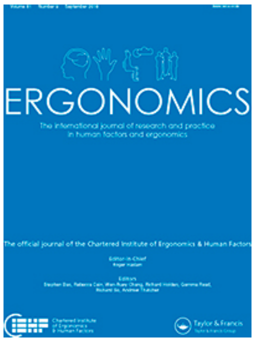

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Covariation between workplace physical and psychosocial stressors: evidence and implications for occupational health research and prevention

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There is increasing interest in distinguishing the effects of physical and psychosocial workplace stressors on the aetiology of work-related musculoskeletal disorders (MSD). Modest associations have been found between psychosocial stressors and MSD, such as intensive load, monotonous work and low job control. Interpretation of these results has been limited by likely covariation between physical and psychosocial stressors. This investigation examined exposure covariation among blue- and white-collar workers employed in a mass production manufacturing environment (N = 410). Physical stressors were assessed from questionnaire and accelerometry. Psychosocial stressors were assessed from questionnaire. Pearson and Spearman correlation coefficients were computed. An exploratory factor analysis procedure identified possible common factors linking specific physical and psychosocial stressors. Moderate to high correlations between some physical and psychosocial stressors showed evidence of covariation both across and within groups. Covariation was strongest among blue-collar production and low-status office workers. Factor analysis results showed considerable shared variance between some physical and psychosocial stressors, such as repetition and job control, suggesting that these disparate stressors manifest from common work organization factors that govern the structure of work. While recognizing the conceptual differences between physical and psychosocial stressors, these results call attention to the strong empirical relationships that can exist between some stressors in the workplace setting. To guard against ambiguous study findings that can occur when exposures are mixed, it is critical that future epidemiologic studies include information about the degree of association between task-level stressors. Future research on work organization determinants of task-level stressors, and their coincident occurrence in jobs with greater specialization, may provide promising new insights into the nature of risk for MSD and effective prevention strategies.

1. Introduction

US Bureau of Labor Statistics (BLS) data show that workers with the highest incidence of the illness category Disorders Associated with Repeated Trauma

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(DART) are employed largely within mass production manufacturing environments such as meatpacking, automobile, textile and garment, household appliance, footwear, electrical equipment and food processing (BLS 1999). Labourers, assembly line operators, packers, machine operators and material handling workers have the highest rates of DART for the upper extremities within the manufacturing sector. Non-manufacturing occupations also identified within the highest rate group were cashiers, cleaners, secretaries, nursing aides and orderlies, registered nurses, and truck drivers (Burnett *et al.* 2001). While there are some unique physical and psychosocial stressor attributes among these high-risk occupational groups, there are also general commonalities: specialized tasks with limited job content, rigid work pace with physically intensive work cycles, posturally fixed (static) or repetitive body motions, low-decision authority and skill discretion, rigid work-scheduling demands with highly regulated break patterns and, often, social isolation.

Disparities in the incidence of MSD between occupational groups employed among highly specialized job tasks reflect broad inequities in the distributional patterns of exposure in both the physical and psychosocial dimensions of work. Karasek and Theorell (1990) showed a strong negative correlation between overall physical exertion and decision latitude (i.e. job control) across a wide range of occupational titles from a nationally representative survey in the USA. The roots of these distributional patterns took hold as recently as the early 1900s when the social and organizational structure of work was transformed by separating task planning and task execution functions between management and labour, resulting in a level of specialization not seen previously (Taylor 1967). These changes in the vertical division of labour were promoted as 'scientific management,' and this new structure of work led to increasingly greater management control over the production process. For labour, task specialization correspondingly resulted in less control in both physical and psychosocial aspects of work, manifesting in an accelerated pace of work, increased restrictions on worker autonomy, and the reduction of craft skills and apprentice traditions (Waring 1991).

Musculoskeletal epidemiology studies increasingly incorporate measures of exposure to both physical and psychosocial workplace stressors, with the goal of distinguishing the etiologic effects of these stressors. Yet successfully distinguishing the effects of different stressor conditions requires that they not be strongly correlated (Stevens 1996). The measurement redundancy that occurs when covariation among stressors exists within a specific data set can severely limit statistical power. Of even greater consequence is the risk of representing an association obtained with a single covariant stressor (or set of stressors) as having unique influence on the health outcome, when the result may be partly or entirely explained by correlated exposure conditions (Cohen and Cohen 1983). With the potential for strong correlations between physical and psychosocial stressors, there is a resultant need for researchers to explicitly consider exposure covariation in the generation and interpretation of study results.

This paper seeks to examine empirically the relationship between physical and psychosocial workplace stressors among blue- and white-collar workers employed full-time within a mass production manufacturing environment. It was hypothesized that covariation in exposure between physical and psychosocial stressors would exist and be especially elevated among blue-collar workers with greater task specialization. The specific goals of this study were (1) to examine the correlations between physical and psychosocial workplace stressors among blue- and white-collar workers, (2) to perform an exploratory factor analysis to investigate the structure of possible underlying factors linking these conceptually distinct stressor conditions, and (3) to discuss the implications of these findings for future occupational epidemiology studies and prevention.

2. Study methods

2.1. *Study population*

A questionnaire was administered to 410 workers (84% participation) enrolled in a baseline epidemiologic survey at an appliance manufacturing plant where household washing machines were produced. All white-collar workers (with an annual pay scale) and all blue-collar workers (with an hourly pay scale) assigned to work in one of two washing machine assembly operations were eligible for the study. On the traditional assembly line, workers were assigned to direct production (assembly) or support functions (e.g. in-line repair or utility workers). For direct production workers, a conveyor transported washing machine units between workstations at a rate of one every 22 s and work was hand intensive and highly routinized. On the 'new' line, start-up operations for the production of a newly designed washing machine were being performed. The work activities on this new line were non-routinized, focused on pre-production planning (e.g. part ordering, tolerance checks, etc.), and work pace was not yet governed by fixed cycle times.

White-collar workers comprised nearly half of the study subjects and included a significantly higher proportion (77%) of males (table 1). On average, white-collar workers were 2 years older than and had twice the job tenure of blue-collar workers, but plant tenure was not significantly different between the two groups. Among white-collar workers, clerical and secretarial staff (n = 18) were exclusively female and had a significantly higher mean job tenure of 8.2 years (SD = 7.15) compared with a mean (SD) of 4.38 (4.67) years for all 'other' white-collar workers. Clerical and secretarial workers performed more routinized office work tasks than those employed in management and supervision, engineering, and various professional positions (e.g. sales, accounting).

2.2. *Physical stressor measures*

Physical stressors were measured by workers' questionnaire responses and by accelerometery (table 2). Two composite physical load scores were computed from questions adapted for worker respondents from exposure checklists proposed in the Occupational Safety and Health Administration's (OSHA) draft Ergonomic Protection Standard (OSHA 1995). Scoring for the composite measures was based upon weighting specific stressors in accordance with intensity and daily duration criteria, as specified in the proposed checklist. The composite score for the upper

Table 1. Demographics of study participants, by work group ($n = 410$).

Demographic factors	Blue-collar ($n = 220$) Mean	(SD)	White-collar ($n = 190$) Mean	(SD)
Gender	50% male		77% male	
Age (years)	39.65	(9.43)	41.48	(8.94)
Job tenure (years)	2.39	(3.18)	4.74	(5.06)
Plant tenure (years)	9.77	(6.24)	10.32	(8.60)

Table 2. Summary of physical stressor measures.

