Scand J Work Environ Health 2008;34(5):364-373

<https://doi.org/10.5271/sjweh.1282>

Published online: 14 Oct 2008, Issue date: 00 Oct 2008

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Corrections

See [2009;35\(1\):80](#) for a correction.

Refers to the following text of the Journal: [1997;23\(4\):243-256](#)

The following article refers to this text: [2012;38\(6\):577-581](#)

Key terms: [back](#); [back pain](#); [case-control study](#); [driving](#); [imaging](#); [low back](#); [low-back pain](#); [magnetic resonance imaging](#); [mental health](#); [MRI](#); [occupational risk factor](#); [radiology](#); [risk factor](#); [vibration](#); [whole-body vibration](#)

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/18853063

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Case-control study of low-back pain referred for magnetic resonance imaging, with special focus on whole-body vibration

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Palmer KT, Harris EC, Griffin MJ, Bennett J, Reading I, Sampson M, Coggon D. Case-control study of low-back pain referred for magnetic resonance imaging, with special focus on whole-body vibration. *Scand J Work Environ Health* 2008;34(5):364–373.

Objectives This study investigated risk factors for low-back pain among patients referred for magnetic resonance imaging (MRI), with special focus on whole-body vibration.

Methods A case-control approach was used. The study population comprised working-aged persons from a catchment area for radiology services. The cases were those in a consecutive series referred for a lumbar MRI because of low-back pain. The controls were age- and gender-matched persons X-rayed for other reasons. Altogether, 252 cases and 820 controls were studied, including 185 professional drivers. The participants were questioned about physical factors loading the spine, psychosocial factors, driving, personal characteristics, mental health, and certain beliefs about low-back pain. Exposure to whole-body vibration was assessed by six measures, including weekly duration of professional driving, hours driven in one period, and current root mean square A(8). Associations with whole-body vibration were examined with adjustment for age, gender, and other potential confounders.

Results Strong associations were found with poor mental health and belief in work as a causal factor for low-back pain, and with occupational sitting for ≥ 3 hours while not driving. Associations were also found for taller stature, consulting propensity, body mass index, smoking history, fear-avoidance beliefs, frequent twisting, low decision latitude, and low support at work. However, the associations with the six metrics of whole-body vibration were weak and not statistically significant, and no exposure-response relationships were found.

Conclusions Little evidence of a risk from professional driving or whole-body vibration was found. Drivers were substantially less heavily exposed to whole-body vibration than in some earlier surveys. Nonetheless, it seems that, at the population level, whole-body vibration is not an important cause of low-back pain among those referred for MRI.

Key terms back; driving; imaging; mental health; occupational risk factor; radiology.

Occupational exposure to whole-body vibration is very common in working populations. One British survey estimated that 7.2 million men and 1.8 million women were exposed to whole-body vibration at work in a 1-week period, the estimated vibration dose value exceeding a proposed British standard action level of 15 m/s^{1.75} for some 374 000 men and 9000 women (1). Major exposures arose from lift truck driving, mechanical truck driving, farm work, and driving of other off-road vehicles, and surveys of groups in such heavily exposed work have pointed to a relation between whole-body vibration and back disorders (2–8).

However, exposures of a lower vibration magnitude, such as those arising from cars, vans, buses, coaches, and motorcycles, are numerically far more common in the general population. [In Great Britain, for example, there are an estimated five million occupational users of cars and vans (1).] Therefore, evidence on risk from such sources is particularly relevant in assessments of the population burden of low-back pain attributable to whole-body vibration.

Relatively few studies have been conducted in which the predominant exposure is to common population sources of low-level exposure to whole-body vibration.

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However, two case-control studies by Kelsey et al have suggested an elevated risk of surgically managed prolapsed intervertebral disc for truck (9) and car (10) drivers, while, in a large survey of commercial travelers by Pietri et al (11), a relation was found both between weekly hours of driving and the 12-month period prevalence and the cumulative incidence of low-back pain. An increased prevalence of low-back pain has also been reported for urban bus drivers when they were compared with maintenance workers (12). By contrast, a community-based cross-sectional survey found little association between whole-body vibration and low-back pain and estimated the overall risk and attributable burden of disease arising from whole-body vibration in British workers to be relatively small when compared with the effects of lifting (13).

In our present study, we gauged the public health impact of whole-body vibration on back disorders severe enough to be referred for specialist investigation by nuclear magnetic resonance imaging (MRI) of the lumbar spine and the extent to which such referrals were associated with whole-body vibration and professional driving as compared with other recognized risk factors for low-back pain.

