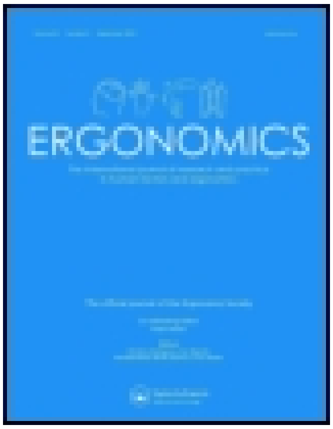

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A prospective cohort study of neck and shoulder pain in professional drivers

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A prospective cohort study of neck and shoulder pain in professional drivers

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In a three-year follow-up study, the occurrence of neck and shoulder pain (NSP) in terms of frequency, duration and intensity was investigated in a population of 537 male professional drivers. Over the follow-up period, the cumulative incidences for neck and shoulder pain were 31.9% and 21.4%, respectively. After adjustment for potential confounders, a measure of cumulative whole-body vibration exposure was significantly associated with all NSP outcomes. Lifting loads and work with hands above shoulder level were significantly related to shoulder outcomes, while driving with trunk bent or twisted was associated with neck pain. Limited job decision, low social support and job dissatisfaction were significant predictors of neck outcomes. Psychological distress was associated with all NSP outcomes. The findings of this cohort study suggest that NSP outcomes are of multifactorial origin in driving occupations.

Practitioner Summary: This prospective cohort study highlighted the multifactorial nature of neck and shoulder pain (NSP) outcomes in a population of professional drivers. Cumulative whole-body vibration exposure, physical load factors and adverse psychosocial environment at the workplace, as well as individual-related psychological distress, were significant predictors of the occurrence of NSP in the professional drivers.

Keywords: whole-body vibration; health risks; musculoskeletal disorders; psychological stress; driving

1. Introduction

The Fifth European Working Conditions Survey by Eurofound (2012) reported that exposures to ergonomic risk factors at the workplace have not diminished over the last two decades, and, contrariwise, some physical loads, such as ‘tiring and painful positions’ and ‘repetitive hand or arm movements’, show an upward trend. Occupational exposures to physical risk factors are still prevalent in the 27 EU Member States compared to exposures to dust, fumes and/or vapours, chemical agents or biological agents (Eurofound 2012). According to the EU Agency for Safety and Health at Work (2010), musculoskeletal disorders in the (lower) back, neck and upper limbs are the most frequent causes of occupational diseases, sickness and absenteeism among European workers. In addition to these adverse health effects, there is an increasing impact of musculoskeletal disorders on economic and social costs in European countries (EU-OSHA 2010).

Repetitive work, awkward postures, forceful movements, manual materials handling (lifting, carrying or moving heavy loads) and vibration exposure are the most important physical risk factors for musculoskeletal disorders, among which neck and shoulder pains are common complaints (EU-OSHA 2010; Eurofound 2012). Epidemiological studies have provided strong evidence for an association between neck pain and awkward working postures (NIOSH 1997; EU-OSHA 1999). There is also evidence for a causal relationship between highly repetitive work and neck and shoulder pain (NSP), and between neck disorders and forceful movements. Some studies and reviews of the epidemiological literature have also found a positive relationship between NSP and exposures to hand-transmitted vibration from powered tools (Ariëns et al. 2000; van der Windt et al. 2000; Åström et al. 2006; van Rijn et al. 2010; Tornqvist et al. 2011; Mayer, Kraus, and Ochsmann 2012).

According to a NIOSH review of work-related musculoskeletal disorders (1997), there is strong epidemiological evidence for an association between occupational exposures to whole-body vibration (WBV) and low back symptoms or disorders, while epidemiological data are insufficient to provide support for a relationship of WBV to neck and/or shoulder pain. Nevertheless, more recent studies have reported some associations between symptoms in the neck and upper extremities and driving occupations with combined exposures to WBV and other physical risk factors such as awkward postures and lifting (Rehn et al. 2002, 2009; Hagberg et al. 2006).

Several studies have suggested that work-related psychosocial factors and individual-related psychological distress may play a role in the development of neck and/or shoulder pain, although the etiopathogenetic mechanisms are poorly understood. Adverse psychosocial environment includes, among others, high job demands, poor decision latitude, low supervisor support and job dissatisfaction, but the findings are not consistent across studies (van der Windt et al. 2000; Bongers, Kremer, and ter Laak 2002; Ariëns et al. 2011).

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The aims of this prospective cohort study were to investigate the occurrence of NSP and the relation between NSP and individual- and work-related factors in a cohort of Italian professional drivers recruited in a four-year research project entitled "Risks of Occupational Vibration Injuries" (VIBRISKS 2007) and funded by the EU Commission. VIBRISKS is a European research project which seeks to improve understanding of the risk of injury from occupational exposures to mechanical vibration by means of epidemiological studies supported by fundamental laboratory research.