Physical stressors	Questionnaire items	Absolute scale range
Composite physical load scores		
Upper Extremity Score (UESCORE)	17 items: short cycle ($\leqslant$ 15 s), time typing, squeezing, forceful pinch, neck lateral, neck flex, abduct shoulder, forearm rotation, wrist flexion, forceful finger grasp, contact stress, palm as hammer, power tool use, whole-body vibration, poor lighting, cold temperatures, work pace regulation	0–35[a]
Back and Lower Extremity Score (BLSCORE)	12 items: bend moderate, bend severe, back extension, twist back, time sitting, time standing, kneeling, foot pedal use, contact stress, knee kick, whole-body vibration, forceful push/pull	0–30[a]
Repetitiveness measures		
Physical Monotony Scale	2 items: how variable are the physical demand requirements of the job between and within days.	1–4[b]
Time in Short Cycle Work	1 item: how much time/day spent performing similar body motions every 15 s or less.	1–4[c]
Repetition Rating Scale	1 item: select the description that best describes your typical hand/arm motion while working.	1–5[d]
Work Pace Regulation	1 item: how is your work pace or work speed determined: self-paced, deadlines or co-workers, or machine/assembly pacing	0–2[b]
Difficulty with Pace	1 item: how difficult is it to maintain your work pace 8 h per day.	1–4[b]
Instrumentation-based repetitiveness measure		
Accelerometer	Wrist-worn single axis accelerometer measuring dynamic upper limb motion.	0–256[e]

Source: [a]Questions and scoring adapted from a checklist (OSHA 1995); [b]new measure developed for this study; [c]OSHA (1995); [d]question adapted from Latko *et al.* (1997); [e]instrument manufactured by Computer Sciences and Applications Incorporated, Shalimar, Florida, USA.

extremity (UESCORE) was derived from 17 stressor items and the score for the back/lower extremities (BLSCORE) was derived from 12 stressor items.

Physically repetitive work was assessed from five questionnaire items (table 2) and from accelerometry. Nineteen Model 7164 Version 1.0 accelerometer instruments were used in the study (Computer Science and Applications, Shalimar, Florida, USA) to provide a quantitative measure of dynamic upper limb motion demands. Due to a limited number of instruments available, it was not feasible to obtain accelerometer data on every study subject. Accelerometry data were obtained from a convenience sample of 146 (36%): 79 blue-collar workers from the chassis department on the traditional assembly line, 12 blue-collar workers from the new line, and 55 white-collar workers. Instrument specifications and sampling procedures are detailed in Estill *et al.* (2000).

2.3. *Psychosocial scale measures*

Psychosocial stressors were measured by workers' questionnaire responses. Over 30 individual questions or items were selected primarily from two sources: the NIOSH Generic Job Stress Questionnaire and the Job Content Questionnaire (Hurrell and McLaney 1988, Karasek *et al.* 1998, used with permission from Robert Karasek). The psychosocial questions were reduced to 10 stressor measures that described specific characteristics of the work environment (table 3). Cronbach's α coefficient, measuring the internal reliability of the scales, ranged from 0.70 to 0.86 for all scales, except for psychological job demands which was 0.59. Psychosocial measures were coded so that higher numeric values signified higher exposure or a less favourable psychosocial condition. However, in contrast, higher levels of decision latitude represented the *desirable* condition of higher levels of job control.

Table 3. Summary of psychosocial stressor measures.

Psychosocial stressors	Questionnaire items	Absolute scale range
Job strain	Ratio of two scales: psychological demands and decision latitude	0.25 – 2[a]
Psychological demands	5 items: work fast, work hard, excessive work, not enough time, conflicting demands	12 – 48[a]
Decision latitude	Sum of two subscales: (1) *skill discretion* (6-items: keep learning, requires creativity and skill, has variety, can develop abilities, repetitive work (R)); (2) *decision authority* (3-items: make decisions, a lot of say, little freedom to decide (R)).	24 – 96[a]
Mental work load	4 items: concentration, interrupt, hectic work, wait for work	4 – 16[a]
Poor work schedule control (R)	1 item: able to influence work hours	1 – 4[b]
Lack of group cohesion (R)	4 items: harmony, support ideas, we feeling, friendly	1 – 4[b]
Group pressure	4 items: relax, keep up, urgency, group pressure	1 – 4[c]
Lack of supervisor support (R)	3 items: supervisor makes work life easier, is easy to talk to, can be relied upon	1 – 4[b]
Lack of co-worker support (R)	3 items: co-workers make work life easier, are easy to talk to, can be relied upon	1 – 4[b]
Opinions not accepted by work group (R)	1 item: can voice opinion to work group and still be accepted	1 – 4[c]

Source: [a]Job Content Questionnaire (Karasek *et al.* 1998); [b]NIOSH Generic Job Stress Questionnaire (Hurrell and McLaney 1988); [c]new measure; (R), reverse coded.

2.4. *Data analyses*
Exposure distributions were compared by occupational group with the Wilcoxon rank-sum test. When exposure was examined across the entire study population, two variables had highly skewed distributions (skewness $>|0.80|$). Square-root transformation was applied to the repetition measure 'difficulty maintaining pace' and the $\log_{10}$ transformation was applied to the job strain measure (Rummel 1970). Pearson correlation coefficients (r) were computed among all pairs of exposure conditions, including both physical load measures (composite scores and repetition measures) and psychosocial stressors. When exposure was examined by occupational group, skewed distributions were more common and Spearman correlation coefficients (r_s) were computed. $p = 0.01$ was used as the criterion for statistical significance.

An exploratory factor analysis was performed (Rummel 1970) to explore the interrelationships between the physical and psychosocial stressors. Since construct validity or the development of new measures was not the goal, scale measures were entered into an iterated principal factor analysis rather than individual scale items. The start values used for this iterative procedure are the squared multiple correlations (SMC) of each variable with all the other variables in the analysis. In factor analysis, the SMC have been shown to be the lower bound estimates of the communality of each item with the common factors (Rummel 1970). Both orthogonal (Varimax) and oblique (Harris Kaiser) rotation procedures were used. All data analyses were performed using SAS software (SAS System for Windows 1989–96).

3. Study results

3.1. *Physical and psychosocial stressor levels*
As expected, blue-collar workers had higher physical work demands than white-collar workers, measured by the upper extremity and back/lower extremity scores, and the six repetition measures (table 4). The range of physical exposure was fairly wide among the blue-collar workers, as reflected in large standard deviations,

Table 4. Mean, standard deviation (SD) and range of physical stressor measures among blue- and white-collar workers.

