climate*: this section consisted of 10 items rated on a five-point scale ranging from 'strongly disagree' to 'strongly agree' (e.g. 'There is an honest commitment to quality at [company name]', '[Company name] treats its employees fairly').
- (2) *Job control*: this section consisted of 15 items rated on a five-point scale ranging from 'very little' to 'very much' (e.g. 'How much influence do you have over the decisions as to when things will be done in your work unit', 'How much influence do you have over the amount of work you do').
- (3) *Supervisory behaviours*: this section consisted of 32 questions rated on a five-point scale ranging from 'never' to 'always' ('Indicate how often the following statements describe your supervisor's behaviour: Lets group members know what is expected of them; Assigns group members to particular tasks; Gives feedback on how you are doing your job').
- (4) *Social support*: the degree to which social support was obtained from supervisors, co-workers and spouse, and family and friends was rated on a four-point scale ('not at all' to 'very much').

- (5) *Inter-group and intra-group conflict*: this section consisted of 15 questions rated on a five-point scale ranging from 'strongly disagree' to 'strongly agree' ('There is harmony within my work group', 'There is agreement between my group and other groups').
- (6) *Workload*: this section consisted of seven questions rated on a five-point scale ranging from 'rarely' to 'very often' ('How often does your job require you to work very hard', 'How often does your job leave you with little time to get things done').
- (7) *Skill utilization*: this section consisted of eight items rated on a five-point scale ranging from 'strongly disagree' to 'strongly agree' ('To be successful on my job requires all my skill and ability', 'My job is very challenging').
- (8) *Innovation and communication*: this section contained five questions on innovation ('In my unit, new ideas on how work should be done are encouraged') and two questions on communication ('When I need to communicate with people in my unit, it is difficult to get in touch with them'). All questions were rated on a five-point scale ranging from 'never' to 'always'.
- (9) *Role conflict*: this section consisted of seven questions rated on a seven-point scale ranging from 'very inaccurate' to 'very accurate' ('I receive incompatible requests from two or more people', 'I have to do things that should be done differently').
- (10) *Role ambiguity*: this section consisted of seven questions rated on a seven-point scale ranging from 'very inaccurate' to 'very accurate' ('I know exactly what is expected of me', 'There are clear, planned goals and objectives for my job').
- (11) *Motivation*: this section consisted of seven items rated on a five-point scale ranging from 'strongly disagree' to 'strongly agree' ('I take pride in doing my job as well as I can', 'I feel unhappy when my work is not up to my usual standard').
- (12) *Job commitment*: this section consisted of seven items rated on a five-point scale ranging from 'strongly disagree' to 'strongly agree' ('I am quite proud to be able to tell people who I work for', 'I would not recommend to a close friend to join our staff').
- (13) *Job hassles*: this section consisted of six items on the extent to which work backlogs, deadlines, under-staffing, lack of notification, work quality requirements and contact with upset people was present in the job, which were rated on a four-point scale ('none', 'a little', 'some', 'a lot').
- (14) *Stress*: this consisted of a single item, 'At your job, during the last month, would you say that you experienced: a lot of stress, a moderate amount of stress, relatively little stress, almost no stress at all'.

2.2.2. Musculoskeletal symptom survey. This survey asked about current 'pain, aching, stiffness, burning, numbness or tingling' in the neck, right and left shoulders, right and left arms, right and left hands and back. If current symptoms were indicated, a respondent then answered questions about the duration, frequency and intensity of the symptoms. The survey was a shortened version of the NIOSH musculoskeletal symptom survey used by Bernard *et al.* (1994). Only the current symptoms question was used in the analyses.

2.2.3. Keyboards. The keyboards consisted of a conventional keyboard in general use in the company and a non-adjustable alternative keyboard with the keyboard halves at fixed angles.

2.3 Procedure

Participants volunteered to take part in the study and were assigned identification numbers by NIOSH to use on all surveys in order to maintain confidentiality. At each work site, company health and safety personnel set up meeting times over several workdays for survey administration at baseline and again 1 year later. Participants attended the meeting that was most convenient for them. If a participant was unable to attend any of the meetings (e.g. on vacation, in training), a packet of surveys and an addressed envelope was left for them and they were requested to complete the surveys and mail them to the NIOSH investigators. Study participants were randomly assigned (within study site and job) to the alternative keyboard or the conventional keyboard condition after the baseline data were collected. There were a total of 95 participants in the conventional keyboard condition and 94 in the alternative keyboard condition.