2. Subjects and methods

2.1. *Study population*

In the Italian arm of the VIBRISKS project the study population included all male professional drivers ($n = 628$) employed in several industries (marble quarries, marble laboratories, dockyards, paper mills) and public utilities (garbage services, public transport) located in various Provinces of Italy. The rate of participation in the initial cross-sectional survey in the calendar period October 2003 to February 2004 was 95.2% ($n = 598$). A total of 317 responders participated in two follow-up investigations carried out in the same calendar periods in 2004–2005 and 2005–2006. Owing to either organisational problems due to time schedules at the workplace or opposition by the employers, 220 workers could participate in only one-year follow-up survey. A total of 61 subjects were lost at the follow-up; of these, 15 had changed their place of residence, 36 refused to participate in the follow-up and 10 could not be identified. At baseline, the lost subjects did not differ significantly from the participants in the study with respect to age, anthropometric characteristics, smoking and drinking habits, measures of work-related risk factors (WBV, physical and psychosocial load) and prevalence of NSP.

Written informed consent to the study was obtained from employers and employees at each company.

A minimum of one year of professional driving in the current job was established as the basic criterion for the inclusion of the drivers in the study population.

Drivers were divided into three groups according to the machines and/or vehicles more frequently used in their work activities: earth-moving machines in marble quarries and laboratories (Group A, $n = 124$), forklift trucks in marble laboratories, dockyards and paper mills (Group B, $n = 169$) and buses in public transport and garbage machines in public services (Group C, $n = 244$).

2.2. *The questionnaire*

The drivers were interviewed by certified occupational health personnel who were trained to administer a structured questionnaire developed within the VIBRISKS project. The questionnaire has been undergoing a process of improving revisions on the basis of the findings of pilot studies and epidemiological surveys conducted across some European countries (Pope et al. 2002; Lundström 2007; Pinto and Bovenzi 2007).

The questionnaire consisted of various sections dedicated to personal and general information, occupational history, personal medical history with reference to neck pain, shoulder pain and low back pain, which have been described in detail in our previous papers (Bovenzi, Pinto, and Stacchini 2002; Bovenzi 2009, 2010). Twelve questions requested information about personal characteristics (age, height, weight, smoking and drinking habits, education, marital status, physical activity and annual car driving), 8 questions asked about driving history in the current and previous companies (job titles, duration of employment, types of machines or vehicles driven, daily and cumulative duration of driving on specific machine or vehicle), 19 questions related to physical load during a typical working day (walking and standing, sitting, non-neutral postures, lifting, work with hands above shoulder level), 5 questions related to psychosocial factors at work (job decision, job support from supervisors or co-workers, job satisfaction) and 10 questions related to individual psychological feelings and psychosomatic symptoms.

NSP were investigated using a modified version of the Nordic questionnaire on musculoskeletal symptoms (Kuorinka et al. 1987). Cases of neck and/or shoulder pain in the previous 12 months were those who reported at least one episode of pain lasting one day or more in the neck or shoulder anatomical areas shown in a diagram. The drivers who reported NSP were requested to answer additional questions concerning duration, frequency, pain radiation, pain intensity, health care use because of symptoms, treatment (e.g. anti-inflammatory drugs or physical therapy) and sick leave due to symptoms in the previous 12 months. Pain intensity in the previous 12 months was rated on an 11-point scale, where 0 is 'no pain at all' and 10 is 'pain as bad as it could be' according to the Numerical Rating Scale (NRS) method (von Korff, Jensen, and Karoly 2000).

2.3. *Definition of NSP outcomes*

In this study the outcomes were neck pain or shoulder pain in the previous 12 months at baseline and during the follow-up. NSP outcomes were treated as four-level ordinal scale response variables as follows:

(i) number of episodes of neck or shoulder pain in the previous 12 months (0, 1–5, 6–10, >10 episodes);
(ii) duration of neck or shoulder pain in the previous 12 months (0, 1–6, 7–30, >30 days);
(iii) pain intensity in the neck or the shoulder in the previous 12 months (NRS score: 0, 1–3, 4–5, 6–10).

The four-level ordinal scales for the response variables (frequency, duration and intensity of NSP) were assumed to correspond to no, mild, moderate and severe pain in the neck or shoulder.

2.4. Measurement and assessment of vibration exposure

Vibration measurements were made on representative samples of industrial machines and vehicles ($n = 68$) used by the professional drivers. Vibration was measured at the driver–seat interface during actual operating conditions according to the recommendations of the International Standard ISO 2631-1 (1997) and the VIBRISKS protocol (Lundström 2007). Details of the vibration measurements and sampling procedures are reported elsewhere (Pinto and Stacchini 2006; Bovenzi 2009, 2010).

From one-third octave band frequency spectra (1–80 Hz) recorded from x-, y- and z-directions, frequency-weighted accelerations ($a_{w,x}$, $a_{w,y}$, $a_{w,z}$) were obtained by using the weighting factors suggested in ISO 2631-1 (1997).

The root-sums-of-squares (also called the vibration total value, a_{ws}) of the root-mean-square (r.m.s.) acceleration values for each machine or vehicle was calculated according to the following equation (ISO 1997):

$$a_{ws} = (1.4a_{w,x}^2 + 1.4a_{w,y}^2 + a_{w,z}^2)^{1/2} \quad (\text{ms}^{-2}\ \text{r.m.s.}).$$

For each operator, questionnaire data, information obtained by interviewing employees and employers, and company records were used to estimate daily and lifetime exposure to WBV expressed in driving hours. In addition, samples of driving activities were monitored by a digital chronometer. In case of discrepancy between self-reported (interview) and observed (stopwatch method) daily duration of vehicle driving, the observed driving time was used in data analysis. Details of the sampling method to estimate the actual duration of vibration exposure during a typical workday are reported elsewhere (Pinto and Stacchini 2006).