Study population and methods

A case-control approach was used. The study population comprised all adults aged 20–64 years resident (as defined by certain postal codes) in the catchment area served by the radiology services of the main public hospital in Southampton. The cases were a consecutive series of patients from the study population referred to the radiology department at the public hospital or to either of two local private hospitals for MRI of the lumbar spine during 2003–2006. Patients who had an MRI because of external trauma or nonmechanical pathology (eg, cancer, metabolic bone disease, infections, congenital disorders) were excluded, as were patients with previous back surgery. The controls were those who attended the emergency department of the public hospital and were X-rayed over the same period. They were identified according to a predefined algorithm. The eligible controls fulfilled the same residency requirement as the cases and were group-matched to them by gender and 5-year age groups; the participants who had radiographs after a road traffic accident or who had ever had a scan of or surgery on their back were excluded. The potential cases and controls were identified from the patient records of the participating radiology departments.

The possible participants were mailed a questionnaire and a single reminder as necessary after four weeks. The cases were asked about their history of

low-back pain and sciatica, and their recent disability was assessed using the Roland-Morris questionnaire (14). The cases and controls also completed a common question set on current or more recent job and other occupations held for more than 12 months, physical and psychosocial risk factors at work, professional driving and exposure to whole-body vibration (vehicle types, duration and intensity), personal characteristics (eg, height, weight, age, gender, smoking habits), mental health (low mood, somatizing tendency), fear-avoidance beliefs, beliefs regarding work as a cause or aggravation of low-back pain, and the propensity to ask for consultation for low-back pain.

Various standard instruments of inquiry were used. Low mood was assessed using the mental health section of the SF-36 (SF-36 MH) (15), with the participants categorized into groups (best, intermediate, worst) according to approximate thirds of the distribution of the scores across all of the participants. Somatizing tendency was assessed using elements of the Brief Symptom Inventory (16), a validated self-reported measure of distress, comprised of items on bothersome nausea, faintness or dizziness, chest pain, and breathing difficulties during the past 7 days. The number of symptoms reported as “extremely”, “quite a bit”, or “moderately” distressing were summed, with the data analyzed in three groups (0, 1, ≥ 2 distressing symptoms). Fear-avoidance beliefs were assessed using elements of the validated Fear-Avoidance Beliefs Scale of Waddell et al (17), a sum being made of the number of statements with which the respondent agreed (0, 1–2, 3–4). Three questions were also asked concerning beliefs about work as a cause or aggravation of low-back pain and two on attitudes towards consulting (whether it was important to see a physician straightaway at the first sign of trouble, whether neglecting problems of this kind could lead to permanent health problems) (18); in each case, the number of items of agreement was summed. Questions on occupational psychosocial risk factors were based on the Karasek model (19), with the participants classified according to decision latitude (three groups) and support (three groups), as well as self-reported job satisfaction (two groups). The participants were categorized by age into three groups and by height into rough thirds of the overall distribution by gender, and a count was made of the number of anatomical sites outside the back (knees, hips, shoulders, neck, wrist-hand, elbows) with pain lasting ≥ 1 day in the past four weeks (coded as 0, 1–2, 3–6). A series of questions was also asked about exposure in the current or most recent job to digging, lifting ≥ 10 kg (times/day), bending the trunk (times/day), twisting (times/day), standing (hours/day), sitting while not driving (hours/day), and unloading a vehicle by hand.

Finally, occupational exposure to whole-body vibration in the current or most recent job was assessed

according to the following six metrics: (i) professional driving for ≥ 1 hours/day, (ii) professional driving ≥ 3 hours/time, (iii) average weekly hours driven for the most common source of exposure (in three groups), (iv) average weekly hours driven for all exposure sources (in five groups), (v) maximum rms (root mean square) of any machine (three groups: 0, -0.5 , ≥ 0.6 m/s²), and (vi) current A(8) rms [0, $>0-0.5$, $0.5-1.15$, ≥ 1.15 m/s², where 0.5 m/s² represents the daily exposure action level and 1.15 m/s² the daily exposure limit value in the European Directive 2002/44/EC on mechanical vibration (20)]. To establish these last two metrics, we asked questions about the time driven in a typical week for each of a predefined list of vehicles, as well as for an open category. Externally acquired estimates of vibration magnitude [the vertical, z-axis, frequency-weighted acceleration on the seat in accord with BS 6841 (21) or ISO 2631 (22)] for the various commonly reported exposure sources (1) were then applied, and dose measures estimated according to a standard methodology agreed

Table 1. Characteristics of the study participants. (MRI = magnetic resonance imaging)

Characteristic	Cases				Controls (N=820)	
	All (N=252)		Severe ^a (N=125)			
	N	%	N	%	N	%
Gender						
Male	131	52	65	52	383	47
Female	121	48	60	48	437	53
Age at MRI or X-ray examination (years) ^b						
20–34 years	55	22	29	23	173	21
35–49 years	121	48	63	50	347	42
50–64 years	76	30	33	26	300	37
X-ray type						
Chest	–	.	–	.	43	5
Abdomen	–	.	–	.	12	1
Ankle–foot	–	.	–	.	254	31
Upper limb above wrist	–	.	–	.	73	9
Other	–	.	–	.	31	4
Wrist–hand	–	.	–	.	307	37
Lower limb above ankle	–	.	–	.	100	12
Sciatica						
No	48	19	14	11	–	.
Yes	199	79	109	87	–	.
Missing	5	2	2	2	–	.
Hospital						
Public	139	55	80	64	820	100
Private	113	45	45	36	0	

^a Cases with a Roland-Morris score higher than the median (10).