3. Results

Analyses were conducted using SAS, Version 8.01 (1999–2000) and the level of significance was set at $p < 0.05$. All psychosocial and stress scales were factor analysed, using principal factor analysis with oblique rotation and reliabilities (Cronbach's alphas) were calculated for each factor. This analysis resulted in 24 factors. (Three training items factored separately from the skill utilization questions and the three-item factor was named 'training adequacy'.) In the next step, psychosocial variable inter-correlations and the correlations between the psychosocial and stress variables and between the psychosocial and musculoskeletal symptom variables were examined. Only those psychosocial variables with significant correlations with the stress variable or with a musculoskeletal symptom variable were retained. The means, standard deviations, ranges and Cronbach's alphas (where applicable) are presented for the 14 retained psychosocial variables and the stress variable in table 2. The Cronbach's alphas were acceptable for the retained variables, although three (co-worker support, communication, adequacy of training) had alphas of less than 0.70.

As can be seen, at both baseline and Year 1, the respondents reported that their supervisors were often supportive and that co-workers were somewhat supportive. They reported slight agreement that intra-group conflict occurred, slight disagreement that inter-group conflict occurred, fairly high levels of innovation, control, adequacy of training to do their jobs and commitment and a good organizational climate. They also reported fairly high workload levels and job hassles, low levels of role ambiguity and role conflict and moderate levels of stress.

The psychosocial factor inter-correlations and the correlations with the stress question are presented in table 3. While there were a substantial number of significant correlations ($p < 0.05$) among the psychosocial and stress variables, 15 of these had correlations of ~ 0.40 and above. An examination of these latter correlations

Table 2. Descriptive statistics—psychosocial variables, stress.

Variable	Mean	Standard deviation	Observed range	Actual range	Cronbach's alpha
<i>Baseline</i>					
Supervisory support	3.96	0.63	1.7–5	1–5	0.87
Co-worker social support	3.98	0.57	2–5	1–5	0.67
Intra-group conflict	3.52	0.66	1.8–5	1–5	0.88
Inter-group conflict	2.61	0.58	1–4.1	1–5	0.83
Innovation	3.60	0.74	1.5–5	1–5	0.80
Communication	2.17	0.65	1–4	1–5	0.62
Organizational climate	3.73	0.70	1.6–5	1–5	0.92
Job commitment	4.15	0.48	2.8–5	1–5	0.81
Job control	3.75	0.83	1–5	1–5	0.75
Workload	3.59	0.76	1.6–5	1–5	0.87
Adequacy of training	3.73	0.79	1–5	1–5	0.72
Job hassles	2.67	0.58	1–4	1–4	0.66
Role ambiguity	5.25	0.81	1.6–6.7	1–7	0.79
Role conflict	3.15	0.98	1–6	1–7	0.76
Stress	2.34	0.83	1–4	1–4	—
<i>Year 1</i>					
Supervisory support	3.89	0.68	1.6–5	1–5	
Co-worker social support	3.95	0.65	2–5	1–5	
Intra-group conflict	3.42	0.76	1.4–5	1–5	
Inter-group conflict	2.63	0.63	1–4.8	1–5	
Innovation	3.58	0.68	1.3–5	1–5	
Communication	2.16	0.61	1–4	1–5	
Organizational climate	3.65	0.68	1.5–5	1–5	
Job commitment	4.09	0.49	2.8–5	1–5	
Job control	3.64	0.88	1–5	1–5	
Workload	3.65	0.74	1.7–5	1–5	
Adequacy of training	3.65	0.82	1–5	1–5	
Job hassles	2.61	0.61	1–4	1–4	
Role ambiguity	5.22	0.92	1.9–6.7	1–7	
Role conflict	3.07	1.06	1–6	1–7	
Stress	2.25	0.88	1–4	1–4	

reveals the following: supervisory support was associated with higher levels of innovation, a better organizational climate and lower levels of stress. Lower levels of intra-group conflict were associated with greater innovation and lower levels of role ambiguity. Higher levels of inter-group conflict were associated with greater role conflict and lower levels of intra-group conflict. Lower levels of role ambiguity were associated with higher levels of job commitment. A good organizational climate was associated with greater job commitment and lower levels of role ambiguity, while higher workload levels were associated with a greater likelihood of job hassles.

The percentage of participants reporting current musculoskeletal symptoms at baseline and Year 1 is presented in table 4. At baseline, a third or more of the participants reported musculoskeletal symptoms of the neck, back and right hand. Generally, more participants reported symptoms in the right than in the left upper extremity. Substantially fewer participants reported symptoms at Year 1 than at baseline and this was true for all body parts.

