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ORIGINAL ARTICLE

Physical and psychosocial ergonomic risk factors for low back pain in automobile manufacturing workers

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ABSTRACT

Objectives To examine the association between ergonomic physical and psychosocial exposures and the risk of prevalent and incident low back pain (LBP) in a longitudinal cohort of automobile manufacturing workers.

Methods Ergonomic exposure intensity and LBP presence were determined through questionnaires at baseline (n=1181) and to workers in the same job 1 year later (n=505). Models were constructed using log-binomial regression with special attention to interactions between ergonomic exposures.

Results Awkward back posture (prevalence ratio (PR) 1.12, 95% CI 1.07 to 1.17), hand force (PR 1.06, 95% CI 1.02 to 1.10), physical effort (PR 1.10, 95% CI 1.04 to 1.16) and whole body vibration (PR 1.04, 95% CI 1.01 to 1.08) were each associated cross-sectionally with LBP. Awkward back posture (RR 1.13, 95% CI 0.98 to 1.31) and hand force (RR 1.07, 95% CI 0.93 to 1.22) also predicted incident LBP, although estimates were statistically less precise. Neither job control, psychological demands, nor job strain was independently related to risk of incident LBP. Among participants reporting high physical ergonomic exposures and moderate to high job control, increasing job demands was associated with a reduced LBP risk (RR 0.72, 95% CI 0.52 to 1.00). Among participants reporting high physical exposures and low job control, psychological demands was associated with an increased LBP risk (RR 1.30, 95% CI 1.02 to 1.66).

Conclusions Psychosocial workplace interventions for LBP should prioritise jobs in which there are high physical ergonomic exposures. Future studies of LBP should examine the interactions between physical ergonomic risk factors.

What this paper adds

- Physical and (less consistently) psychosocial risk factors have been associated with low back pain (LBP); the interaction between these two categories of exposures has not been resolved epidemiologically.
- These data support previous findings that self-reported occupational physical exposures including awkward back postures, hand force, physical effort and whole body vibration are associated with LBP.
- Psychosocial job strain (high demands, low control) was associated with new LBP only in those with high baseline physical exposures.

INTRODUCTION

Low back pain (LBP) is one of the most common ailments in the USA and at any one time affects 12–30% of the population.[1] Many of the factors that are important in LBP aetiology are associated with the workplace and as much as 30% of all LBP can be attributed to occupational exposures.[2] The occupational physical ergonomic exposures associated with LBP risk include awkward back postures,[3–5] physical effort, including manual exertion related to handling objects or people,[5 6] and exposure to whole body vibration (WBV).[5 7]

In addition to the separate effects of each of these physical ergonomic risk factors, experimental evidence and biomechanical theory suggest that they may interact, for example, producing a higher risk of LBP when hand forces[8] or physical effort[9 10] are exerted in combination with awkward back posture. Biomechanical theory also predicts that local low-back muscle fatigue resulting from job-related physical effort[9] may increase the risk of LBP associated with lifting.[11] Lastly, evidence from epidemiological studies of LBP suggests an interaction between awkward posture and WBV.[7]

Exposure to job-related psychosocial stress has also been implicated in the aetiology of work-related LBP. Job strain is defined in the job demand–control model as a combination of high psychological job demands and low decision-making authority at work ('job control').[12] Job strain has been associated with LBP in two prospective[13 14] and two cross-sectional studies.[15 16] LBP has also been separately associated with both job demands and job control.[3 17]

Physical and psychosocial ergonomic risk factors are often correlated with one another in the workplace,[18] suggesting a more complex aetiology than is characterised by treating them as covariates in separate statistical models. In addition, evidence from both experimental[19] and epidemiological studies[20 21] suggests that psychosocial and physical exposures may interact synergistically to cause musculoskeletal disorders.

In the current study, we examined the association between occupational physical and psychosocial ergonomic risk factors and LBP in a 1-year longitudinal cohort of automobile manufacturing workers. The primary aims of the study were to examine: (1) the separate associations between physical and psychosocial ergonomic risk factors and LBP risk; (2) selected interactions between physical ergonomic risk factors for risk of LBP; and (3) the interaction between physical and psychosocial ergonomic risk factors in their association with LBP.

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METHODS

Study cohort

The study was conducted among a cohort of automobile manufacturing workers (n=1550) from an automotive stamping plant and an engine assembly plant located in Detroit, Michigan.[22] Overall, 85% (n=1315) of workers in the targeted departments were enrolled in the study. Individuals were excluded from the study for poor baseline data quality or cooperation, inability to participate in a physical examination of the musculoskeletal system due to injury (such as an amputation) or if they were employed in non-production work duties (eg, union officers) (n=34). Participants were excluded from these analyses if they reported mechanical back problems (spondylitis, spondylolisthesis or ankylosing spondylitis), a ruptured disc in the neck or back, or a history of back surgery (n=100). Only participants who were LBP-free at baseline (figure 1) and remained in the same job during the study period were eligible for inclusion in the analysis of incident LBP approximately 1 year later.