Vibration measurements and total duration of exposure were used to construct a measure of cumulative vibration dose calculated as:

$$\text{dose} = \sum_i [a_{wsi}^2\, t_i] \quad (\text{m}^2\text{s}^{-4}\text{h}),$$

where a_{wsi} is the vibration total value of the frequency-weighted r.m.s. accelerations measured on vehicle i driven for time t_i in hours (h/d × d/yr × years) (VIBRISKS 2007).

2.5. Physical, psychosocial and psychological risk factors

A combined approach consisting of both direct observation of working conditions and the subject's self-assessment during the interview was used to evaluate the physical load in the professional drivers. Photographs and videos were taken at the workplace to analyse drivers' postures during a working day.

For the adverse health effects on neck and/or shoulder, the following physical load factors were considered: lifting loads, non-neutral postures and work with hands and arms above shoulder level. The drivers were requested to estimate the daily duration of lifting loads >15 kg (comparable to a crate of bottles, or a small suitcase with belongings) with trunk bent or twisted using a three-point ordinal scale ('not at all', '1–45 min', 'more than 45 min'). In addition, they were asked to score bent or twisted postures while driving ('never', 'sometimes', 'often'). The duration of work with hands and arms raised above shoulder level during a typical working day was graded with a three-point response scale ('never', 'less than 1 h', 'more than 1 h').

Perceived psychosocial work environment was investigated from five questions concerning job decision (three questions), job support (one question) and job satisfaction (one question) (Karasek 1979). Job decision and job support were measured on a four-point scale ('often', 'sometimes', 'seldom', 'never/almost never'), as well as job satisfaction ('very satisfied', 'satisfied', 'dissatisfied', 'very dissatisfied').

Psychological distress and psychosomatic symptoms were scored on the basis of 10 questions measured on a five-level ordinal scale ('not at all', 'a little bit', 'moderately', 'quite a bit', 'extremely'). The drivers were requested to score the following symptoms or feelings: faintness or dizziness, pains in the heart or chest, nausea or upset stomach, trouble getting your breath, feeling weak in parts of your body, numbness or tinglings in parts of your body, your feelings being easily hurt, feelings that people are unfriendly or dislike you, feeling inferior to others, feeling very self-conscious with others. On checking the score distribution across the various questions, the psychological distress variable was dichotomised into 'not at all/a little bit' and 'moderate/quite a bit'. No driver scored 'extremely' for any question both at baseline and over the follow-up period.

2.6. *Statistical methods*

The statistical analysis of data was performed with the Stata software®, version 12.1 (StataCorp, College Station, Texas).

Continuous variables were summarised with the mean as a measure of central tendency and the standard deviation (SD) as measure of dispersion.

Comparisons between independent groups were made with one-way analysis of variance. Differences between categorical data cross-tabulated into contingency tables were tested by the χ^2 statistic.

The associations between NSP (ordinal) outcomes and individual- and work-related risk factors were assessed by random-intercept ordered logistic regression analysis to account for the within-subject dependency of the observations over time (gllamm procedure in Stata) (Rabe-Hesketh and Skrondal 2005). Proportional odds ratios (ORs) and 95% confidence intervals (95% CI) were estimated from the logistic regression coefficients and their standard errors. The assumption of proportional ORs of the predictor variables across response categories was checked with the Stata program gologit2.

Random-intercept ordered logistic regression analysis was performed with a time-lag model to investigate the temporal sequence of cause and effect (Twisk 2003): the outcome variable for subject i at time-point t (Y_{it}) was related to the value(s) of independent variable(s) k for subject i at time-point $t-1$ (X_{ikt-1}), i.e. the values of the predictors at one measurement earlier.

Physical, psychosocial and psychological risk factors and potential confounders entered the logistic model as time-dependent categorical covariates, while vibration dose and age at entry were included as time-dependent and time-independent continuous variables, respectively. Since the distribution of the vibration dose was skewed, a natural logarithmic (ln) transform was applied to the dose to convert it into a normally distributed variable. All models included a linear term for time effect. Interactions between covariates were assessed by adding appropriate product terms to the logistic models. The significance of additional variables in the models was tested by the likelihood ratio χ^2 statistic. A p-value $<$ 0.05 was established as the limit of statistical significance.

3. Results

3.1. *Characteristics of the driver groups*

At baseline there were some differences between the driver groups with respect to smoking and drinking habit, and physical activity (Table 1). Age, body mass index, education and amount of car driving per year did not differ between groups.

Job seniority in current job and cumulative (lifetime) WBV exposure were significantly greater in the drivers of earth-moving machines (Group A) than in the other driver groups ($0.001 < p < 0.05$).

Similarly, exposures to physical load factors such as lifting loads and work with hands above shoulder were more frequent in Group A ($p < 0.001$), while awkward postures during driving were more often reported by drivers of forklift trucks (Group B).