The next phase of analysis involved multiple regression analyses to test the relationships in the model depicted in figure 2. In all regressions, age, sex and

Table 3. Correlations between psychosocial variables and stress variables.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Supervisory support														
2. Co-worker social support	0.09													
3. Intra-group conflict	0.27	0.39												
4. Inter-group conflict	-0.19	-0.19	-0.41											
5. Innovation	0.47	0.29	0.50	-0.29										
6. Communication	-0.21	-0.16	-0.18	0.32	-0.19									
7. Organizational climate	0.38	0.19	0.30	-0.38	0.31	-0.05								
8. Job commitment	0.27	0.09	0.26	-0.25	0.23	-0.06	0.61							
9. Job control	0.27	0.11	-0.01	-0.11	0.25	-0.11	0.29	0.22						
10. Workload	-0.24	-0.04	-0.04	-0.18	-0.14	-0.01	-0.13	0.14	-0.05					
11. Adequacy of training	0.19	0.05	0.07	-0.08	0.09	-0.14	0.24	0.14	0.16	0.02				
12. Job hassles	-0.28	-0.12	-0.06	0.28	-0.12	0.14	-0.20	0.01	-0.01	0.58	-0.02			
13. Role ambiguity	0.37	0.23	0.42	-0.39	0.35	-0.25	0.42	0.40	0.26	0.09	0.25	-0.15		
14. Role conflict	-0.34	-0.19	-0.32	0.44	-0.22	0.30	-0.31	-0.24	-0.18	-0.06	-0.21	0.34	-0.58	
15. Stress	-0.45	-0.10	-0.14	0.15	-0.30	0.22	-0.20	-0.16	-0.24	0.33	-0.17	0.35	-0.28	0.22

Emboldened numbers indicate $p < 0.05$.

Table 4. Percentage of participants reporting current musculoskeletal symptoms.

Variable	Baseline %	Year 1 %
Neck	45	26
Right shoulder	25	13
Left shoulder	19	14
Right arm	22	12
Left arm	14	9
Right hand	34	22
Left hand	26	14
Back	42	23

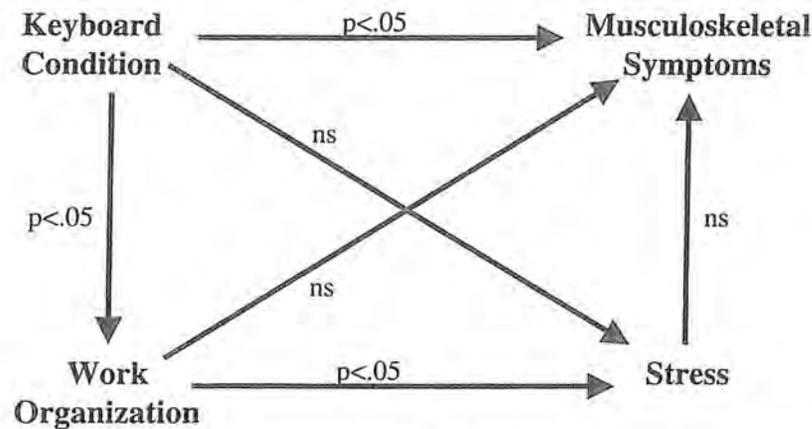


Figure 3. Significance of relationships tested in the present study. Non-significant relationships are denoted by 'ns' and significant relationships by ' $p < .05$ '.

marital status were entered as control variables and separate regressions were conducted for each body part. As detailed in the introduction, the following relationships were tested using Year 1–baseline difference scores.

- The relationship between keyboard condition and musculoskeletal symptoms;
- The relationship between keyboard condition and work organization/psychosocial factors;
- The relationship between keyboard condition and stress;
- The relationship between work organization and musculoskeletal symptoms;
- The relationship between work organization and stress; and
- The relationship between stress and musculoskeletal symptoms.

The results of these analyses are shown in figure 3 and presented below.

- Keyboard condition was significantly related to musculoskeletal symptoms in the left shoulder ($F(4, 182) = 2.53, p < 0.05$) and approached significance for the left hand ($F(4, 181) = 2.19, p = 0.07$). In both instances, the difference between the Year 1 and baseline scores indicated that fewer participants reported symptoms at Year 1 in the alternative keyboard condition than in the conventional keyboard condition.