^b Age at MRI or X-ray examination (years) for all cases: mean 43.3 (SD 10.22), median 43, quartile 1–quartile 2: 36–52, minimum 21–maximum 64; age at MRI or X-ray examination (years) for severe cases: mean 42.4 (SD 9.91), median 42, quartile 1–quartile 2: 35–50, minimum 22–maximum 64; age at MRI or X-ray examination (years) for controls: mean 44.7 (SD 10.73), median 45, quartile 1–quartile 2: 36–53, minimum 20–maximum 64.

on by the VIBRISKS European Research Consortium (23).

Although not a feature of this report, all of the cases had images of the lumbosacral spine taken according to routine departmental practice. Ethical approval was given by the NHS Southampton and South West Hampshire Local Research Ethics Committee.

The analysis was restricted to cases whose present episode of low-back pain started in their current or most recent job and to controls who gave a current or most recent job history. It focused on two main outcome groups: (i) all cases and (ii) cases with a Roland-Morris score of >10 (the median value for all cases) versus the controls. Associations with each outcome were explored by logistic regression and expressed as adjusted odds ratios (aOR) with associated 95% confidence intervals (95% CI). Separate models were constructed in relation to personal risk factors, occupational risk factors other than whole-body vibration, and professional driving and whole-body vibration exposure. All of the models were adjusted for age and gender (as factors of group matching and recruitment). Subsequently, for each outcome–control comparison, a stepwise forward selection regression model was fitted with age and gender constrained to be included in the model and the significance level for the inclusion of other variables (personal, occupational, and whole-body-vibration-related) set at $P<0.20$.

Finally, as some 113 cases were recruited from private hospitals (targeting full case ascertainment) but no controls came from these centers (since accidents and emergencies in the study population were only treated at the public hospital), we explored possible selection bias by re-running the analyses with the exclusion of private cases.

All of the analyses were performed using Stata 10.0 software (StataCorp LP, College Station, TX, USA).

Results

Altogether, 758 cases and 2306 controls were approached. Usable replies were received from 393 (52%) of the cases and 980 (43%) of the controls. The major reason for nonresponse was failure to return a questionnaire, but other reasons included moving away (7 cases and 38 controls), postal errors (1 case and 2 controls), serious concomitant illness (1 case), and mental handicap (5 controls). Among the remaining 393 cases, 4 were excluded because they did not confirm low-back pain in the questionnaire, and 7 were ineligible because of previous surgery to the back; while among the 980 controls, 97 were excluded because they had previously had either a scan of or surgery on the back. A further 108 cases were excluded because their low-back pain

began before their current or most recent job; 1 case and 18 controls had never held a job; 13 cases and 45 controls gave an incomplete occupational history; and 8 cases gave incomplete information concerning the timing of low-back pain onset and the start or stop dates of the current or most recent job. Thus a total of 252 cases and 820 controls were finally included in the occupational analyses.

Table 1 on page 366 summarizes the characteristics of the participants included in the analyses of personal and occupational risk factors. The controls had most commonly attended for X-rays of the wrist–hand or ankle–foot. They were well matched to the cases according to age and gender. They had also started their current or most recent job in a similar interval before the scan or X-ray [median 8.7 and interquartile range

Table 2. Associations with demographic and personal characteristics in the study groups.^a (OR = odds ratio, 95% CI = 95% confidence interval, M = male, F = female)