Assessment of exposures and outcome

Ergonomic exposures, demographics and LBP status were assessed during structured interviews conducted during work time. The five physical exposures used in the current analysis included exposure to awkward back postures, WBV, physical effort, hand forces related to handling tools or materials, and work pace. The Borg CR-10 scale[23] was used to grade the intensity of the physical exposures on a 0–10-point scale. A composite physical exposure metric was computed by summing the five individual psychophysical (Borg CR-10) exposure scores. Participants were divided into low and high physical exposure categories based on the median of the composite physical score. These physical exposure measures were obtained at baseline (T0) and at follow-up (T1).

The psychosocial work environment was assessed using the Job Content Questionnaire (JCQ)[12] only in the follow-up interview. The standard JCQ algorithm was used to score each participant's exposure to job demands and job control. Job strain was defined as a dichotomous variable where job demands scores were ≥30.67 and job control scores were ≤65.92, based on mean values for the US male working population.[12]

LBP was assessed by a question on the presence of any musculoskeletal symptoms experienced more than three times or lasting more than 1 week during the previous 12 months.[24] Participants were asked to locate the source of their symptoms using a body map. Those individuals who located the source of pain in the lower back were designated as having reported LBP.

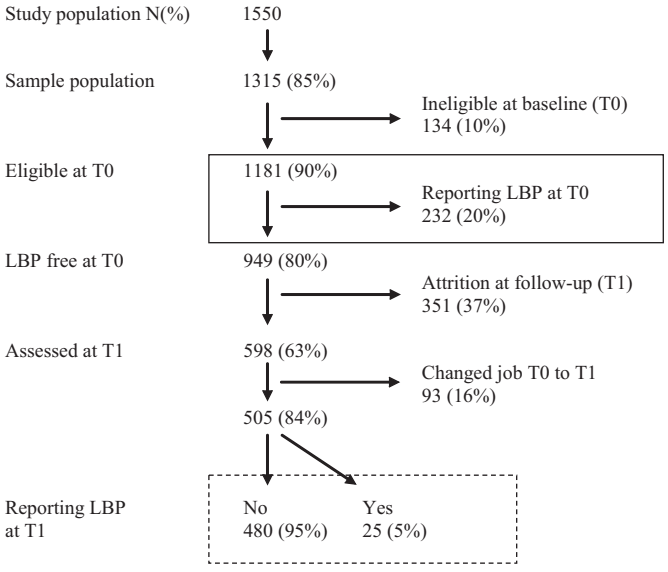


Figure 1 Sample population enrolment, retention and reported low back pain (LBP) at baseline (T0) and at follow-up (T1). The solid box reflects the population included in the baseline prevalent LBP analysis. The dashed box highlights the populations included in the analysis of incident LBP.

Analytical methods

The analysis of LBP was conducted in two stages. First, the cross-sectional association between physical exposures and prevalent LBP at T0 was examined in all subjects. Second, the risk of 1-year 'incident' LBP (present at T1 among those pain-free at T0) among participants who remained in the same job during the study period, was examined in relation to physical risk factors measured at baseline and psychosocial factors measured at T1.

Demographic and occupational factors examined included age, seniority in the company, body mass index (BMI), height, weight and gender. Differences between means were assessed with the Student t test or Satterthwaite's approximate t test (t_s) if there were significantly different variances between groups. χ^2 Tests were used to assess differences between proportions. All analyses were conducted using SAS v. 9.1 (SAS Institute). A p value of ≤0.05 denoted statistical significance.

Univariate and multivariable log-binomial regression models[25] were used to compute prevalence ratios (PR) in the cross-sectional analysis of prevalent LBP and RRs in the longitudinal analysis of incident LBP. Physical and psychosocial ergonomic risk factors were entered as interval data into the models predicting LBP.

Confounding was defined as a change of 20% or more in the computed risk estimate. No confounding effects were observed among the covariates examined.

A number of exposures were hypothesised to interact with one another in their association with LBP. To examine these conditional relationships, the association between LBP and one exposure was stratified on the second exposure. Participant exposure scores were divided into tertiles (low, medium and high) based on the distribution of the data in the sample, to give roughly one-third of the study population in each stratum. Risk estimates were computed within each strata of the suspected effect modifier. A noteworthy interaction was defined as a >100% change in the calculated risk estimates among strata.

In the analysis of the interaction between physical exposure and psychosocial job characteristics, there were relatively few incidents of reported LBP among participants with a high physical workload and medium or high job control. Therefore, the medium and high job control strata were combined to ensure convergence of the log-binomial model.