Physical stressors	Blue-collar ($n = 220$) mean	SD	(range)	White-collar ($n = 190$) mean	SD	(range)	p
Composite physical scores							
Upper Extremity Score (UESCORE)	10.61	6.46	(0–26)	2.25	3.24	(0–16)	0.0001
Back and Lower Extremity Score (BLSCORE)	4.60	3.73	(0–18)	0.87	1.58	(0–10)	0.0001
Repetitive measures							
Physical monotony	2.87	1.02	(1–4)	2.43	1.04	(1–4)	0.0001
Time in short cycle work	3.40	1.04	(1–4)	1.71	0.94	(1–4)	0.0001
Repetition rating scale	3.17	0.87	(1–5)	1.98	0.89	(1–4)	0.0001
Work pace regulation	1.53	0.74	(0–2)	0.26	0.44	(0–1)	0.0001
Difficulty with pace	1.89	0.87	(1–4)	1.56	0.80	(1–4)	0.0001
Accelerometer[1]	70.22	25.65	(20–165)	25.88	15.44	(6–97)	0.0001

[1]Accelerometer data were collected among 91 blue-collar and 55 white-collar workers.

whereas the measures were more narrowly concentrated toward lower exposure levels among the white-collar workers. White-collar workers had higher psychological job demands and mental workload, but they had more favourable levels of job control (i.e. greater decision latitude and schedule control) (table 5). Consequently, job strain was significantly higher among the blue-collar workers. Social-relations measures were comparable between the two groups, except that 'group pressure' was higher among white-collar workers.

3.2. *Relationships among physical stressor measures*

Moderate to high correlations were found for most pairs of physical load measures among blue-collar workers (table 6). The correlation between the two composite scores was high ($r_s = 0.59$) and, as expected, moderate to strong correlations were found between the composite scores and the physical repetition measures. Only physical monotony and difficulty maintaining work pace showed no relationship. Correlations among blue-collar workers involving the accelerometer measure ($n = 91$, 41%) were moderately strong for all self-reported physical load measures except physical monotony, work pace regulation, and difficulty maintaining work pace. The intercorrelations among physical load measures were generally weaker among white-collar workers.

3.3. *Covariance patterns among physical and psychosocial stressors*

3.3.1. *Blue-collar workers*: The correlations between some physical and psychosocial stressors were as high as those found among physical stressors alone (table 7). Moderately high positive correlations were found for job strain and the six repetition measures. Correlations were also substantial among the two stressor components of job strain: psychological job demands and decision latitude. The correlations were especially strong (and negative) between decision latitude and physical load; for example, decision latitude had a marked inverse relationship with the composite upper extremity score among the blue-collar workers, $r_s = -0.61$ (figure 1a). The correlation between UESCORE and the two subscale components of decision latitude, skill discretion and decision authority, were also strong ($r_s = -0.58$ and -0.52, respectively).

Table 5. Mean, standard deviation (SD) and range of psychosocial stressor measures among blue- and white-collar workers.

Psychosocial stressors	Blue-collar ($n = 220$) mean	SD	(range)	White-collar ($n = 190$) mean	SD	(range)	p
Job strain (ratio)	0.57	0.19	(0.3–1.6)	0.45	0.11	(0.3–0.9)	0.0001
Psychological demands	30.64	5.02	(16–43)	32.00	5.52	(16–48)	0.0221
Decision latitude	57.23	12.09	(24–90)	72.10	10.31	(40–96)	0.0001
Mental work load	9.66	1.80	(4–16)	12.50	1.81	(8–16)	0.0001
Poor work schedule control	3.25	0.70	(2–4)	2.52	0.67	(2–4)	0.0001
Lack of group cohesion	2.18	0.45	(1–4)	2.85	0.48	(1.5–4)	0.6902
Group pressure	2.25	0.43	(1–3.8)	2.66	0.50	(1.5–4)	0.0001
Lack of supervisor support	2.13	0.78	(1–4)	2.27	0.86	(1–4)	0.1654
Lack of co-worker support	1.94	0.63	(1–4)	2.00	0.63	(1–4)	0.5229
Opinions not accepted by work group	2.04	0.76	(1–3)	2.00	0.81	(1–3)	0.3620

Table 6. Spearman correlations between physical stressor measures, by work group.

Physical stressors	UESCORE	BLSCORE	Physical monotony	Time in short cycle	Repetition rating scale	Work pace regulation	Difficulty with pace	Accelerometer
Blue-collar workers (n = *220*)								
UESCORE	–	–	–	–	–	–	–	–
BLSCORE	**0.59**[a]	–	–	–	–	–	–	–
Physical monotony	**0.38**[a]	0.20[d]	–	–	–	–	–	–
Time in short cycle	**0.69**[a]	**0.49**[a]	**0.36**[a]	–	–	–	–	–
Repetition rating scale	**0.35**[a]	**0.31**[a]	0.16[d]	**0.38**[a]	–	–	–	–
Work pace regulation	**0.30**[b]	0.17[d]	**0.20**[c]	**0.38**[a]	**0.29**[a]	–	–	–
Difficulty with pace	**0.26**[c]	**0.28**[b]	—0.01	0.13	**0.42**[a]	**0.18**[c]	–	–
Accelerometer (*n* = 91)	**0.43**[b]	**0.44**[b]	0.16	**0.34**[c]	**0.40**[b]	0.16	0.18	–
White-collar workers (n = *190*)								
UESCORE	–	–	–	–	–	–	–	–
BLSCORE	**0.21**[c]	–	–	–	–	–	–	–
Physical monotony	0.01	—0.08	–	–	–	–	–	–
Time in short cycle	**0.47**[a]	0.14	0.01	–	–	–	–	–
Repetition rating scale	**0.46**[a]	0.18[d]	0.07	**0.53**[a]	–	–	–	–
Work pace regulation	**0.40**[a]	0.00	0.05	0.14	0.16	–	–	–
Difficulty with pace	**0.24**[c]	—0.04	—0.12	0.15	0.14	**0.36**[a]	–	–
Accelerometer (*n* = 55)	0.14	0.04	—0.21	—0.05	0.16	0.18	0.09	–

Significance: [a]$\leqslant 0.0001$, [b]$\leqslant 0.001$, [c]$\leqslant 0.01$, [d]$\leqslant 0.05$ (bold if significance $\leqslant$ 0.01). Power varies due to missing values for some measures.

Table 7. Spearman correlations between composite physical demand scores and repetitive work demands with workplace psychosocial stressors, by work group.