Conversely, poor psychosocial environment at the workplace in terms of job decision, job support and job satisfaction, as well as psychological/psychosomatic problems, were more frequently complained by the drivers employed in public utilities (Group C) ($p < 0.001$).

Previous jobs with either WBV exposure or heavy physical demands were more frequently reported by drivers of Group C and drivers of Group A, respectively.

3.2. *Prevalence and incidence of NSP outcomes*

At the initial survey, in the entire population of professional drivers the point prevalence of neck and shoulder pain was 43.4% and 19.9%, respectively (Table 2). There were no significant differences in the baseline prevalence of 12-month NSP between the driver groups.

Over the follow-up period, there were 97 new cases of neck pain and 92 new cases of shoulder pain, giving rise to cumulative incidence rates of 31.9% and 21.4%, respectively, with no significant difference between groups ($p = 0.67$ for neck pain; $p = 0.12$ for shoulder pain). However, at some points of the follow-up period there were 70 prevalent/incident cases of neck pain and 69 prevalent/incident cases of shoulder pain who reported recovery from symptoms. As a result, the occurrence of persistent neck and shoulder pain in the study population (calculated over period prevalence) was 78.8% and 65.3% of the prevalent/incident cases, respectively, with no difference between groups ($p = 0.29$ for neck pain; $p = 0.19$

Table 1. Characteristics of the study population at the cross-sectional survey. Data are given as means (SD) or numbers (%). See text for the definition of driver groups.

	Driver groups			
	Group A ($n = 124$)	Group B ($n = 169$)	Group C ($n = 244$)	Total ($n = 537$)
Age (yr)	41.0 (8.3)	40.3 (8.4)	41.5 (7.8)	41.0 (8.1)
Body mass index (kg/m^2)	26.5 (3.5)	25.9 (4.0)	26.7 (3.6)	26.4 (3.7)
Smoking				
Never	50 (40.3)	66 (39.1)	130 (53.3)	246 (45.8)
Ex-smokers	30 (24.2)	33 (19.5)	49 (20.1)	112 (20.9)
Current smokers	44 (35.5)	70 (41.4)	65 (26.6)*	179 (33.3)
Drinking (units/week)				
0	39 (31.4)	49 (29.0)	104 (42.6)	192 (35.7)
1–6	70 (56.5)	92 (54.4)	92 (26.7)	254 (47.3)
> 6	15 (12.1)	28 (16.6)	48 (19.7)**	91 (17.0)
Education (yr)				
≤ 6	10 (8.0)	16 (9.5)	9 (3.7)	35 (6.5)
7–12	87 (70.2)	105 (62.1)	163 (66.8)	355 (66.1)
> 12	27 (21.8)	48 (28.4)	72 (29.5)	147 (27.4)
Physical activity				
Never	69 (57.7)	86 (50.9)	82 (33.6)	237 (44.1)
< 1 per week	9 (7.3)	17 (10.0)	38 (15.6)	64 (11.9)
1–2 per week	33 (26.6)	34 (20.1)	74 (30.3)	141 (26.3)
≥ 3 per week	13 (10.4)	32 (19.0)	50 (20.5)**	95 (17.7)
Car driving (km/yr)				
< 8000	36 (29.0)	38 (22.5)	71 (29.1)	145 (27.0)
8–24,000	81 (65.3)	117 (69.2)	149 (61.1)	347 (64.6)
$> 24{,}000$	7 (5.7)	14 (8.3)	24 (9.8)	45 (8.4)
Previous jobs with vibration exposure	37 (29.8)	46 (27.2)	149 (61.1)**	232 (43.2)
Previous job with heavy physical load	33 (26.6)	35 (20.7)	33 (13.5)**	101 (18.8)
Seniority in current job (yr)	14.6 (9.7)	12.0 (8.7)	11.9 (8.8)****	12.5 (9.0)
Vibration dose (ln(m^{2}s^{-4}h))	8.32 (1.45)	7.57 (1.39)	7.20 (1.30)*****	7.58 (1.43)
Lifting ($>$15 kg) with trunk bent or twisted				
0–15 min/day	42 (33.9)	83 (49.1)	209 (85.6)	334 (62.2)
16–45 min/day	48 (38.7)	49 (29.0)	31 (12.7)	128 (23.8)
> 45 min/day	34 (27.4)	37 (21.9)	4 (1.6)***	75 (14.0)
Work with hands above shoulder level				
Never	73 (58.9)	120 (71.0)	143 (58.6)	336 (62.6)
< 1 h/day	16 (12.9)	24 (14.2)	92 (37.7)	132 (24.6)
> 1 h/day	35 (28.2)	25 (14.8)	9 (3.7)***	69 (12.8)
Driving with trunk bent or twisted				
Never/seldom	36 (29.0)	26 (15.4)	48 (19.7)	110 (20.5)
Sometimes	43 (34.7)	33 (19.5)	95 (38.9)	171 (31.8)
Often	45 (36.3)	110 (65.1)	101 (41.4)***	256 (47.7)
Job decision				
Often	47 (37.9)	74 (43.8)	11 (4.5)	132 (24.6)
Sometimes	45 (36.3)	53 (31.4)	45 (18.4)	143 (26.6)
Seldom/never	32 (25.8)	42 (24.8)	188 (77.1)***	262 (48.8)
Job support				
Often	105 (84.7)	149 (88.2)	127 (52.0)	381 (70.9)
Sometimes	14 (11.3)	13 (7.7)	92 (37.7)	119 (22.2)
Seldom/never	5 (4.0)	7 (4.1)	25 (10.3)***	37 (6.9)
Job satisfaction				
Very satisfied	69 (55.7)	43 (25.4)	70 (28.7)	182 (33.9)
Satisfied	52 (41.9)	101 (59.8)	143 (58.6)	296 (55.1)
Dissatisfied/very dissatisfied	3 (2.4)	25 (14.8)	31 (12.7)***	59 (11.0)
Psychological distress				
Not at all/a little bit	65 (52.4)	81 (47.9)	82 (33.6)	228 (42.5)
Moderate/quite a bit	59 (47.6)	88 (52.1)	162 (66.4)**	309 (57.5)