RESULTS

Baseline cohort characteristics

In total, 1181 participants were included in the cross-sectional baseline analysis of prevalent LBP (figure 1). This population was mostly male and on average overweight (mean BMI 27 kg/m^2, SD 4.84), with a mean age of 46 years (SD 8.21) and a mean of 20 years (SD 6.60) of seniority at the automobile manufacturing company (table 1). The overall age range of the cohort was

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Table 1 Demographic characteristics of the autoworker cohort, overall and stratified by LBP status at baseline, and mean baseline physical exposure ratings and follow-up psychosocial exposures among eligible participants

		LBP at T0	
	Total	Yes	No
Total, n	1181	232 (20%)	949 (80%)
Demographics, mean (SD)			
Age	46.3 (8.21)	45.6 (7.82)	45.7 (8.31)
Seniority at company	21.4 (6.60)	20.8 (6.95)	21.5 (4.88)*
BMI (kg/m^2)	27.5 (4.84)	27.2 (4.65)	26.9 (4.82)
Height (in)	68.7 (3.62)	68.7 (3.67)	68.1 (3.40)
Weight (lb)	184 (35.7)	182 (35.9)	179 (34.9)
Gender, n (%)			
Male	964 (82%)	185 (80%)	779 (82%)
Female	217 (18%)	47 (20%)	170 (18%)
Physical exposure, mean (SD), T0 score			
Awkward back posture	5.35 (3.06)	6.36 (2.80)	5.11 (3.07)
Hand force	5.56 (3.21)	6.16 (2.91)	5.41 (3.27)
Physical effort	6.80 (2.53)	7.38 (2.44)	6.66 (2.54)
Whole body vibration	2.66 (3.23)	3.12 (3.32)	2.55 (3.20)
Job pace	7.12 (2.31)	7.23 (2.33)	7.09 (2.31)
Aggregate exposure score	27.6 (9.31)	30.4 (8.89)	26.9 (9.29)
Psychosocial exposure, mean (SD), T1 score			
Job demands	28.3 (3.74)		
Job control	61.2 (9.43)		

*$p<0.05$, X^2 test comparing proportions ; t-test comparing means for demographic factors only.
BMI, body mass index; LBP, low back pain; T0, baseline; T1, follow-up.

20–73 years with the middle 50% of the population between 41 and 52 years of age (inter-quartile range of 11 years). The highest reported exposure rating was for job pace (mean 7.12; table 1), followed by physical effort (mean 6.80). The lowest perceived exposure intensity was reported for WBV (mean 2.66).

Prevalent LBP

At baseline, 20% of participants (n=232) reported having had LBP in the previous 12 months (figure 1). Participants reporting LBP at baseline had 8–9 months higher seniority (t_s (489)=2.22, $p<0.05$) than participants free of LBP (table 1). No other demographic variables examined were associated with prevalent LBP and none of these confounded the effects of the occupational exposures examined.

Awkward back posture (PR 1.12, 95% CI 1.07 to 1.17), physical effort (PR 1.10, 95% CI 1.04 to 1.16), WBV (PR 1.04, 95% CI 1.01 to 1.08) and hand force (PR 1.06, 95% CI 1.02 to 1.10) were each significantly associated with LBP at baseline (figure 2). No effect was observed for job pace on prevalent LBP (PR 1.02, 95% CI 0.97 to 1.08). There was no effect modification between awkward back posture and either physical effort or hand force. Exposure to WBV did not appear to affect the association between awkward back posture and prevalent LBP.

Follow-up cohort and new LBP

Of the participants without LBP at baseline (n=949), 598 (63%) were assessed at T1 and 84% of these (505) reported being in the same job (figure 1). A total of 25 cases of incident LBP (5%) were identified among these 505 participants. No significant demographic differences were observed between participants with and without incident LBP at follow-up.

Participants lost to follow-up had slightly higher BMI at baseline (mean 28.0 kg/m^2, SD 5.41) than those assessed at follow-up (mean 27.2 kg/m^2, SD 7.2) (t_s (621)=2.20, $p<0.05$). There were no significant differences between the two groups in age, seniority or gender. Among the physical exposures measured at baseline, only the hand force rating differed between those assessed at T1 (mean 5.63, SD 3.17) and those lost to follow-up (mean 5.02, SD 3.40) (p=0.01).

For incident LBP, awkward back posture and hand force at baseline had similar coefficients for risk per unit exposure rating to those obtained in the cross-sectional data, although with wider confidence intervals (figure 2). Exposure to physical effort, WBV and job pace were unrelated to risk of incident LBP.