Psychosocial stressors	UESCORE	BLSCORE	Physical monotony	Time in short cycle	Repetition rating scale	Work pace regulation	Difficulty with pace	Accelerometer[1]
Blue-collar workers (n = 220)								
Job strain	**0.58**[a]	**0.34**[a]	**0.37**[a]	**0.46**[a]	**0.48**[a]	**0.39**[a]	**0.41**[a]	**0.37**[b]
Psychological demands	**0.24**[c]	**0.25**[c]	−0.01	0.16[d]	**0.40**[a]	**0.19**[c]	**0.43**[a]	0.23[d]
Decision latitude	**−0.61**[a]	**−0.34**[a]	**−0.51**[a]	**−0.50**[b]	**−0.33**[a]	**−0.37**[a]	**−0.26**[b]	**−0.32**[c]
Mental demands	−0.11	0.02	**−0.19**[c]	−0.09	0.07	**−0.19**[c]	**0.26**[a]	−0.12
Poor work schedule control	0.16[d]	0.17[d]	0.09	0.12	0.02	0.03	0.11	0.01
Lack of group cohesion	0.09	0.07	−0.12	−0.06	0.08	0.05	**0.19**[c]	−0.05
Group pressure	0.21[d]	0.17[d]	0.03	0.10	**0.32**[a]	0.09	**0.38**[a]	0.18
Lack of supervisor support	**0.25**[c]	0.11	−0.05	0.13	0.09	0.12	**0.22**[c]	−0.03
Lack of co-worker support	0.01	−0.03	−0.12	−0.08	0.05	0.06	0.17[d]	−0.16
Opinions not accepted	0.13	0.05	−0.12	−0.01	0.08	0.12	0.13	0.01
White-collar workers (n = 190)								
Job strain	**0.34**[a]	0.14	−0.12	0.16[d]	0.18[d]	**0.24**[c]	**0.37**[a]	0.26
Psychological demands	**0.26**[b]	0.09	−0.18[d]	0.04	0.13	**0.21**[c]	**0.43**[a]	0.12
Decision latitude	**−0.24**[c]	−0.09	−0.06	−0.19	−0.15[d]	−0.14	−0.08	−0.10
Mental demands	0.19[d]	0.06	−0.10	0.04	0.13	**0.22**[c]	**0.24**[c]	0.20
Poor work schedule control	0.06	−0.07	−0.05	−0.05	−0.04	0.08	−0.02	0.14
Lack of group cohesion	−0.15[d]	0.12	−0.13	−0.05	−0.10	0.07	0.14	−0.02
Group pressure	0.19[d]	0.03	−0.07	0.06	0.17[d]	**0.23**[c]	**0.28**[b]	0.22
Lack of supervisor support	−0.19[d]	−0.01	0.01	−0.03	−0.10	0.04	0.09	0.15
Lack of co-worker support	0.03	0.05	−0.04	0.01	−0.03	0.01	0.07	−0.12
Opinions not accepted	0.03	0.05	−0.04	0.01	−0.03	0.01	0.07	−0.12

Significance: [a] $\leqslant 0.0001$, [b] $\leqslant 0.001$, [c] $\leqslant 0.01$, [d] $\leqslant 0.05$ (bold if significance $\leqslant 0.01$). Power varies due to missing values for some measures.
[1] Accelerometer data were collected among 91 blue-collar and 55 white-collar workers.

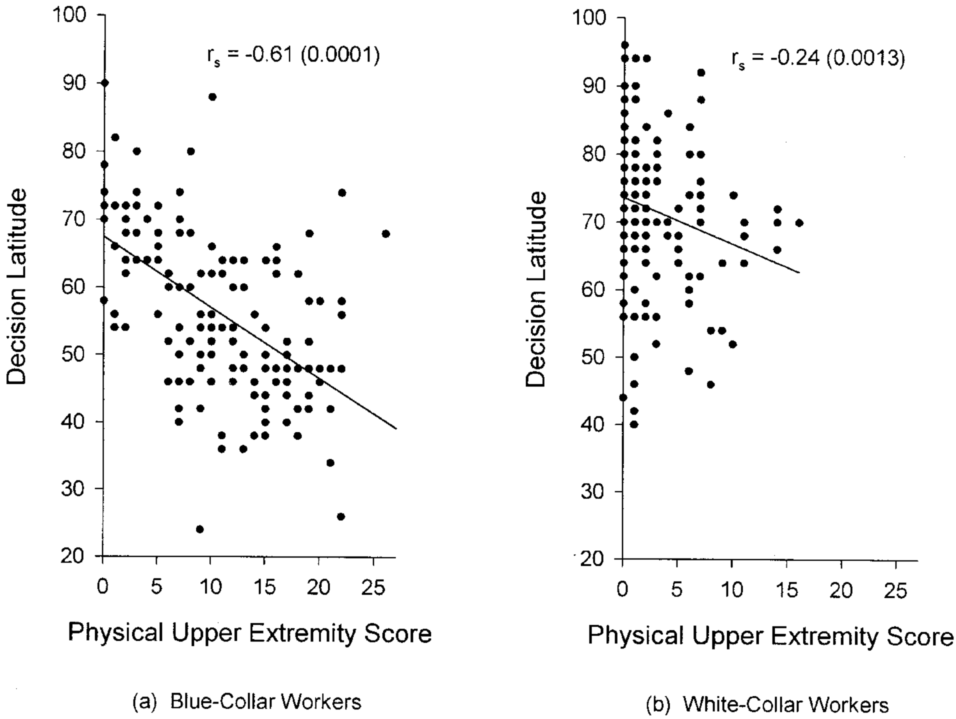

Figure 1. Scatter plots of decision latitude and the composite physical upper extremity score by occupational group. (a) Blue-collar workers, (b) white-collar workers.

Mental demands were generally negatively correlated with physical load among blue-collar workers, although a moderate positive correlation was found between mental demands and the qualitative repetition item 'difficulty maintaining work pace.' Interestingly, difficulty maintaining work pace was also significantly correlated with unfavourable social conditions: lack of group cohesion, group pressure, and lack of supervisor and co-worker social support. UESCORE was moderately correlated with lack of supervisor support and UESCORE and the repetition rating scale were both correlated with group pressure.

3.3.2. *White-collar workers*: Correlations between physical and psychosocial stressors were generally much weaker among white-collar workers (table 7). Again, the relationship between physical load and job strain, and its component dimensions (psychological demands and decision latitude), were among the strongest findings. The scatter plot of decision latitude and UESCORE showed more skewed exposure distributions—grouped toward lower physical demands and higher job control, with a correspondingly less pronounced negative slope than for blue-collar workers (figure 1b). The correlation between UESCORE and the two subscale components of decision latitude, skill discretion and decision authority, were comparable (r_s = −0.20 and −0.22, respectively). Moderate positive correlations were found between mental demands and several physical stressor measures. Difficulty maintaining work pace was, again, moderately correlated with unfavourable social conditions: lack of group cohesion and group pressure, and work pace regulation was moderately correlated with group pressure.

When clerical workers and secretaries were removed from the analysis, correlations with the composite upper extremity score were reduced: $r_s = 0.28$ for job strain (versus 0.34), $r_s = 0.22$ for psychological demands (versus 0.26), and $r_s = -0.18$ for decision latitude (versus -0.24). Among clerks and secretaries only, the covariation patterns were often as strong as the findings among blue-collar workers. In spite of the small sample size ($n = 18$), significance levels were <0.05 for correlations between UESCORE and two psychosocial stressors (job strain and group pressure) ($r_s = 0.66$, $p = 0.004$ and $r_s = 0.64$, $p = 0.006$, respectively).

3.4. *Covariance patterns between accelerometry and psychosocial stressors*

Among workers with accelerometer data, the correlations between the instrument-based measure of repetition (dynamic motion) and the psychosocial stressors were generally consistent with those found using the self-reported measures of repetition. Despite the smaller sample size, the correlations between accelerometer data and job strain and decision latitude were moderately strong and highly significant among blue-collar workers; the coefficients were smaller for white-collar workers. Correlations between the accelerometer data and the two subscale components of decision latitude, skill discretion and decision authority, were comparable to those obtained for decision latitude among blue-collar workers ($r_s = -0.29$, $p = 0.006$ and $r_s = -0.27$, $p = 0.014$, respectively); among white-collar workers, the correlation was more comparable for decision authority ($r_s = -0.21$, $p = 0.130$) but not skill discretion ($r_s = -0.01$, $p = 0.961$).

3.5. *Covariance patterns among blue and white-collar workers combined*

Covariation examined across all study participants showed strong positive associations between physical stressors and job strain and poor scheduling control. Strong negative associations were found between the physical stressors and decision latitude, mental demands and group pressure (table 8).