Chi-square test: *$p < 0.05$; **$p < 0.01$; ***$p < 0.0001$. Oneway ANOVA: ****$p < 0.05$; *****$p < 0.001$.

Table 2. Prevalence at baseline, period prevalence and cumulative incidence of neck and shoulder pain over the follow-up period by driver groups (Group A = 124; Group B = 169; Group C = 244). Data are given as numbers (%). Percentages of persistent outcomes are calculated over period prevalence.

Outcome	Prevalence at baseline	Cumulative incidence	Period prevalence	Persistence over follow-up
Neck pain				
Group A	46 (37.1)	27 (52.9)	73 (58.9)	55 (75.3)
Group B	70 (41.4)	33 (33.3)	103 (60.9)	78 (75.7)
Group C	117 (47.9)	37 (29.1)	154 (63.1)	127 (82.5)
Total	233 (43.4)	97 (31.9)	330 (61.5)	260 (78.8)
Shoulder pain				
Group A	23 (18.6)	29 (28.7)	52 (41.9)	37 (71.5)
Group B	26 (15.4)	28 (19.6)	54 (31.9)	35 (64.8)
Group C	58 (23.8)	35 (18.8)	93 (38.1)	58 (62.4)
Total	107 (19.9)	92 (21.4)	199 (37.1)	130 (65.3)

for shoulder pain). Excluding those who recovered from symptoms, at the end of the follow-up the prevalence was 48.4% for neck pain and 24.2% for shoulder pain.

At baseline the prevalence of neck pain radiating to the upper extremities was 10.6% (57 cases). The cumulative incidence of radiating neck pain over the follow-up period was 11.9% (57 new cases). There were no significant differences between driver groups ($p = 0.18$ for prevalence; $p = 0.51$ for incidence).

At the cross-sectional study, the point prevalence of 12-month NSP outcomes treated with anti-inflammatory drugs or physiotherapy was 16.6% for the neck ($n = 89$) and 6.7% for the shoulder ($n = 36$). The corresponding cumulative incidence over the follow-up period was 17.9% (80 new cases) for the neck and 3.4% (17 new cases) for the shoulder.

At baseline, sick leave $\geq$ 7 days due to neck and shoulder troubles was reported by 13 (2.4%) and 8 (1.5%) drivers, respectively. The corresponding cumulative incidence over the follow-up was 2.5% and 1.5% for neck- and shoulder-related sick leave $\geq$7 days, respectively.

Table 3 reports the distribution of NSP ordinal outcomes at baseline by driver groups. There were no significant differences in the frequency and the severity of either neck or shoulder pain between groups. The duration of neck pain was more prolonged in the drivers of forklift trucks (Group B) than in the other two groups ($p = 0.038$), while no difference between groups was observed for the duration of shoulder pain.

Table 3. Prevalence at baseline of neck and shoulder pain ordinal outcomes (number of episodes, duration, intensity) in the previous 12 months by driver groups. Data are given as numbers (%).