The risk due to awkward back posture did not change by level of exposure to physical effort or hand force. Similarly, there was no interaction between physical effort and hand force. However, the risk of incident LBP associated with awkward back postures did increase when combined with high exposure to WBV. At low (Borg CR-10 score 0, RR 1.10, 95% CI 0.94 to 1.32) and medium (Borg CR-10 score 0.5–4, RR 1.11, 95% CI 0.81 to 1.53) levels of WBV, risk estimates associated with awkward back postures were similar to those associated with awkward back posture overall. At higher exposures to WBV (Borg CR-10 score 5–10), the effect of awkward back postures was larger although not statistically significant (RR 1.66, 95% CI 0.91 to 3.03).

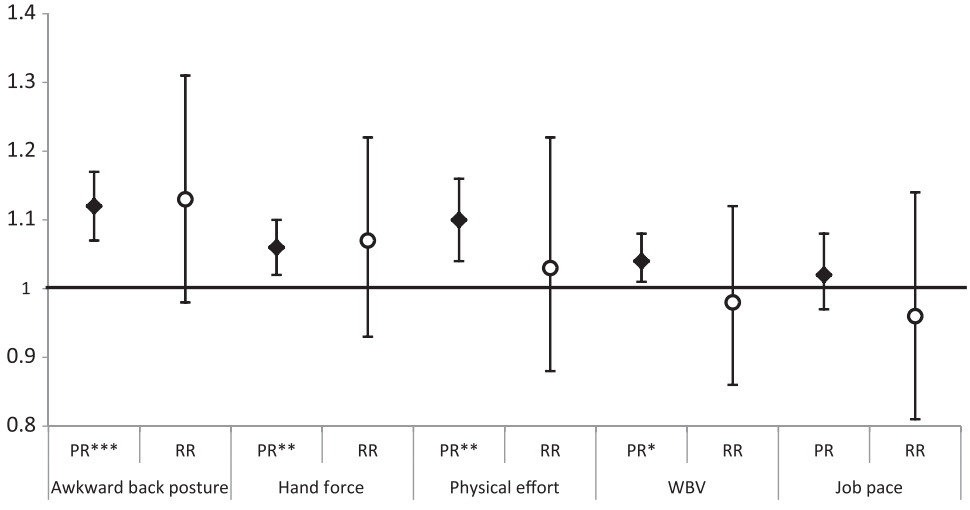


Figure 2 Coefficients for physical estimates of ergonomic exposures and prevalent (black diamond) and incident (white circle) low back pain (LBP), from univariate log-binomial regression models. Error bars represent the 95% CI of the risk estimate from the same regression models. Prevalence ratios (PRs) are presented for the entire population eligible at baseline (T0; n=1181). Relative risks (RRs) are presented for participants who did not report LBP at baseline and remained in the same job throughout the 1-year follow-up period (n=505). RR and prevalence ratios represent the increased risk or prevalence of reported LBP per unit increase across the Borg CR-10 psychophysical exertion scale. WBV, whole body vibration. *$p<0.05$; **$p<0.01$; ***$p<0.001$.

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Table 2 Relative risks of incident LBP for increasing psychological job demands among participants remaining in the same job during the study period, stratified by job control tertiles (n=485*)

Job control tertile (score range)	n	Job demands and incident LBP: RR (95% CI)
1. Low (24–57)	183	1.03 (0.90 to 1.20)
2. Medium (58–65)	155	0.97 (0.76 to 1.24)
3. High (66–96)	147	0.99 (0.81 to 1.20)

Risk estimates reflect increasing risk of LBP associated with a per unit increase in reported psychological job demands.
*Excludes 20 workers who did not complete the Job Content Questionnaire items.
LBP, low back pain.

Psychosocial risk factors and new LBP

There was no association between incident LBP and psychological job demands (RR 1.01, 95% CI 0.90 to 1.12) or job control (RR 0.98, 95% CI 0.95 to 1.03) assessed at T1 for the cohort as a whole. In addition, being in a high strain job at T1 was unrelated to incident LBP (RR 0.96, 95% CI 0.34 to 2.76). The risk of incident LBP due to high psychological job demands did not change by job control tertile (table 2).

In contrast, there was an interaction between demands and control after further stratification on physical workload. Among participants with both high physical exposures and low job control, job demands was associated with a significantly increased risk of incident LBP (RR 1.30, 95% CI 1.02 to 1.66) (table 3). Among those with high physical exposure and medium to high job control, increasing job demand was protective against risk of incident LBP (RR 0.72, 95% CI 0.52 to 1.00). When physical exposure was low, job demand was unrelated to LBP, regardless of level of job control.

A moderate correlation was observed between physical workload and psychological job demands ($r=0.33$, $p<0.001$). This correlation was consistent across job control tertiles (low job control: $r=0.33$, $p<0.001$; medium job control: $r=0.38$, $p<0.001$; high job control: $r=0.33$, $p<0.001$). No correlation was observed between job control and physical exposures ($r=-0.03$, $p=0.55$).