3.6. *Distribution of occupations for decision latitude and physical load*

Occupational groups were plotted by their group median values for decision latitude and the UESCORE, showing a steep inverse relationship (figure 2). The relative exposure level for each occupation on these two stressor dimensions is consistent with our observational understanding of exposure levels among the population under study. A very strong negative correlation was found between these two stressors using the group aggregate measures ($r = -0.91$, $p = 0.001$). Strong negative correlations were also found between occupational group aggregate measures of decision latitude and the aggregate measures of other physical stressor measures: BLSCORE ($r = -0.82$, $p = 0.0002$) and accelerometry ($r = -0.75$, $p = 0.005$).

3.7. *Psychological demands scale items*

Factor analysis results not shown here indicated that the five items that comprised the psychological demand scale loaded on two factors rather than one factor. Correspondingly, the exploratory factor analysis procedure included the two smaller scale measures in place of the full psychological demands scale measure. One scale (time demands) was derived from the sum of three reverse-coded items: 'not asked to do an excessive amount of work', 'have enough time' and 'free from conflicting demands', and had an internal reliability (α) = 0.71. The other scale measure

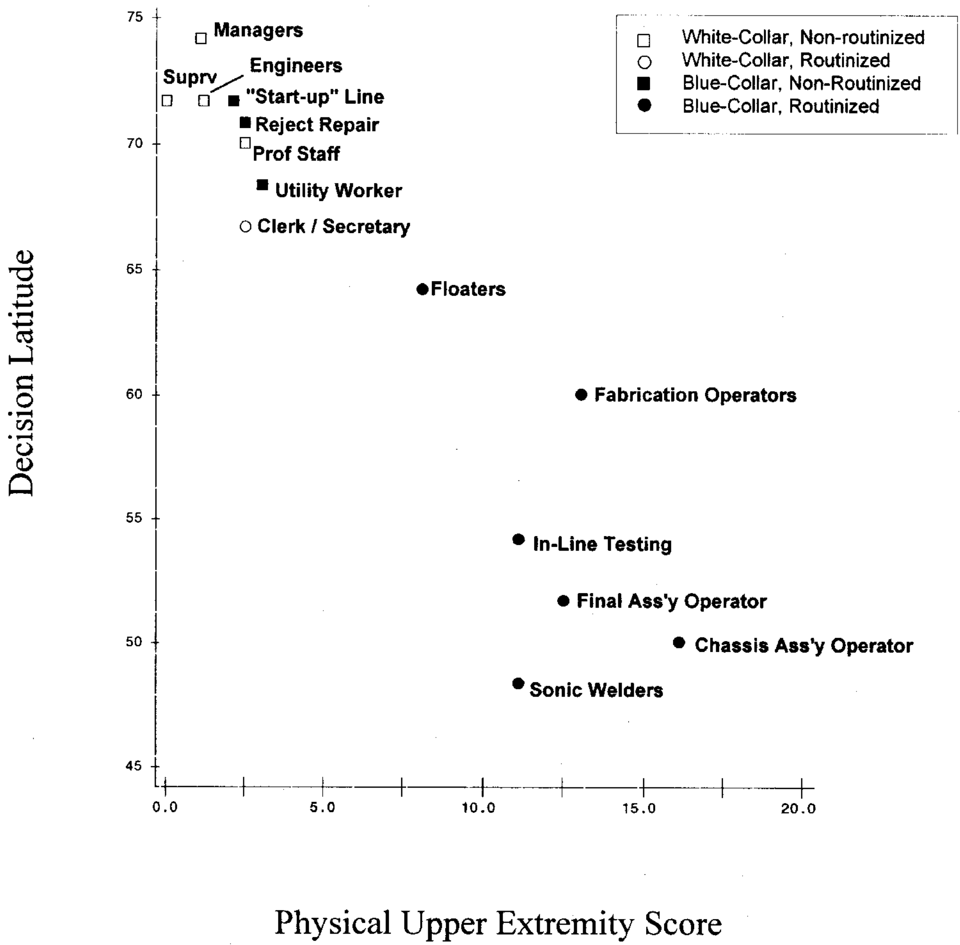

Figure 2. Distribution of occupations by median decision latitude and median composite physical load score, $r = -0.91$ ($p = 0.001$).

(hard*fast) was derived from the sum of two items: 'job requires working very hard' and 'job requires working very fast', and had an internal reliability = 0.70. In addition, correlations between the five items of the psychological demands scale were each examined in relation to the physical stressors to provide a more detailed assessment of covariation within the component parts of this construct, and to yield possible insights into the bidimensional results (table 9). The full-scale measure generally correlated less strongly with physical demands than its component items.

3.8. *Exploratory factor analysis*

The principal factor analysis extraction with orthogonal rotation is reported in table 10, showing the stressor measure loadings on the four factor solution in columns 2–5 and the squared multiple correlations and the final communalities (Rummel 1970) in columns 6 and 7, respectively. Covariation between physical and psychosocial measures was evident in two factors. Repetition (physical) and job control (psychosocial) measures were clustered with bipolar loadings on factor 2, called

Table 8. Pearson correlations of the intercorrelation of physical work demands, and the correlations between physical and psychosocial workplace stressors among all study participants (blue- and white-collar, $n = 410$).

Physical stressors	UESCORE	BLSCORE	Physical monotony	Time in short cycle	Repetition rating scale	Work pace regulation	Difficulty with pace	Accelerometer[1]
UESCORE	–	–	–	–	–	–	–	–
BLSCORE	**0.67**[a]	–	–	–	–	–	–	–
Physical monotony	**0.34**[a]	**0.22**[a]	–	–	–	–	–	–
Time in short cycle	**0.80**[a]	**0.61**[a]	**0.29**[a]	–	–	–	–	–
Repetition rating scale	**0.64**[a]	**0.53**[a]	**0.22**[a]	**0.67**[a]	–	–	–	–
Work pace regulation	**0.66**[a]	**0.54**[a]	**0.26**[a]	**0.65**[a]	**0.57**[a]	–	–	–
Difficulty with pace	**0.32**[a]	**0.21**[a]	−0.02	**0.24**[a]	**0.38**[a]	**0.32**[a]	–	–
Accelerometer[1]	**0.55**[a]	**0.62**[a]	0.11	**0.51**[a]	**0.53**[a]	**0.54**[a]	**0.24**[c]	–
Job strain	**0.56**[a]	**0.39**[a]	**0.23**[a]	**0.49**[a]	**0.49**[a]	**0.48**[a]	**0.43**[a]	**0.45**[a]
Psychological demands	0.08	0.00	−0.10	0.04	**0.16**[c]	0.06	**0.41**[a]	0.01
Decision latitude	−**0.64**[a]	−**0.49**[a]	−**0.36**[a]	−**0.58**[a]	−**0.49**[a]	−**0.58**[a]	−**0.25**[a]	−**0.53**[a]
Mental demands	−**0.34**[a]	−**0.39**[a]	−**0.23**[a]	−**0.40**[a]	−**0.28**[a]	−**0.46**[a]	0.08	−**0.47**[a]
Poor scheduling control	**0.36**[a]	**0.32**[a]	0.14[c]	**0.36**[a]	**0.28**[a]	**0.39**[a]	**0.15**[c]	**0.42**[a]
Lack of group cohesion	−0.01	0.09	−0.11[d]	0.00	0.02	0.10	**0.17**[b]	0.08
Group pressure	−0.12[d]	−**0.20**[b]	−0.10	−**0.20**[a]	−0.02	−**0.21**[a]	−**0.23**[a]	−0.16
Lack of supervisor support	0.05	0.03	−0.04	−0.02	−0.03	0.01	0.10	−0.15
Lack of co-worker support	−0.10	−0.03	−0.07	−0.07	−0.03	0.01	0.13	−0.06
Opinions not accepted	0.08	0.04	−0.07	0.04	0.06	0.09	0.11[d]	0.06

Significance: [a]$\leqslant 0.0001$, [b]$\leqslant 0.001$, [c]$\leqslant 0.01$, [d]$\leqslant 0.05$ (bold if significance $\leqslant 0.01$). Power varies due to missing values for some measures.
[1]Accelerometer data were collected among 91 blue-collar and 55 white-collar workers.