Characteristic	Cases				Controls (N=820)		All cases versus controls		Severe cases ^b versus controls	
	All (N=252)		Severe ^b (N=125)							
	N	%	N	%	N	%	OR	95% CI	OR	95% CI
Height (cm)										
Shortest third (<176 M, <161 F)	81	32	43	34	316	39	1.0	..	1.0	..
Middle third (176–181 M, 161–168 F)	80	32	38	30	280	34	1.1	0.8–1.6	1.0	0.6–1.6
Tallest third (>181 M, >168 F)	84	33	41	33	205	25	1.6	1.1–2.2	1.4	0.9–2.3
Missing	7	3	3	2	19	2	.	.	.	.
Body mass index										
<25 kg/m ²	95	38	40	32	312	38	1.0	..	1.0	..
25–<30 kg/m ²	90	36	46	37	300	37	1.0	0.7–1.3	1.2	0.7–1.8
≥30 kg/m ²	50	20	30	24	169	21	1.0	0.7–1.5	1.5	0.9–2.5
Missing	17	7	9	7	39	5	.	.	.	.
Smoking status										
Never	117	46	40	32	358	44	1.0	..	1.0	..
Ex	71	28	39	31	247	30	0.9	0.6–1.2	1.4	0.9–2.3
Current	63	25	46	37	208	25	0.9	0.6–1.3	1.9	1.2–3.0
Missing	1	0.4	–	.	7	0.9	.	.	.	.
Somatizing tendency (number of symptoms at least moderately distressing)										
0	138	55	50	40	493	60	1.0	..	1.0	..
1	54	21	36	29	181	22	1.2	0.8–1.7	2.3	1.4–3.7
≥2	54	21	37	30	141	17	1.4	1.0–2.1	2.8	1.8–4.6
Missing	6	2	2	2	5	0.6	.	.	.	.
SF-36 MH score ^c										
Best	87	35	21	17	343	42	1.0	..	1.0	..
Intermediate	73	29	43	34	263	32	1.1	0.8–1.6	2.9	1.6–4.9
Worst	86	34	59	47	210	26	1.7	1.2–2.4	4.8	2.8–8.2
Missing	6	2	2	2	4	0.5	.	.	.	.
Fear–avoidance beliefs (number of statements agreed)										
0	68	27	26	21	260	32	1.0	..	1.0	..
1–2	134	53	67	54	383	47	1.3	0.9–1.8	1.7	1.0–2.7
3–4	45	18	30	24	168	20	1.0	0.7–1.5	1.8	1.0–3.1
Missing	5	2	2	2	9	1	.	.	.	.
Number of other sites with pain (in the past 4 weeks)										
0	75	30	31	25	216	26	1.0	.	1.0	..
1–2	121	48	62	50	371	45	0.9	0.7–1.3	1.2	0.7–1.9
3–6	54	21	32	26	231	28	0.7	0.5–1.1	1.1	0.6–1.8
Missing	2	0.8	–	.	2	0.2	.	.	.	.
Propensity to consult for low-back pain (number of statements agreed)										
0	60	24	28	22	310	38	1.0	..	1.0	..
1	82	33	42	34	226	28	1.8	1.3–2.7	2.0	1.2–3.3
2	105	42	53	42	271	33	2.0	1.4–2.8	2.1	1.3–3.4
Missing	5	2	2	2	13	2	.	.	.	.

^a Each risk factor was considered separately, with adjustment for age (categorized into three groups) and gender. The percentages may not sum to 100% due to rounding.

^b Cases with a Roland-Morris score higher than the median (10).

^c Mental health section of the SF-36 (short form 36 of the mental health questionnaire).

(IQR) 4.3–16.3) years for the cases and median 6.9 (IQR 2.9–16.5) years for the controls].

Among the cases, the median duration of the current episode of low-back pain (defined as the interval since last free of pain for as much as a month) was 1.0

(IQR 0.5–2.2) years, and 79% reported sciatica (pain spreading down the leg to below the knee or causing distal neurological symptoms). The median Roland-Morris score for the past 4 weeks was 10 (IQR 5–16). Altogether, 68% of the cases reported taking at least

Table 3. Associations with occupational risk factors in the study groups.^a (OR = odds ratio. 95% CI = 95% confidence interval)