DISCUSSION

Awkward back posture and hand force were associated with an increased risk of both prevalent and 1-year incident LBP in a cohort of automobile manufacturing workers. Neither psychological job demands nor job control alone was associated with incident LBP for the cohort as a whole. Among participants with high physical exposure at baseline and low job control, job demand was associated with an increased risk of incident LBP during the 1-year follow-up period.

Table 3 Relative risks of incident LBP for increasing psychological job demands among participants remaining in the same job during the study period, stratified by both job control (tertiles) and physical exposure (split at the median) (n=485†)

Physical exposure (score)	Job control tertile (score)	n	Job demands and incident LBP: RR (95% CI)
Low (0–27)	Medium to high (58–96)	172	1.13 (0.92 to 1.40)
Low (0–27)	Low (24–57)	102	0.98 (0.83 to 1.18)
High (28–50)	Medium to high (58–96)	130	0.72 (0.52 to 1.00)*
High (28–50)	Low (24–57)	81	1.30 (1.02 to 1.66)*

Risk estimates reflect increasing risk of LBP associated with a per unit increase in reported psychological job demands.
*$p<0.05$.
†Excludes 20 workers who did not complete the JCQ survey item.
LBP, low back pain.

One in five participants enrolled at baseline reported LBP in the prior year. This is similar to the 23% prevalence rate observed in a previous study of autoworkers[15] and is within the 12–30% annual point prevalence of LBP in the US adult population.[1] Among participants who did not report prevalent LBP at baseline, approximately 5% reported an episode of incident LBP during the 1-year follow-up period. This is greater than the 1-year incidence rate of 2% observed in a cohort of Iranian autoworkers.[15]

The date of the first occurrence of LBP was not ascertained in this cohort. Hence, workers without back symptoms at baseline may have experienced prior LBP that had resolved. Therefore, it is possible that LBP 'incident' cases (defined as those without back symptoms at baseline, and with back symptoms at follow-up) may include both re-occurring and new LBP cases. Because of this limitation, the observed rate of incident LBP may overestimate the true rate in the study population.

Strengths and limitations of the study

One of the primary strengths of the current study is the large cohort of workers (n=1181) enrolled, representing 85% of the autoworkers in the targeted departments at baseline. Despite the high enrolment rate, about 40% of participants were lost to follow-up. However, many participants probably simply aged out of the workforce. The population lost at T1 was similar to the population assessed at follow-up in terms of demographics, physical exposures and baseline reports of LBP. This suggests that attrition did not likely result in selection bias.

Another advantage of the current study is that it included both a cross-sectional and longitudinal component. The longitudinal analysis ensured that the physical exposures being examined occurred prior to the outcome of new LBP, providing support for a causal association. In addition, validated measures were used for grading participant's perceived physical (Borg CR-10)[23] and psychosocial exposures (JCQ).[12]

Despite the large cohort of participants enrolled at baseline, the analysis of incident LBP is limited by statistical power, specifically the small number of new cases. In part, this may be a function of the maturity and seniority of the cohort, representing a 'survivor' group. The current cohort of automobile manufacturing workers was on average employed in the company for over 20 years. If musculoskeletal pain leads to earlier departure from the workplace, it is possible that those workers still employed after 20 years, and subsequently enrolled in the current study, would have a lower risk of work-related pain associated with ergonomic exposures than an employee who had recently started working (the 'healthy worker effect').[26] For example, Miranda *et al*[27] observed a stronger relationship between exposure to physical ergonomic risk factors and incident LBP among younger than older workers. If the population included in our study was less susceptible to developing work-related LBP, the effects observed could underestimate the true risk that a new employee would face from similar exposures.

One limitation in the analysis of psychosocial factors is that these variables were only assessed at follow-up. Although subjects analysed at follow-up were in the same jobs as at baseline, the study is unable to address definitively the directionality of the association between LBP and psychological job demands or job control. It has been suggested that the development of LBP may lead individuals to perceive a poorer psychosocial work environment,[28] and it cannot be conclusively determined that LBP did not affect the participant's reporting of their psychosocial work environment.

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Physical exposures were assessed through self-report, which introduces the potential for information bias. An analysis of self-reported versus direct measures of exposure in this cohort found no evidence of a differential bias that might lead to a spurious association with musculoskeletal symptoms.[29] This analysis examined upper extremity exposures, and, as such, examined all of the physical exposures analysed in the current study with the exception of self-reported awkward back postures. Hence, there is still potential for a bias in this self-reported exposure. But the nature of this bias (whether differential or non-differential) is unknown, as the published literature is inconclusive with regard to how those with back pain estimate their physical exposures.[30–32]

Lastly, only automobile manufacturing workers were included in the study suggesting there may be limited variability in ergonomic exposures. However, the two plants included in the study had different degrees of automation and were selected to enrol a cohort of autoworkers with variability in physical ergonomic exposures. Nonetheless, at baseline, almost all participants were working in highly routinised jobs, such as on machine paced assembly lines, with the majority focused on a single cyclical task.[33] Therefore, there may be limited variation in psychosocial ergonomic exposures, particularly with regards to job control.