Table 9. Spearman correlations between composite physical demands scores and repetitive work measures with five items from the psychological demands scale across and within work groups.

Psychological job demands scale items	UESCORE	BLSCORE	Physical monotony	Time in short cycle	Repetition rating scale	Work pace regulation	Difficulty with pace	Acelerometer[1]
Blue-collar workers (n = *220*)								
Not an excessive amount (R)	0.15	**0.20**^{d}	−0.08	**0.19**^{c}	**0.21**^{c}	0.14	**0.27**^{a}	−0.01
Have enough time (R)	0.07	0.10	−0.14	0.05	**0.24**	0.15^{d}	**0.26**^{b}	−0.01
Free of conflict demands (R)	−0.09	−0.10	**−0.20**^{c}	−0.04	−0.02	0.06	0.18^{d}	−0.22^{d}
Requires working fast	**0.29**^{b}	**0.20**^{d}	**0.19**^{c}	**0.23**^{b}	**0.37**^{a}	**0.27**^{a}	**0.24**^{b}	**0.28**^{c}
Requires working hard	0.12	**0.20**^{c}	0.02	0.06	**0.33**^{a}	0.03	**0.36**^{a}	**0.29**^{c}
White-collar workers (n = *190*)								
Not an excessive amount (R)	0.18^{d}	0.07	−0.14	0.01	**0.21**^{c}	0.14	**0.24**^{c}	0.07
Have enough time (R)	0.11	0.08	**−0.25**^{b}	−0.09	0.06	0.05	**0.24**^{c}	−0.09
Free of conflict demands (R)	0.05	0.03	**−0.24**^{c}	−0.08	−0.01	**0.22**^{c}	**0.25**^{b}	0.06
Requires working fast	**0.21**^{c}	−0.07	0.03	0.11	0.04	**0.20**^{c}	**0.35**^{a}	0.27
Requires working hard	**0.22**^{c}	0.10	−0.12	0.15^{d}	0.12	0.11	**0.32**^{a}	0.08
All workers combined (n = *410*)								
Not an excessive amount (R)	0.00	−0.02	−0.13^{d}	0.00	0.10^{d}	0.01	**0.22**^{a}	−0.09
Have enough time (R)	**−0.18**^{b}	**−0.19**^{b}	**−0.26**^{a}	**−0.24**^{a}	−0.09	**−0.20**^{a}	**0.15**^{c}	**−0.27**
Free of conflict demands (R)	**−0.39**^{a}	**−0.38**^{a}	**−0.29**^{a}	**−0.37**^{a}	**−0.31**^{a}	**−0.31**^{a}	0.05	**−0.58**^{a}
Requires working fast	**0.39**^{a}	**0.26**^{a}	**0.17**^{c}	**0.36**^{a}	**0.36**^{a}	**0.41**^{a}	**0.35**^{a}	**0.40**^{a}
Requires working hard	**0.14**^{c}	0.12^{c}	−0.04	0.12^{c}	**0.23**^{a}	0.09	**0.34**^{a}	0.16

Significance: $^{a}\leqslant 0.0001$, $^{b}\leqslant 0.001$, $^{c}\leqslant 0.01$, $^{d}\leqslant 0.05$ (bold if significance $\leqslant 0.01$). Power varies due to missing values for some measures.
[1]Accelerometer data was collected among 146 subjects (91 blue-collar and 55 white-collar workers). (R), reverse coded.

Table 10. Factor loading pattern from principal factor analysis with orthogonal rotation.

Stressor measures (bold if a physical load measure)	Supportive environment	Organizational constraint	Soft tissue load	Work pace pressure	SMC†	Final communalities
Lack of group cohesion	<u>0.712</u>	0.050	0.143	0.096	0.445	0.538
Opinions not accepted	<u>0.596</u>	0.116	0.039	0.027	0.352	0.371
Lack of co-worker support	<u>0.586</u>	−0.102	−0.031	0.093	0.365	0.364
Lack of supervisor support	<u>0.552</u>	0.010	−0.009	0.142	0.336	0.325
Work pace regulation	−0.022	<u>0.776</u>	0.200	0.035	0.617	0.645
Short cycle work	−0.093	<u>0.774</u>	0.272	0.080	0.675	0.688
Repetition rating scale	−0.097	<u>0.628</u>	0.268	0.254	0.546	0.540
Physical monotony	−0.112	<u>0.486</u>	−0.114	−0.000	0.272	0.262
Poor work schedule control	0.105	<u>0.455</u>	0.246	−0.068	0.294	0.283
Skill discretion[1]	−0.252	−<u>0.654</u>	−0.202	−0.043	0.585	0.534
Decision authority[1]	−0.134	−<u>0.827</u>	−0.081	0.154	0.682	0.732
Forearm rotation	0.076	0.109	<u>0.707</u>	−0.141	0.360	0.538
Wrist deviation	0.009	<u>0.309</u>	<u>0.606</u>	0.064	0.415	0.467
Manual force (squeezing)	0.014	0.134	<u>0.542</u>	0.029	0.266	0.313
Forceful pinching	0.011	0.016	<u>0.295</u>	0.074	0.101	0.093
Group pressure	<u>0.338</u>	−0.187	−0.098	<u>0.602</u>	0.461	0.521
Mental demands	0.184	−<u>0.527</u>	−0.148	<u>0.581</u>	0.586	0.672
Hard*fast[2]	0.017	0.256	0.122	<u>0.530</u>	0.346	0.361
Time demands[3]	<u>0.384</u>	−<u>0.360</u>	−0.068	<u>0.501</u>	0.515	0.532
Difficulty maintaining pace	0.101	0.252	0.246	<u>0.493</u>	0.357	0.377
Rotated eigenvalues	1.95	3.87	1.69	1.65		
Percent variance explained	9.75	19.35	8.45	8.25		

[1]Sub scale component of decision latitude (job control); [2]two-items from the JCQ psychological job demands scale; [3]three-items from the JCQ psychological job demands scale.

†Squared multiple correlations (SMC), providing the lower bound estimates of the communalities. SMC $\times$100 measures the percentage of linear variation explained for one variable from the others (Rummel 1970).

Note: loading values >0.30 (explaining $>9\%$ factor variance) are underlined.