Risk factor	Cases				Controls (N=820)		All cases versus controls		Severe cases ^b versus controls	
	All (N=252)		Severe ^b (N=125)							
	N	%	N	%	N	%	OR	95% CI	OR	95% CI
Activities in a typical workday										
Digging										
No	244	97	119	95	786	96	1.0	..	1.0	..
Yes	8	3	6	5	34	4	0.7	0.3–1.5	1.0	0.4–2.6
Lifting ≥10 kg										
0 times/day	96	38	42	34	308	38	1.0	..	1.0	..
1–10 times/day	110	44	52	42	344	42	1.0	0.7–1.4	1.1	0.7–1.7
>10 times/day	46	18	31	25	168	20	0.8	0.5–1.2	1.2	0.7–2.1
Bending trunk										
0 times/day	100	40	43	34	313	38	1.0	..	1.0	..
≤20 times/day	96	38	50	40	303	37	1.0	0.7–1.4	1.2	0.8–1.9
>20 times/day	56	22	32	26	204	25	0.8	0.6–1.2	1.1	0.7–1.8
Twisting (times/day)										
0 times/day	145	58	58	46	520	63	1.0	..	1.0	..
≤20 times/day	71	28	45	36	212	26	1.2	0.9–1.7	1.9	1.3–2.9
>20 times/day	36	14	22	18	88	11	1.4	0.9–2.2	2.2	1.3–3.8
Standing										
<1 hours/day	61	24	28	22	150	18	1.0	..	1.0	..
1–3 hours/day	79	31	33	26	221	27	0.9	0.6–1.3	0.8	0.5–1.4
3 hours/day	112	44	64	51	449	55	0.6	0.4–0.9	0.8	0.5–1.2
Sitting while not driving										
<1 hours/day	73	29	43	34	324	40	1.0	..	1.0	..
1–3 hours/day	54	21	28	22	219	27	1.1	0.8–1.6	1.0	0.6–1.6
>3 hours/day	125	50	54	43	277	34	2.0	1.5–2.8	1.5	1.0–2.3
Unloading a vehicle by hand (as professional drivers)										
No	229	91	113	90	748	91	1.0	..	1.0	..
Yes	23	9	12	10	72	9	0.9	0.6–1.6	1.0	0.5–1.9
Beliefs and psychosocial factors										
Beliefs about work as a cause of low-back pain										
0	44	17	11	9	225	27	1.0	..	1.0	..
1–2	97	38	49	39	265	32	1.9	1.3–2.8	3.8	1.9–7.5
3	100	40	60	48	293	36	1.7	1.1–2.5	4.1	2.1–8.1
Missing	11	4	5	4	37	5	.	.	.	.
Decision latitude										
Often	112	44	47	38	387	47	1.0	..	1.0	..
Sometimes	71	28	34	27	220	27	1.1	0.8–1.6	1.3	0.8–2.1
Seldom or never	65	26	42	34	196	24	1.2	0.8–1.7	1.8	1.1–2.8
Missing	4	2	2	2	17	2	.	.	.	.
Job support from colleagues or managers										
Often	104	41	46	37	372	45	1.0	..	1.0	..
Sometimes	75	30	44	35	240	29	1.1	0.8–1.6	1.5	1.0–2.3
Seldom or never	45	18	23	18	110	13	1.5	1.0–2.2	1.7	1.0–3.0
Not applicable	25	10	11	9	92	11	1.0	0.6–1.6	1.0	0.5–2.1
Missing	3	1	1	0.8	6	0.7	.	.	.	.
Job satisfaction										
Satisfied or very satisfied	222	88	109	87	710	87	1.0	..	1.0	..
Dissatisfied or very dissatisfied	29	12	15	12	103	13	0.9	0.6–1.4	0.9	0.5–1.7
Missing	1	0.4	1	0.8	7	0.9	.	.	.	.

^a Each risk factor was considered separately, with adjustment for age (categorized into three groups) and gender. The percentages may not sum to 100% due to rounding.

^b Cases with a Roland-Morris score higher than the median (10).

2 weeks off work in the last year because of symptoms.

Table 2 on page 367 compares the distribution of the demographic and personal characteristics for the cases and controls. Associations were found with tall stature, somatizing tendency, poor SF-36 MH score, and propensity to consult over low-back pain. In addition, among the cases with a Roland-Morris score of >10, there were associations with body mass index, current smoking status, and fear-avoidance beliefs, while the associations with a poor SF-36 MH score and somatizing tendency were strengthened. Thus, for example, the odds ratio versus controls was raised in the worst versus best group of the SF36 MH score, by 1.7-fold among the cases as a whole and by 4.8-fold for the severe cases.

Table 3 on page 368 shows the associations with occupational risk factors other than whole-body vibration, with adjustment for age and gender. Associations were found with twisting, sitting while not driving, job support, belief in work as a cause of low-back pain, and lack of decision latitude. For the most part, the associations were strengthened when the analysis focused on severe cases. Thus the odds ratio for twisting (>20 times/day versus not at all)

was 1.4 for all of the cases versus the controls but 2.2 for a Roland-Morris score of >10 versus the controls.

The study included 185 professional drivers (42 cases and 143 controls), and, of these, 164 reported driving a single vehicle occupationally. The predominant exposure was to cars (115 reports), there being also 25 truck drivers, 8 bus drivers, 7 drivers of forklift trucks, 6 ambulance drivers, 2 drivers of loaders, and 1 tractor driver. The median weekly exposure time for drivers was 16 (IQR 10–30) hours, and the estimated median A(8) was 0.79 (IQR 0.56–1.24) m/s² rms.

Few positive associations were found between the six metrics of whole-body vibration and the two case outcomes. Table 4 presents the effect estimates for each exposure definition with adjustment for age and gender. In the comparison of severe cases versus controls (but not in that for all cases versus controls), professional driving for ≥3 hours at a time was associated with a higher odds of low-back pain (1.3), and increases in odds ratios were found in the groups with A(8) ≥0.5–1.15 versus 0 m/s² (OR 1.3) and regular driving for <15 hours/week. But no finding was significant at the 5% level, and no exposure metric showed an exposure-response pattern.