Physical exposures

Awkward back posture, hand force, physical effort and WBV were associated with an increased prevalence of LBP at baseline. In the analysis of incident LBP, only exposure to awkward back postures and hand force predicted an LBP episode, although with low precision.

Awkward back postures have been previously associated with LBP in a number of prospective,[3 4 27] case–control[5 24] and cross-sectional studies.[34 35] The LBP risk estimates associated with awkward back postures observed in the current study are smaller than the majority of the risk estimates previously reported. However, a direct comparison of effect sizes is problematic due to differences in exposure assessment. Similarly, the risk of LBP associated with hand force observed in the current study is smaller than the associations observed in previous studies.[6]

WBV was associated with a small, but statistically significant, increased prevalence of LBP at baseline. A number of epidemiological studies have examined the association between WBV and LBP.[5 7 27 36] Much of the epidemiological literature examining the effect of WBV on LBP has been conducted in drivers or in heavy machine operators exposed through the seat of a vehicle. In the current study, exposure occurred as a steady state vibration through the feet and legs when workers were in contact with the vibrating floor in the stamping plant. Biomechanically, the stiffness of the coupling (in the current study, whether or not the supporting legs are flexed) may have had a substantial effect on the transmission of vibration to the spinal column.[37] Since this factor was not accounted for, there may have been some further misclassification of exposure leading to dilution of effect.

There was limited evidence of an increased risk of incident LBP in participants exposed to both WBV and awkward back postures, compared to those exposed only to awkward back postures. An interaction between WBV and awkward postures in bus drivers was previously reported by Okunribido *et al*.[7] The physiological mechanism for this interaction is unknown, although laboratory studies suggest possible mechanisms including increased muscle fatigue and disc compression.[37]

Psychosocial exposures

Incident LBP was higher in a high demand–low control psychosocial work environment for workers also heavily exposed to physical ergonomic factors. No effect modification was observed between job control and demands in the incident LBP analysis for the cohort as a whole. However, there was a three-way interaction among physical exposures, psychological demands and job control. The association between job demands and incident LBP was only observed among participants with low job control who were also highly exposed to physical stressors. Surprisingly, the risk of LBP decreased with increasing job demands in participants with medium to high job control and high physical exposures. It was anticipated that risk of LBP would not be associated with job demands in these participants. Potentially, this may represent a protective effect of the psychosocial work environment for musculoskeletal disorders associated with increased active learning (eg, high demand, high control jobs). Active jobs have been associated with other protective health effects.[38] Further research is needed to confirm a protective effect of active learning on LBP.

A moderate correlation between psychological demands and physical exposures was observed suggesting that the findings in table 3 are due to psychological demands over and above physical demands. In addition, this correlation was consistent across job control tertiles. The observed interaction between job demands, job control and physical exposures suggests a more complex relationship between psychosocial and physical ergonomic exposure than one of simple confounding.

The association between the physical and psychosocial risk factors in the aetiology of LBP has been explored in previous studies.[20 21 39 40] Waters *et al*[21] identified an interaction between work stress and heavy lifting. Huang *et al*[20] found effect modification between biomechanical exposures and low 'participatory management', which may be analogous to greater job control. Devereux *et al*[40] examined the interaction between psychosocial and physical exposures and LBP in a cross-sectional survey using additive risk models. A large proportion of risk (65%) was attributed to interaction effects for recent LBP in mixed-sex models using proportional prevalence ratios. However, there were no female participants in the high physical exposure group; when the model calculating proportional prevalence ratios was examined in only male participants, a minimal deviation from additivity was observed (12%). The impact of job control modifying the risk of LBP (or any other musculoskeletal disorder) due to psychological demands in the presence of high, but not low, physical exposures has not been previously reported.

The exact mechanism by which psychosocial stress may lead to an increased risk of musculoskeletal disorders is not well understood. One hypothesis is that job strain leads to increased muscle tension that magnifies the impact of physical stressors on the lower back.[5] Alternatively, observed increased spinal loading when a lifting task was combined with simultaneous mental processing was attributed to an over-reaction of the musculoskeletal system characterised by less controlled movements and increases in muscle co-activation.[19]

CONCLUSION

Exposure to awkward back postures and hand force exertion in automotive manufacturing increased the risk of LBP at both baseline and 1-year follow-up. Job demands were associated with the development of incident LBP, although only in workers with low job control and high reported baseline exposure to physical risk factors. Results suggestive of an interaction between awkward postures and WBV were also observed.