	Driver groups							
	Group A ($n = 124$)		Group B ($n = 169$)		Group C ($n = 244$)		Total sample ($n = 537$)	
Outcome	Neck	Shoulder	Neck	Shoulder	Neck	Shoulder	Neck	Shoulder
Pain episodes (n)								
0	78 (62.9)	101 (81.5)	99 (58.6)	143 (84.6)	127 (52.0)	186 (76.2)	304 (56.6)	430 (80.1)
1–5	29 (23.4)	9 (7.3)	41 (24.3)	13 (7.7)	56 (22.9)	34 (13.9)	126 (23.5)	56 (10.4)
6–10	5 (4.0)	5 (4.0)	12 (7.1)	4 (2.4)	21 (8.6)	8 (3.3)	38 (7.1)	17 (3.2)
$\geq$ 10	12 (9.7)	9 (7.3)	17 (10.1)	9 (5.3)	40 (16.4)	16 (6.5)	69 (12.9)	34 (6.3)
Pain duration (days)								
0	78 (62.9)	101 (81.5)	99 (58.6)	143 (84.6)	127 (52.0)	186 (76.2)	304 (56.6)	430 (80.1)
1–6	41 (33.1)	17 (13.7)	54 (31.9)	19 (11.2)	96 (39.3)	43 (17.6)	191 (35.5)	79 (14.7)
7–30	0 (0)	3 (2.4)	4 (2.4)	2 (1.2)	12 (4.9)	9 (3.7)	16 (3.0)	14 (2.6)
$\geq$ 30	5 (4.0)	3 (2.4)	12 (7.1)	5 (3.0)	9 (3.7)*	6 (2.5)	26 (4.8)	14 (2.6)
Pain intensity (score)[a]								
0	78 (62.9)	101 (81.5)	99 (58.6)	143 (84.6)	127 (52.0)	186 (76.2)	304 (56.6)	430 (80.1)
1–3	16 (12.9)	4 (3.2)	26 (15.4)	4 (2.4)	40 (16.4)	22 (9.0)	82 (15.3)	30 (5.6)
4–5	14 (11.3)	8 (6.5)	14 (8.3)	7 (4.1)	32 (13.1)	15 (6.2)	60 (11.2)	30 (5.6)
6–10	16 (12.9)	11 (8.9)	30 (17.8)	15 (8.9)	45 (18.4)	21 (8.6)	91 (16.9)	47 (8.8)

Chi-square test (duration of neck pain between driver groups): *$p = 0.038$.
[a] Numerical Rating Scale (NRS) method (see text for the definition of NRS).

3.3. NSP outcomes and individual- and work-related risk factors

In the entire study population, univariable data analysis showed no associations between NSP ordinal outcomes and individual-related variables over the follow-up period, although some positive, not significant, trends were observed for age, body mass index and smoking, and an inverse trend, still not significant, was observed for regular physical activity (results not shown). Moreover, there were no significant associations between NSP outcomes and previous jobs with either WBV exposure or heavy physical load.

In multivariable data analysis, cumulative WBV exposure was significantly associated with both neck (Table 4) and shoulder (Table 5) outcomes over the follow-up period. For each ln(one-unit) increase in the cumulative vibration dose, the odds of neck outcomes increased by 26–35%, and that of shoulder outcomes increased by 47–53%.

Frequent awkward postures while driving were significantly related to the frequency and severity of neck pain, while lifting loads with trunk bent or twisted > 45 min/day was associated with the duration of neck pain (Table 4). Tasks involving prolonged exposures to lifting loads with awkward postures (> 45 min/day) and work with hands above shoulder level (> 1 h/day) were strongly associated with nearly all shoulder outcomes (Table 5).

Low job decision and job dissatisfaction were significant predictors of episodes of neck pain over time, and poor social support was related to pain intensity in the neck (Table 4). Perceived psychosocial work factors were not significantly associated with shoulder outcomes even though there was some evidence for a positive trend (Table 5).

Psychological distress and psychosomatic symptoms were strongly related to all NSP outcomes (Tables 4 and 5).

There were no significant interactions between work-related risk factors (WBV, physical load, psychosocial environment) and individual-related psychological distress when appropriate product terms were included in multivariable

Table 4. Association between neck (ordinal) outcomes over the follow-up period and individual- and work-related factors in the professional drivers. Proportional odds ratios (ORs) and 95% confidence intervals (95% CI) are estimated by random-intercept ordered logistic regression with a time-lag model to account for the within-subject correlation between repeated measures. See Table 3 for the ordered categories of neck outcomes.

Predictors	Episodes of neck pain OR (95% CI)	Duration of neck pain OR (95% CI)	Intensity of neck pain OR (95% CI)
Age at entry (× 10 yr)	1.03 (0.74–1.43)	1.05 (0.76–1.44)	0.95 (0.68–1.33)
Vibration dose ($\ln(m^2s^{-4}h)$)	**1.26 (1.02–1.56)**	**1.35 (1.09–1.67)**	**1.28 (1.03–1.59)**
Lifting (>15 kg) with trunk bent or twisted			
0–15 min/day	1.0 (–)	1.0 (–)	1.0 (–)
16–45 min/day	0.94 (0.47–1.87)	1.46 (0.74–2.89)	1.25 (0.62–2.50)
>45 min/day	1.26 (0.85–1.86)	**1.49 (1.00–2.23)**	1.43 (0.94–2.15)
Work with hands above shoulder level			
Never	1.0 (–)	1.0 (–)	1.0 (–)
<1 h/day	1.25 (0.85–1.85)	1.32 (0.89–1.95)	1.15 (0.77–1.71)
>1 h/day	1.65 (0.70–3.88)	1.44 (0.60–3.42)	1.46 (0.62–3.43)
Driving with trunk bent or twisted			
Never	1.0 (–)	1.0 (–)	1.0 (–)
Sometimes	1.20 (0.80–1.81)	1.14 (0.76–1.73)	1.34 (0.88–2.03)
Often	**1.57 (1.03–2.41)**	1.40 (0.91–2.14)	**1.84 (1.19–2.85)**
Job decision			
Often	1.0(–)	1.0 (–)	1.0 (–)
Sometimes	1.66 (0.98–2.78)	1.44 (0.81–2.56)	1.62 (0.91–2.87)
Seldom/never	**1.82 (1.07–3.09)**	1.72 (0.95–3.12)	1.70 (0.94–3.07)
Job support			
Often	1.0 (–)	1.0 (–)	1.0 (–)
Sometimes	0.95 (0.62–1.47)	1.31 (0.84–2.03)	1.31 (0.84–2.05)
Seldom/never	1.09 (0.57–2.08)	1.39 (0.73–2.64)	**1.98 (1.02–3.82)**
Job Satisfaction			
Very satisfied	1.0 (–)	1.0 (–)	1.0 (–)
Satisfied	1.24 (0.81–1.89)	1.01 (0.65–1.56)	1.01 (0.64–1.60)
Dissatisfied/very dissatisfied	**1.93 (1.02–3.67)**	1.36 (0.71–2.60)	1.41 (0.73–2.75)
Psychological distress			
Not at all/a little bit	1.0 (–)	1.0 (–)	1.0 (–)
Moderate/quite a bit	**1.85 (1.27–2.69)**	**1.97 (1.35–2.88)**	**2.12 (1.45–3.12)**