Table 4. Associations with exposure to whole-body vibration and professional driving in the study groups.^a [OR = odds ratio, 95% CI = 95% confidence interval, rms = root mean square, rms A(8) = 8-hour energy equivalent acceleration]

	Cases				Controls (N=820)		All cases versus controls		Severe cases ^b versus controls	
	All (N=252)		Severe ^b (N=125)							
	N	%	N	%	N	%	OR	95% CI	OR	95% CI
Professional driving (≥1 hours/day)										
No	210	83	101	81	677	83	1.0	.	1.0	.
Yes	42	17	24	19	143	17	0.9	0.6–1.3	1.1	0.6–1.7
Professional driving (≥3 hours/time)										
No	233	92	114	91	765	93	1.0	.	1.0	.
Yes	19	8	11	9	55	7	1.0	0.6–1.8	1.3	0.6–2.5
Average hours driven/week for the most common exposure source										
None	210	83	101	81	677	83	1.0	.	1.0	.
<16	24	10	15	12	67	8	1.1	0.6–1.8	1.4	0.8–2.6
≥16	18	7	9	7	76	9	0.7	0.4–1.2	0.7	0.3–1.5
Total hours driven/week, all sources										
Not a regular driver	210	83	101	81	677	83	1.0	.	1.0	.
<15	22	9	13	10	54	7	1.2	0.7–2.1	1.5	0.8–2.9
≥15	20	8	11	9	89	11	0.6	0.4–1.1	0.8	0.4–1.5
Maximum rms of any machine (m/s ²)										
Not a regular driver	210	83	101	81	677	83	1.0	.	1.0	.
0.5	28	11	16	13	87	11	1.0	0.6–1.5	1.2	0.6–2.1
≥0.6	14	6	8	6	56	7	0.7	0.4–1.3	0.9	0.4–1.9
Current rms A(8) (m/s ²)										
Not a regular driver	210	83	101	81	677	83	1.0	.	1.0	.
>0–<0.5	4	2	2	2	20	2	0.6	0.2–1.9	0.7	0.2–2.9
0.5–1.15	28	11	17	14	79	10	1.0	0.6–1.7	1.3	0.7–2.4
>1.15	10	4	5	4	44	5	0.6	0.3–1.3	0.7	0.3–1.8

^a Each risk factor was considered separately, with adjustment for age (categorized into three groups) and gender. Percentages may not sum to 100% due to rounding.

^b Cases with a Roland-Morris score higher than the median (10).

Table 5 shows the final models selected by the stepwise regression. In the all cases versus controls comparison, positive associations with being tall, in poor mental health, and having a propensity to consult over back pain were confirmed, while associations with occupational risk factors (twisting, sitting while not driving, belief about work as a cause of back pain) tended to strengthen. Among the severe cases, the association with somatizing tendency was somewhat weaker than among the cases as a whole, while those with sitting while not driving and beliefs about work as a cause of back pain were stronger. The associations with sitting while not driving were noteworthy in all of the comparisons (OR 3.4–3.7). Relative to the data presented in table 4, stronger but nonsignificant associations were found with professional driving for >3 hours at a time (OR 1.8–2.3), but no dose–response pattern was found in relation to hours driven per week, and the A(8) exposure metric was not retained in either model.

Table 5. Stepwise regression analysis of the risk factors for being a case or severe case of low-back pain.^a (OR = odds ratio, 95% CI = 95% confidence interval, M = male, F = female)

	All cases (N=252) versus controls (N=820)		Severe cases ^b (N=125) versus controls (N=811)	
	OR	95% CI	OR	95% CI
Demographic and personal characteristics				
Height (cm)				
Shortest third (<176 M, <161 F)	1.0	..	.	.
Middle third (176–181 M, 161–168 F)	1.1	0.8–1.6	.	.
Tallest third (>181 M, >168 F)	1.7	1.1–2.4	.	.
Smoking status				
Never smoker	.	.	1.0	..
Ex-smoker	.	.	1.4	0.9–2.4
Current smoker	.	.	1.6	0.9–2.6
Somatizing tendency (number of symptoms at least moderate)				
0	.	.	1.0	..
1	.	.	1.9	1.1–3.2
≥2	.	.	1.8	1.1–3.2
SF-36 MH score ^c				
Best	1.0	.	1.0	..
Intermediate	1.1	0.7–1.6	2.7	1.5–4.8
Worst	1.8	1.2–2.6	4.6	2.5–8.4
Fear–avoidance beliefs (number of statements agreed)				
0	1.0	..	.	.
1–2	1.2	0.8–1.7	.	.
3–4	0.7	0.4–1.1	.	.
Number of other sites with pain (in the past 4 weeks)				
0	1.0	..	1.0	..
1–2	0.9	0.6–1.3	0.7	0.4–1.2
3–6	0.5	0.3–0.8	0.4	0.2–0.7
Propensity to consult over low-back pain (number of statements agreed)				
0	1.0	..	1.0	..
1	2.0	1.3–3.0	2.0	1.1–3.4
2	2.3	1.6–3.5	2.0	1.2–3.4

(continued)