- (b) Keyboard condition was significantly related to the work organization/psychosocial factor of co-worker support ($F(4, 183) = 2.44, p < 0.05$). Participants in the conventional keyboard group reported a reduction in co-worker support from baseline to Year 1, while participants in the alternative keyboard group reported an increase in co-worker support.
- (c) The relationship between keyboard condition and stress was non-significant.
- (d) The relationship between work organization/psychosocial factors and musculoskeletal symptoms was non-significant.
- (e) The relationship between stress and musculoskeletal symptoms was non-significant.
- (f) Work organization/psychosocial factors was significantly related to stress ($F(17, 166) = 3.17, p < 0.0001$). This was accounted for by an increase in supervisory support and a reduction in intra-group conflict between baseline and Year 1 that resulted in lower stress scores.

Given that the analyses examining the relationships between work organization and musculoskeletal symptoms and between stress and musculoskeletal symptoms were not significant, it was not deemed necessary to control for work organization in the analyses examining the relationships between keyboard condition and musculoskeletal symptoms or to control for stress in the analyses examining the relationship between work organization and musculoskeletal symptoms or between keyboard condition and musculoskeletal symptoms.

4. Discussion

The results indicated that some of the relationships between keyboard design, work organization, stress and musculoskeletal symptoms that were predicted by the ecological model did occur in these longitudinal intervention data. Participants in the alternative keyboard condition reported significantly less musculoskeletal symptoms in the left shoulder and a significant increase in co-worker support. Additionally, changes in work organization resulted in changes in reported stress. Participants reported increases in supervisory support and decreases in within-group conflict, which resulted in lower levels of perceived stress. However, the analyses did not reveal changes in perceived stress due to keyboard condition or that reports of musculoskeletal symptoms were related to changes in perceived stress or work organization.

While figure 1 predicts that changes in VDT technology will result in changes in work organization, there was weak support for such a relationship in these analyses. In the present study, major technological or physical work environment changes were not made. The physical work environment, office technology and software, tasks and furniture all remained the same with the exception (for half of the participants) of the keyboard. While the keyboard geometry for the alternative keyboard was somewhat different than that for the conventional keyboard, both keyboards were used in the same way. Therefore, it is not surprising that keyboard design appeared to have little effect on the psychosocial work environment in this study. The one effect that was found, an increase in co-worker social support in the alternative keyboard group and a decrease in co-worker social support in the

conventional keyboard group over the year, is rather puzzling. It is possible that it is a chance significance (i.e. a Type I error) and that there was no relationship between keyboard design and co-worker social support. Another possible explanation relates to the perceived desirability of the alternative keyboards. Although none of the participants expressed dissatisfaction to the experimenters about the keyboard condition to which they were assigned, it is possible that the participants in the conventional keyboard group harboured some resentment toward those chosen to receive an alternative keyboard and thus may have perceived diminished co-worker support over the year. If this was the case, it did not appear to translate into symptoms, as the co-worker support variable was not significantly related to either the stress or musculoskeletal symptom outcomes.

The support for the predicted relationship between keyboard condition and musculoskeletal symptoms was also fairly weak in these analyses. While there were substantial declines in the reporting of musculoskeletal symptoms over the first year of the study (refer to table 4), there was a significant differential decline between the keyboard conditions for the left shoulder only, with a trend ($p=0.07$) toward significance for the left hand. It is unclear why symptoms appeared to decline significantly on the left side only for the alternative keyboard condition. The most probable explanation is that while there was a greater reduction in right upper extremity symptoms for participants in the alternative keyboard condition, these reductions did not differ enough from those that occurred in the conventional keyboard condition to reach significance. An examination of the data supports this explanation. There was a greater drop in the number of participants reporting right upper extremity symptoms at Year 1 in the alternative keyboard condition than in the conventional keyboard condition, where the reduction at Year 1 was very slight. (Within groups analyses indicate that these differences were significant for all body parts for the alternative keyboard condition, but not for the conventional keyboard condition.) However, any change in symptom reporting in the conventional keyboard condition, however small, had the potential to reduce the size of the difference between keyboard conditions and, hence, the possibility for significance.

Given the large body of literature showing relationships between work organization or psychosocial factors and musculoskeletal symptoms, it may seem surprising that no such relationships were found in these analyses. However, as an examination of table 2 reveals, the work organization variables remained quite stable over the year, therefore reducing the likelihood that work organization changes would result in reduced/increased stress or musculoskeletal symptoms.

In general, given the variability available in these data, the present analyses provide some support for the relationships among physical, psychosocial, stress and musculoskeletal variables as defined in the ecological model. Future analyses are planned for the full complement of data from the study to further explore the relationships between these variables over time.

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