Note: Bold indicates significant associations between neck outcomes and predictors Proportional odds ratios are adjusted by body mass index, smoking, drinking, education, physical activity, previous exposures to whole-body vibration and/or heavy workload, and survey time.

Table 5. Association between shoulder (ordinal) outcomes over the follow-up period and individual- and work-related factors in the professional drivers. Proportional odds ratios (ORs) and 95% confidence intervals (95% CI) are estimated by random-intercept ordered logistic regression with a time-lag model to account for the within-subject correlation between repeated measures. See Table 3 for the ordered categories of shoulder outcomes.

Predictors	Episodes of shoulder pain OR (95 % CI)	Duration of shoulder pain OR (95% CI)	Intensity of shoulder pain OR (95% CI)
Age at entry (×10 yr)	1.21 (0.75–1.95)	1.17 (0.75–1.81)	1.21 (0.75–1.96)
Vibration dose ($\ln(m^2 s^{-4} h)$)	**1.53 (1.13–2.07)**	**1.47 (1.11–1.94)**	**1.48 (1.09–1.99)**
Lifting (> 15 kg) with trunk bent or twisted			
0–15 min/day	1.0 (–)	1.0 (–)	1.0 (–)
16–45 min/day	1.18 (0.35–3.98)	0.99 (0.32–3.06)	0.84 (0.25–2.85)
> 45 min/day	**2.48 (1.27–4.85)**	**2.16 (1.14–4.08)**	**2.50 (1.26–4.95)**
Work with hands above shoulder level			
> never	1.0 (–)	1.0 (–)	1.0 (–)
< 1 h/day	0.93 (0.18–4.88)	1.89 (0.99–3.58)	0.97 (0.18–5.16)
> 1 h/day	**2.00 (1.02–3.92)**	1.29 (0.27–6.18)	**2.38 (1.19–4.78)**
Driving with trunk bent or twisted			
Never	1.0 (–)	1.0 (–)	1.0 (–)
Sometimes	1.09 (0.51–2.32)	1.02 (0.50–2.10)	1.02 (0.47–2.20)
Often	1.07 (0.51–2.24)	1.34 (0.67–2.69)	1.14 (0.54–2.42)
Job decision			
Often	1.0 (–)	1.0 (–)	1.0 (–)
Sometimes	1.65 (0.70–3.89)	1.54 (0.68–3.47)	1.78 (0.75–4.20)
Seldom/never	1.96 (0.81–4.74)	1.61 (0.70–3.69)	2.07 (0.86–4.96)
Job support			
Often	1.0 (–)	1.0 (–)	1.0 (–)
Sometimes	1.59 (0.74–3.39)	1.39 (0.68–2.86)	1.36 (0.62–2.94)
Seldom/never	2.35 (0.77–7.17)	2.16 (0.77–6.08)	2.27 (0.73–7.05)
Job satisfaction			
Very satisfied	1.0 (–)	1.0 (–)	1.0 (–)
Satisfied	0.84 (0.41–1.73)	0.96 (0.49–1.88)	0.68 (0.33–1.41)
Dissatisfied/very dissatisfied	1.38 (0.47–4.02)	1.23 (0.45–3.34)	1.28 (0.43–3.82)
Psychological distress			
Not at all/a little bit	1.0 (–)	1.0 (–)	1.0 (–)
Moderate/quite a bit	**2.26 (1.46–3.51)**	**1.97 (1.29–3.02)**	**2.29 (1.47–3.57)**

Note: Bold indicates significant associations between shoulder outcomes and predictors. Proportional odds ratios are adjusted by body mass index, smoking, drinking, education, physical activity, previous exposures to whole-body vibration and/or heavy workload, and survey time.

data analysis ($p = 0.11$ to 0.96). A statistical test (program gologit2 in Stata) revealed that the ordered logistic models did not violate the assumption of proportional odds of the predictors across all cut-off points of the response variables (mild, moderate and severe NSP vs no NSP, moderate and severe NSP vs mild and no NSP, severe NSP vs moderate, mild and no NSP).