'organizational constraint.' Organizational constraint explained the greatest amount of variance in the data. Covariation between difficulty maintaining work pace (physical), with several psychosocial stressors (mental demands, group pressure, hard*fast and time demands) are illustrated by the clustering of these measures in factor 4, called 'work pace pressure.' In the oblique rotation, cross-loading was reduced and was found only between 'organizational constraint' and 'work pace pressure.' Moderately strong correlations were found for supportive environment and the work pace pressure (0.40) and between organizational constraint and soft tissue load (0.49).

4. Discussion

This study of full-time workers in a mass production manufacturing environment focused on an empirical examination of the relationships between physical and psychosocial stressors in the workplace. Consistent with our observational understanding of the distribution of these stressors within the study population, substantial differences in exposure were found between blue- and white-collar workers. Moderate to high correlations between selected physical and psychosocial stressors showed evidence of covariation both across and within groups. The strength of these correlations was especially notable considering that imperfect scale reliability can attenuate empirical relationships (Cohen and Cohen 1983). Covariation was strongest among blue-collar production workers and low status office workers (clerks and secretaries), supporting the hypothesis that covariation is more pronounced in groups with greater task specialization. While the covariation observed among non-clerical white-collar workers was weaker, the findings in this group were greater than expected.

Extending the results of the correlational analysis, a principal factor analysis procedure illustrated that selected physical and psychosocial stressors share considerable common variance. The 'organizational constraint' factor showed an inverse relationship between, and substantial clustering of, physical repetition and job control measures. The 'work pace pressure' factor illustrated a strong interrelationship between time demands and social pressure in the workplace. Covariation between physical and psychosocial stressors is further exemplified by the cross-loading of mental demands and time demands with organizational constraint.

4.1. *Study implications*

While recognizing the conceptual differences between physical and psychosocial stressors, the findings of this study call attention to the strong empirical relationships that can exist between some of these stressors in the workplace setting. Covariation between selected stressors challenges the simple assumptions that govern the treatment of these stressors as wholly unique in epidemiologic research. The goal of isolating the separate effects of workplace stressors on the development of MSD may not have practical value when combined exposure conditions are ubiquitous (Johansson 1981).

Ecologic understandings of workplace exposure situations are critical to formulating correct inferences about the components of risk as well as effective prevention strategies. The transition away from the use of job titles as a proxy for exposure is a historically important phenomenon within occupational health.

Characterization of specific etiologically relevant exposure agents can more directly inform the development of effective health prevention efforts that are generalizable across workplaces and thus serve a critical role in advancing public health. However, caution is needed to ensure that efforts directed toward greater exposure specificity in mixed exposure environments do not obfuscate the larger organizational context from which task-level exposures manifest. To guard against ambiguous study findings that can occur when exposures are mixed, it is critical that epidemiologic studies provide information concerning the degree of association between task-level stressor conditions. Furthermore, work organization factors that govern the structure of work and from which distinct stressors, such as repetitive work and low job control, concurrently arise can provide an important ecologic framework from which we can further develop and refine our understandings of the role of these stressors in the development of MSD.

The findings of this study are largely consistent with previous reports on the relationship between physical and psychosocial stressors in the workplace. In a small study of male blue-collar workers, Johansson and Nonås (1994) found high correlations between repetitive movements and the following three psychosocial stressors: low job control (0.39), poor supervisor climate (0.54) and poor co-worker climate (0.52). In a pilot study of retail beverage handling, Ingelgård *et al.* (1996) found that higher levels of physical work load were negatively correlated with influence on and control over work ($r = -0.33$). In contrast to these findings, Johansson (1995) reported a two-factor oblique solution from a principal components analysis in which physical demands (lifting, monotonous movements, and awkward postures) and psychosocial stressors (influence over work, social support, psychological demands) showed limited evidence of covariation in a sample of 305 home healthcare workers.

In a large cross-national study of working conditions in Europe, the relationship between physical work load (a composite of environmental conditions, materials handling, work posture and chemical exposures) and a two-item job control measure was more weakly correlated (−0.19) (Andries *et al.* 1996). In the population-based MUSIC-Norrtälje Study, heavy work load was four times higher among women in jobs with high job strain, but not in men (Josephson *et al.* 1999). In a cross-national comparison of job characteristics, Karasek *et al.* (1998) found inverse relationships between physical demands and decision latitude and its two component measures, in two studies from the USA and one from The Netherlands—although, again, the correlations were somewhat weaker than the findings in the present study. In all of these national studies, the correlations involving skill discretion and decision authority were comparable, although the correlation between physical demands and decision authority was *stronger* in the study from The Netherlands (−0.27 versus −0.32, respectively for men and −0.09 versus −0.23 for women). Although differences in the measures employed in these various studies do not permit a direct comparison across all studies, the nearly consistent finding of an inverse relationship between physical demands and job control suggest that this result is robust and relatively insensitive to measurement differences.

The factor analysis findings suggest that concomitant exposure to biomechanical and psychosocial stressors arises from organization-level antecedents. The social and organizational structure of work, in its current widely adopted form, is a historically new phenomenon that evolved from efforts to replace the rule-of-thumb work practices of the craft and apprentice traditions with *scientific* work practices. In his highly influential *Principles of Scientific Management* (1911), Frederick Taylor proposed a transformation in the roles of management and workers by instituting a vertical division of labour that separated the control and planning functions of work, which would become the exclusive realm of management, from the execution functions (Taylor 1967). The social transformation of work roles was well described by Taylor:

> Under the old type of management, success depends almost entirely upon getting the 'initiative' of the workmen, and it is indeed a rare case in which this initiative is really attained. Under scientific management the 'initiative' of the workmen (that is, their hard work, their good-will, and their ingenuity) is obtained with *absolute uniformity*, and to a greater extent than is possible under the old system; and in addition to this improvement on the part of the men, the managers assume new burdens, new duties, and responsibilities never dreamed of in the past. The managers assume, for instance, the burden of gathering together all of the traditional knowledge which in the past has been possessed by the workmen and then of classifying, tabulating, and reducing this knowledge to rules, laws, and formulae which are immensely helpful to the workmen in doing their daily work. (p. 35, emphasis added)

The assimilation of the tenets of scientific management into industrial practice allowed industry, for the first time since the start of the industrial revolution, to reduce its dependence on skilled workers and to more directly control the volume of output in a manner that was predictable from day to day. While the new digital workplace and the increasingly global marketplace could become a catalyst for the development of alternative skill-based work systems, instead, the diffusion of the structure of work advanced by Taylor has often resulted in a facilitation of the occurrence of these changes even within segments of highly skilled labour, such as in the machinist trades, as well as in low status white-collar and service delivery work (Howard 1986, Shaiken 1986, Office of Technology Assessment 1987, Garson 1988). The covariation findings suggest that risk may be multifaceted and that effective prevention may require consideration of work organization antecedents of task-level stressors.