The observed relationship between psychosocial and physical exposures may help explain some of the inconsistency observed between studies examining the impact of the psychosocial work

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environment on the risk of LBP. The current results suggest that if the association between the psychosocial work environment and LBP risk were examined in a population with an overall low exposure to physical risk factors, no association would be detected. It is possible that physical stress is one component of the pathway through which psychosocial factors increase the risk of LBP. Alternatively, it may be that job stress does not cause LBP directly but instead aggravates the impact of physical stressors on the lower back.

It will be important to examine the interaction between the physical and psychosocial risk factors in additional populations and using alternative methods of exposure assessment. A number of hypothesised relationships between physical risk factors were not observed in the current study. However, many of these relationships have not been previously explored outside of the laboratory. These should be examined using epidemiological methods in other occupational settings to conclusively determine their impact on LBP.

The current study, in addition to identifying and quantifying specific LBP risk factors, illustrates the complex multi-factorial nature of LBP aetiology. While it is widely recognised that many different factors may be the cause of an episode of LBP, it is also important to consider that these factors are not experienced in isolation. Identifying interactions between LBP risk factors is particularly important when designing control measures. For example, an intervention designed to address the psychosocial work environment may be most effective if it is focused on increasing job control and/or reducing job demands for workers who are exposed to a high physical ergonomic load. When designing a prevention program or evaluating a workplace risk factor, recognising that some workers or departments are more at risk will help to maximise the impact of any intervention efforts.

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Contributors All authors contributed to the conception and design, acquisition of data or analysis and interpretation of data, and to the drafting or critical revision of the article for important intellectual content. All authors gave final approval for the version published.