When we repeated the analysis after excluding the cases from the private hospitals (N=113), the final stepwise regression models for all cases versus controls and severe cases versus controls showed positive associations with frequent lifting (OR 1.5 and 1.8, respectively, for >10 versus 0 lifts/day), frequent twisting (OR 2.9 and 2.8, respectively, for >20 versus 0 twists/day), sitting while not driving (OR 2.4 and 2.4, respectively, for >3 versus <1 hours/day), beliefs about work as a cause of low-back pain (OR 2.2 and 3.9, respectively, for 3 versus 0 beliefs), and propensity to consult over low-back pain (OR 2.6 and 2.0, respectively, for 2 versus 0 statements agreed with). In addition, there was an association with somatizing tendency for all cases versus controls (OR 1.7 for a score of ≥2 versus 0) and with the SF-36 MH score for severe cases versus controls (OR 3.9 for worst versus best category of the score). However, no vibration or driving metrics were retained in the two finally selected stepwise models.

Table 5. Continued.

	All cases (N=252) versus controls (N=820)		Severe cases ^b (N=125) versus controls (N=811)	
	OR	95% CI	OR	95% CI
Occupational risk factors				
Twisting (times/day)				
0	1.0	..	1.0	..
≤20	1.4	1.0–2.1	1.8	1.1–3.0
>20	1.8	1.1–2.9	2.1	1.0–4.1
Sitting while not driving (hours/day)				
<1	1.0	..	1.0	..
1–3	1.3	0.9–2.0	1.4	0.8–2.5
>3	3.4	2.3–5.2	3.7	2.1–6.5
Beliefs about work as a cause of low-back pain				
0	1.0	..	1.0	..
1–2	2.1	1.4–3.3	4.2	2.0–8.6
3	2.7	1.6–4.4	5.4	2.4–12.0
Job satisfaction				
Satisfied or very satisfied	.	..	1.0	..
Dissatisfied or very dissatisfied	.	..	0.5	0.2–0.9
Exposure to whole-body vibration				
Professional driving (≥3 hours at a time)				
No	1.0	..	1.0	..
Yes	1.8	0.8–4.1	2.3	0.8–6.5
Total hours driven/week, all sources				
Not a regular driver	1.0	..	1.0	..
<15	1.2	0.7–2.2	1.5	0.7–3.2
≥15	0.5	0.2–1.0	0.4	0.1–1.1

^a Starting with the null model, which included adjustment for age and gender, each factor was entered independently, and the most significant factor was retained and adjusted for in all of the models in the next stage in an iterative forward stepwise process. If the P-values were tied, then the factor with the highest likelihood ratio test statistic, based on the degrees of freedom) was selected. If information on a risk factor was missing for some participants, a “missing” category was included in the analysis. However, odds ratios for these “missing” categories have not been presented.

^b Cases with a Roland Morris score higher than the median (10).

^c Mental health section of the SF-36 (short form 36 of the mental health questionnaire).

Discussion

As judged by these findings, there are positive associations between low-back pain referred for MRI of the lumbar spine and low mood, somatizing tendency, certain beliefs about low-back pain, and consulting propensity, as well as with being tall, smoking, and work involving frequent or prolonged twisting, sitting while not driving, and low decision latitude. Beyond these findings, which are supported by a broader research literature, we found only very limited evidence of a risk from exposure to professional driving and whole-body vibration, and none for exposures estimated to exceed the daily exposure limit value in the Physical Agents Directive of the European Union (20).

When the findings of our study are weighed, a few limitations need to be considered. Response was incomplete. However, an incomplete response would be a source of bias in relation to questions about whole-body vibration only if the nonrespondents' associations with professional driving differed from those of the respondents, and we have no reason to expect such a difference.

A more-important limitation is that, among the cases, the exposure history came after the occurrence of low-back pain. The relevant exposures are those that precede the onset of symptoms, but the most reliable and complete information came from the most recent or currently held job. Bias could have arisen if workers with low-back pain developed symptoms in driving jobs but then moved to work with less exposure because of symptoms (unhealthy worker selection bias). Assessing this bias is challenging in practice, as low-back pain often begins early in adulthood (24), sometimes before employment begins (25), and then runs a relapsing and recurrent course. Defining an exposure that predates symptoms may seem arbitrary, while the distinction between whole-body vibration as an initiating factor as compared with a factor of aggravation is also not straightforward. A censoring of recent exposure experience for cases would need to be mirrored by a censoring for controls. In practice, we focused on the current episode of low-back pain, and when it began, and limited the analysis to cases whose symptoms began in the current or most recent job, comparing their exposure to controls reporting a current or recent job. While it remains possible that some drivers had reduced their exposure but remained within the same job, we consider the scope for this possibility to be more limited than for a change of occupation; and no such selection was evident in relation, say, to occupational twisting.