4.2. *Study limitations*

This study sought to examine covariation between job conditions. Workers' judgements of their exposure to physical and psychosocial stressors were used in many of the analyses performed in this study. Alternative assessment techniques were employed as criterion measures to provide convergent validity indicators of the physical stressor measures. As reported elsewhere, the self-reported physical exposures of blue-collar assembly workers were compared with data obtained from trained ergonomists during on-site direct observational assessments (MacDonald 2000). Highly favourable agreement was shown for several stressors, and all of the self-reported measures used in this study showed at least slight agreement. Additionally, accelerometer data obtained from a subsample of blue- and white-collar workers showed favourable agreement with self-reported physical demands among blue-collar but not among white-collar workers. While limited exposure range may have obscured the association among the white-collar workers, the finding is believed to accurately reflect higher static postural loading of the upper arm among those employed in specialized office tasks (Estill *et al.* 2000). Although the reduced sample size limited statistical power, correlations between the accelerometer data and psychosocial stressors in both groups largely mirrored the findings obtained with the self-reported physical measures in relative strength and direction.

An important limitation in the use of self-reported exposure measures, directly relevant to the goals of this investigation, is the problem of content overlap between measures whose association is being examined (Kasl 1978). One of the six items used in the derivation of skill discretion, a component of decision latitude, was 'my job involves a lot of *repetitive* work.' The content of this measure would likely overlap with the conceptual sphere of physical work demands, having the possible effect of inflating the strength of the correlation with physical work demands. Thus to assess whether the association between repetition and job control was spurious, it was important to examine the correlational findings obtained between the other job control measures that were believed to be operationally independent of repetition and physical job demands more generally. The magnitude of the correlations between decision authority and physical stressors were similar to, although slightly lower than, the findings with skill discretion for both blue- and white-collar workers. For example, the correlations were -0.50 versus -0.55, respectively, for the correlations involving UESCORE among blue-collar workers and $r = -0.26$ versus -0.33, respectively, among white-collar workers. The omission of skill discretion from the factor analysis procedure did not result in a change in the representation of repetition and job control measures in factor 2 (nor any other factor) and the individual load values of these measures remained high.

Concerns about content overlap between the physical and psychosocial domains also exist regarding the psychological demands scale, an indicator of psychologically taxing work that arises from environmental cues for sympathetic arousal. Evidence for the construct validity of the psychological demands scale has been shown in population-based studies (Karasek *et al.* 1983, Karasek *et al.* 1998). Yet, in this study, a factor analysis of the five scale items revealed a two-factor solution. Bidimensional results were also found in a study of automobile workers where the psychological demands scale items 'I work hard, I work fast' and 'not asked to do an excessive amount of work', which formed a single factor, were highly correlated with workers' self-reported exposure to physical job demands (JCQ physical exertion measures and 0–14 Borg scale) (Kerr *et al.* 1999). Our results showed that the psychological demands scale measure generally correlated less strongly with physical demand measures (self-report and accelerometry) than did its component items. Inconsistency in the factor analysis results for the psychological job demands scale between population based and worksite specific studies of workers highly exposed to physical stressors requires further examination in larger data sets.

The aggregation of self-reported measures by occupational group can be used as objective evidence of exposure (Kasl 1998). Aggregation can reduce the potential impact of bias arising from idiosyncratic responses that may occur with individual self-reported exposure measures (Frese and Zapf 1988). When decision latitude and the composite upper extremity physical demands were aggregated by occupational group and plotted, the results showed a strong inverse relationship consistent with the findings obtained using individual-level exposure. In addition, the relative position of the occupational groups on the distributional plot were consistent with our understanding of the role and functional differences between each occupational group—evidence that supports the content validation of these exposure measures. For example, among white-collar workers, managers and supervisors had higher levels of job control and the clerks/secretaries had the lowest levels; among blue-collar workers, those on the 'start-up' line and in production support functions (reject repair and utility workers) had the highest levels of job control and assembly line operators had the lowest levels of job control, combined with the highest levels of physical demands.

Another potential limitation of this study is the distribution of exposure to physical and psychosocial stressors within the study population. Correlational statistics are sensitive to measurement range (Rummel 1970). Ideally, an investigation of covariation between physical and psychosocial workplace stressors should be performed with a representative sample of workers across numerous industries and across a wider spectrum of occupational groups, thus increasing the distributional range of the exposure conditions, enhancing the generalizability of the findings, and permitting more detailed examination of the consistency of covariation patterns between workers employed in different job categories. The exposure and work organization conditions found at this study site are believed to be representative of the Household Appliance Industry in the USA, based upon recent detailed surveys of this industry by investigators at NIOSH (Estill and McGlothlin 1997, Estill *et al.* 1999); these conditions are also believed to be representative of a range of industries involved in mass production manufacturing. Furthermore, the levels of psychological job demands and decision latitude in the current study population were not significantly different from the levels obtained in the US National Quality of Employment Surveys (QES), providing some evidence for the external validity of these study findings (Karasek and Theorell 1990).

The analyses presented in this paper employed the Pearson and Spearman correlation coefficients in examining associations among multiple stressors. The use of multiple tests increases the probability of spurious results (Stevens 1996). The authors employed a more stringent level of significance ($p = 0.01$) in the interpretation of study findings. However, all significance levels $\leqslant 0.05$ were reported, allowing readers to apply alternative criteria in their judgement of the findings. Instability of the analyses involving the small sample ($n = 18$) of clerks and secretaries warrants caution in the interpretation of findings involving this group.

The goal of the factor analysis procedure was to investigate and demonstrate the complex interrelationships between physical and psychosocial stressors and to aid theory construction, not to create new measures. Consequently, the unit of analysis was full-scale measures, rather than the more common use of scale items. New hypotheses arising from this exploratory procedure concerning the role of organization-level factors in the manifestation of physical and psychosocial stressors must be tested in future research.

When examining the structural relationship of a set of variables, it can be difficult to define the boundaries of the domain of related measures (Nunnally 1978). While the number of stressor conditions examined in this study is relatively large (two composite physical demand scores, six repetition measures, and 11 psychosocial stressor measures), a more comprehensive factor analysis assessment that involves a larger number of related variables is needed to refine our understanding of the complex interrelationships under study. The inclusion of more task-specific measures of time pressure, social relations and job control may be promising directions for future work relative to the organizational constraint and work pace pressure factors.

Regarding job control, specific elements of task control that should be considered in future work include administrative control (i.e. determination of which tasks to complete), work autonomy (i.e. ability to function independently from co-workers and/or work systems), control over the physical environment (including refined measures on pacing) and resource control.

Future research will require more integrative approaches, placing greater emphasis not only on a more thorough examination of task-level stressors and their interrelationship, but also on the systematic exploration of organization-level antecedent factors that appear to be determinants of exposure. While the development of such a framework will challenge investigators from different disciplines to integrate unfamiliar theoretical and methodological approaches, such an approach could stimulate new insights into the nature of risk and the most effective strategies for prevention.

5. Conclusions

Evidence of exposure covariation was found between selected physical and psychosocial stressors among workers employed in a mass-production environment. Correlations between selected physical and psychosocial stressors were strongest in blue-collar production and low-status office workers, supporting the hypothesis that covariation is more pronounced in groups with greater task specialization. Considerable shared variance between some physical and psychosocial stressors suggested that these disparate stressors manifest from common work organization factors that govern the structure of work. To guard against ambiguous study findings that can occur when occupational exposures are mixed, epidemiologic research should explicitly consider exposure covariation in the generation and interpretation of study results. Future research on work organization determinants of task-level stressors, and their coincident occurrence in jobs with greater specialization, may provide promising new insights into the nature of risk for MSD and effective prevention strategies.

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