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REFERENCES

1. **Rubin DI.** Epidemiology and risk factors for spine pain. *Neurol Clin* 2007;**25**:353—71.
2. **Punnett L,** Pruss-Ustun A, Nelson DI, *et al*. Estimating the global burden of low back pain attributable to combined occupational exposure. *Am J Ind Med* 2005;**48**:459—69.
3. **Jansen JP,** Morgenstern H, Burdorf A. Dose-response relations between occupational exposures to physical and psychosocial factors and the risk of low back pain. *Occup Environ Med* 2004;**61**:972—9.
4. **Miranda H,** Viikari-Juntura E, Martikainen R, *et al*. Individual factors, occupational loading, and physical exercise as predictors of sciatic pain. *Spine (Phila Pa 1976)* 2002;**27**:1102—9.
5. **National Institute of Occupational S, Health.** *Musculoskeletal Disorders and Workplace Factors*. Washington, DC: U.S. Department of Health and Human Services, 1997.
6. **Yip YB.** A study of work stress, patient handling activities and the risk of low back pain among nurses from Hong Kong. *J Adv Nurs* 2001;**36**:794—804.
7. **Okunribido OO,** Magnusson M, Pope MH. The role of whole body vibration, posture and manual material handling as risk factors for low back pain in occupational drivers. *Ergonomics* 2008;**51**:308—29.
8. **Radwin RG,** Marras WS, Lavender SL. Biomechanical aspects of work-related musculoskeletal disorders. *Theoretical Issues in Ergonomics Science* 2001;**2**:153—217.
9. **Dolan P,** Adams MA. Repetitive lifting tasks fatigue the back muscles and increase the bending moment acting on the lumbar spine. *J Biomech* 1998;**31**:713—21.
10. **Marras WS,** Lavender SA, Leurgans SE, *et al*. Biomechanical risk factors for occupationally related low back disorders. *Ergonomics* 1995;**38**:377—410.
11. **Parianpour M,** Nordin M, Kahanovitz N, *et al*. 1988 Volvo award in biomechanics. The triaxial coupling of torque generation of fatiguing isoinertial movements on the motor output and movement patterns. *Spine (Phila Pa 1976)* 1988;**13**:982—92.
12. **Karasek RA,** Brisson C, Kawakami N, *et al*. The job content questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics. *J Occup Health Psychol* 1998;**3**:322—55.
13. **Clays E,** Bacquer DD, Leynen F, *et al*. The impact of psychosocial factors on low back pain; longitudinal results from the Belstress study. *Spine (Phila Pa 1976)* 2007;**32**:262—8.
14. **Rugulies R,** Krause N. Job strain, iso-strain, and the incidence of low back and neck injuries. A 7.5-year prospective study of San Francisco transit operators. *Soc Sci Med* 2005;**61**:27—39.
15. **Ghaffari M,** Alipour A, Farshad AA, *et al*. Effect of psychosocial factors on low back pain in industrial workers. *Occup Med (Lond)* 2008;**58**:341—7.
16. **Harcombe H,** McBride D, Derrett S, *et al*. Physical and psychosocial risk factors for musculoskeletal disorders in New Zealand nurses, postal workers and office workers. *Inj Prev* 2010;**16**:96—100.
17. **Hoogendoorn WE,** Bongers PM, de Vet HC, *et al*. Psychosocial work characteristics and psychological strain in relation to low-back pain. *Scand J Work Environ Health* 2001;**27**:258—67.
18. **MacDonald LA,** Karasek RA, Punnett L, *et al*. Covariation between workplace physical and psychosocial stressors: evidence and implications for occupational health research and prevention. *Ergonomics* 2001;**44**:696—718.
19. **Davis KG,** Marras WS, Heaney CA, *et al*. The impact of mental processing and pacing in spine loading: 2002 Volvo Award in biomechanics. *Spine (Phila Pa 1976)* 2002;**27**:2645—53.
20. **Huang GD,** Feuerstein M, Kop WJ, *et al*. Individual and combined impacts of biomechanical and work organization factors in work-related musculoskeletal symptoms. *Am J Ind Med* 2003;**43**:495—506.
21. **Waters TR,** Dick RB, Davis-Barkley J, *et al*. A cross-sectional study of risk factors for musculoskeletal symptoms in the workplace using data from the General Social Survey (GSS). *J Occup Environ Med* 2007;**49**:172—84.
22. **Punnett L,** Gold J, Katz JN, *et al*. Ergonomic stressors and upper extremity musculoskeletal disorders in automobile manufacturing: a one-year follow-up study. *Occup Environ Med* 2004;**61**:668—74.
23. **Borg G.** Psychophysical scaling with applications in physical work and the perception of exertion. *Scand J Work Environ Health* 1990;**16**(Suppl 1):55—8.
24. **Punnett L,** Fine LJ, Keyserling WM, *et al*. Back disorders and nonneutral trunk postures of automobile assembly workers. *Scand J Work Environ Health* 1991;**17**:337—46.
25. **Spiegelman D,** Hertzmark E. Easy SAS calculations for risk or prevalence ratios and differences. *Am J Epidemiol* 2005;**162**:199—200.
26. **Pearce N,** Checkoway H, Kriebel D. Bias in occupational epidemiology studies. *Occup Environ Med* 2007;**64**:562—8.
27. **Miranda H,** Viikari-Juntura E, Punnett L, *et al*. Occupational loading, health behavior and sleep disturbance as predictors of low-back pain. *Scand J Work Environ Health* 2008;**34**:411—19.
28. **Frank JW,** Pulcins IR, Kerr MS, *et al*. Occupational back pain-an unhelpful polemic. *Scand J Work Environ Health* 1995;**21**:3—21.
29. **Buchholz B,** Park JS, Gold JE, *et al*. Subjective ratings of upper extremity exposures: inter-method agreement with direct measurement of exposures. *Ergonomics* 2008;**51**:1064—77.
30. **Wiktorin C,** Vingard E, Mortimer M, *et al*. Interview versus questionnaire for assessing physical loads in the population-based MUSIC-Norrtalje Study. *Am J Ind Med* 1999;**35**:441—55.
31. **Wiktorin C,** Karlqvist L, Winkel J. Validity of self-reported exposures to work postures and manual materials handling. Stockholm MUSIC I Study Group. *Scand J Work Environ Health* 1993;**19**:208—14.
32. **Viikari-Juntura E,** Rauas S, Martikainen R, *et al*. Validity of self-reported physical work load in epidemiologic studies on musculoskeletal disorders. *Scand J Work Environ Health* 1996;**22**:251—9.
33. **Gold JE,** Park JS, Punnett L. Work routinization and implications for ergonomic exposure assessment. *Ergonomics* 2006;**49**:12—27.
34. **Burdorf A,** Govaert G, Elders L. Postural load and back pain of workers in the manufacturing of prefabricated concrete elements. *Ergonomics* 1991;**34**:909—18.
35. **Holmstrom EB,** Lindell J, Moritz U. Low back and neck/shoulder pain in construction workers: occupational work-load and psychosocial risk factors. Part 1: Relationship to low back pain. *Spine (Phila Pa 1976)* 1992;**17**:663—71.
36. **Robb MJ,** Mansfield NJ. Self-reported musculoskeletal problems amongst professional truck drivers. *Ergonomics* 2007;**50**:814—27.
37. **Pope MH,** Wilder DG, Magnusson M. Possible mechanisms of low back pain due to whole body vibration. *J Sound Vib* 1998;**215**:687—97.
38. **Karasek R,** Theorell T. *Healthy Work: Stress, Productivity and the Reconstruction of Working Life*. New York: Basic Books, Inc., 1990.
39. **Brulin C,** Gerdle B, Granlund B, *et al*. Physical and psychosocial work-related risk factors associated with musculoskeletal symptoms among home care personnel. *Scand J Caring Sci* 1998;**12**:104—10.
40. **Devereux JJ,** Buckle PW, Vlachonikollis IG. Interactions between physical and psychosocial risk factors at work increase the risk of back disorders: an epidemiological approach. *Occup Environ Med* 1999;**56**:343—53.

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