Assessing exposures after the event has the potential also to inflate some risk estimates through reverse causation. Thus low mood could arise as a consequence of severe low-back pain rather than causing it. However,

it seems implausible that some exposures with positive associations could be influenced in this way (eg, twisting, height) and, less likely for others (eg, tendency to somatize).

Recruitment through secondary medical care raises the possibility that professional drivers might have sought care, or been referred, less readily for MRI investigation than other occupational groups, such as manual laborers. This possibility could lead to an underrepresentation of professional drivers among the cases, while not altering the general conclusion that whole-body vibration does not appear to be an important cause of back-pain cases seen in MRI services.

The hospitals from which the cases were recruited were the only institutions in the study area that provided MRI scans for low-back pain, and the identification of eligible cases from the study population should therefore have been nearly complete. Similarly, the hospital from which the controls were recruited was the only provider of accident and emergency services in the study area, and this exclusivity should have helped to ensure that the control group was representative in terms of relevant exposures. Bias could have occurred, however, if the workers with low-back pain who were in white-collar jobs had more ready access to private medical care and were therefore more likely to be investigated by MRI scanning than those from manual occupations. To explore this possibility, we conducted a sensitivity analysis in which we examined the impact of excluding cases that had been identified from private hospitals, but we found no major impact on the findings in relation to driving and whole-body vibration.

A further challenge lies in the assessment of exposures to whole-body vibration. Estimates of dose relied on self-assessed exposure times and imputed values of vibration magnitude from external field observations. Nondifferential errors could have biased the associations towards the null. However, there is evidence that professional drivers make a reasonably accurate assessment of their exposure times (26). Moreover, it seems unlikely that there would be much misclassification of an exposure metric such as professional driving for ≥ 3 hours at a time. We focused exposure assessment on the current or most recent job, for which reporting was likely to be more complete and reliable, and, in doing so, did not consider total lifetime hours or total lifetime dose of vibration, which (while difficult to measure reliably) may bear a different relation to low-back pain risk.

Finally, in assessments of the null finding in relation to whole-body vibration, the possibility of uncontrolled confounding should be borne in mind. Although we have no direct evidence to this effect, a factor that protected against back pain among the controls, or a greater exposure to whole-body vibration from nonoccupational sources among the controls, may serve to

obscure associations with occupational exposure to whole-body vibration.

Our finding of a lack of a clear relation between low-back pain and whole-body vibration contrasts with the results of several other research reports and reviews (2–12). One explanation, given the relatively low prevalence of professional driving in our study population (17%), is that an effect was missed by chance. The upper confidence intervals for the risk estimates did not exclude a doubling of risk from professional driving for ≥ 3 hours at a time at the 5% level and the absence of any exposure–response effect by estimated A(8), although limited by the numbers with high exposure, tends to argue against this explanation.

A second possibility is that the drivers in our study—representing a population-based sample—were less heavily exposed to whole-body vibration than in surveys of occupational cohorts. Most were drivers of cars, with relatively few other sources of exposure reported. Associations with car driving have been reported in several earlier surveys (9–11), but there are also some contrary observations from general-population-based samples (13, 27). It was estimated that, for only 1 in 6 to 7 of our study participants, was the $A(8) \geq 0.5 \text{ m/s}^2$ and, for only 1 in 20, was it $\geq 1.15 \text{ m/s}^2$. In comparison, in positive studies from occupational settings, the average exposure levels were around 0.5 m/s^2 for crane drivers (28, 29) and helicopter pilots (30), 0.8 m/s^2 for lift truck drivers (4), and $0.7\text{--}1.0 \text{ m/s}^2$ for tractor drivers (6), and drivers of wheel loaders and freight containers (31). Our findings should not be construed as arguing against whole-body vibration as a cause of low-back pain in more highly exposed working populations.

The finding of a clear consistent and strong association with sitting while not driving raises a third possibility—that previously reported associations with whole-body vibration were confounded by constrained sitting, a characteristic ingredient of professional driving. The data in hand provide some support for this idea in that an association was found in the final models between continuous driving in one period (with sitting for >3 hours at time) but not with hours driven in aggregate or other measures of whole-body vibration dose. Some positive associations with sitting while not driving have been reported also in the wider literature (32–35), but the increases in risk have been modest and not wholly consistent, and the balance of evidence is against this explanation (33, 36, 37).

A fourth possibility is that whole-body vibration is generally associated with mild-to-moderate low-back pain, but not with severe low-back pain that leads to investigation by MRI.

Whichever the explanation, our findings suggest that, in the population studied, whole-body vibration seems not to be an important cause of low-back pain severe

enough to be referred for MRI imaging of the lumbar spine. Certain aspects of mental health (low mood, somatizing tendency) and health beliefs (beliefs regarding work as a cause or aggravation of back pain) may make a more important contribution.

Acknowledgments

This research was supported by the European Commission under the Quality of Life and Management of Living Resources program, project QLK4-2002-02650 (VIBRISKS).

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Received for publication: 21 February 2008