4. Discussion

The findings of this epidemiological study of the prevalence and incidence of 12-month neck pain (43.4% and 19.9%, respectively) and 12-month shoulder pain (31.9% and 21.4%, respectively) in professional drivers are broadly consistent with those reported in the available literature. This study also found that at the end of the follow-up period persistent symptoms were complained by 78.8% (neck) and 63.5% (shoulder) of the prevalent/incident cases. The figure for persistent neck pain is in agreement with studies of the course of this symptom in the general and working populations: between 50% and 85% of those who were affected with neck pain at some follow-up points reported neck pain again 1–5 years later (Carroll et al. 2008; Haldeman et al. 2008).

Overall, the findings of this prospective cohort study suggest that NSP outcomes in professional drivers are disorders of multifactorial origin. Combined exposures to excessive WBV, physical overload and poor psychosocial environment at the workplace, as well as individual-related psychological distress, are likely to contribute to the increased risk of neck and shoulder troubles observed in epidemiological studies of musculoskeletal disorders in driving occupations (Backman 1983; Tola et al. 1988; Viikari-Juntura et al. 1994; Magnusson et al. 1996; Scutter, Türker, and Hall 1997; Johanning et al. 2006; Szeto and Lam 2007; Milosavljevic et al. 2010).

4.1. Neck and shoulder pain in the general population

Systematic reviews of the available literature have shown that NSP are common complaints in the general population (Bot et al. 2005; Haldeman et al. 2008; Hogg-Johnson et al. 2008).

A synthesis of 249 scientifically admissible papers published from 1980 to 2006 reported that the 12-month prevalence of neck pain varied from 12.1% to 71.5% in the general population (most estimates ranging between 30% and 50%) (Haldeman et al. 2008; Hogg-Johnson et al. 2008). Neck pain associated with activity limitation or disability is less frequent, with 12-month prevalences ranging from 1.7% to 11.5% (Hogg-Johnson et al. 2008). Follow-up studies of people free from neck complaints at baseline reported that the cumulative incidence rates of self-reporting neck pain surveyed by means of questionnaires varied from 146 to 213 per 1000 persons (Hogg-Johnson et al. 2008). A similar figure was observed in a Dutch national survey of general practice (incidence of neck pain complaints: 23.1 per 1000 person-years) (Bot et al. 2005). Neck pain tends to increase with age with peaks in the middle age and declines thereafter.

Prevalence and incidence data for shoulder pain in the general population are more limited than those for neck pain. A critical review of 19 relevant studies reported estimates of 4.7% to 46.7% for 12-month prevalence and 0.9% to 2.5% for incidence rates of shoulder pain in different age groups of the general population (Luime et al. 2004). In a cross-sectional study of all men and women of working age (25–64 years) registered with two general practices from different geographic locations in Southamptom (UK), the prevalence estimates of specific shoulder disorders and unspecific shoulder pain in the general population were, respectively, 9.7% and 2.1% in men, and 10.9% and 2.5% in women (Walker-Bone et al. 2004). In the aforementioned Dutch survey, the one-year incidence of shoulder symptoms in general practice was estimated around 19.0 per 1000 person-years (Bot et al. 2005).

The large variations of the prevalence estimates for NSP in the general population have been attributed to differences in the demographics and socio-economic status of the surveyed populations, the methods for case definition and ascertainment, and the criteria for inclusion/exclusion of cases in the various studies (Hogg-Johnson et al. 2008).

4.2. Neck and shoulder pain in driving occupations

Epidemiological data on the occurrence of neck and/or shoulder pain in professional drivers have been reported in either studies of occupational groups driving specific machines/vehicles (bus, taxi, all-terrain vehicles, forklift trucks, tractors, earth-moving machines) or studies of the general population including workers employed in driving professions. Most of these studies were of cross-sectional type, while only a few investigations were conducted with either cohort or case-control design.

Studies of drivers employed in public utilities (bus, taxi, transit vehicles) reported that the 12-month prevalence of neck pain varied from 21% to 71% (median value: 52%), and that of shoulder pain ranged between 15% and 52% (median value: 36%), with significantly increased prevalence ratios (PRs) or ORs when compared with control, non-driving, groups (Anderson 1992; Magnusson et al. 1996; Johanning et al. 2006; Szeto and Lam 2007; Tamrin et al. 2007; Raanaas and Anderson 2008; Alperovitch-Najenson et al. 2010a).

Some studies have provided prevalence estimates for NSP in drivers of all-terrain vehicles used in agriculture and forestry. The 12-month prevalence of neck pain was 42% in a sample of New Zealand rural workers driving all-terrain vehicles (Milosavljevic et al. 2010) and 77.7% in Australian farmers driving tractors (Scutter, Türker, and Hall 1997). A Swedish study of forest machine operators and drivers of snowmobile or snow groomers reported 12-month prevalences of 34–61% for neck pain and 44–56% for shoulder pain (Rehn et al. 2009). In another cross-sectional survey of Swedish workforce conducted from 1999 to 2003 (Hagberg et al. 2006), agricultural, forestry, fishery workers and plant and machinery operators exposed to WBV at least one-fourth of their working time showed a prevalence of neck pain of 34.6% (PR vs unexposed: 2.23 (95% CI 1.81–2.74)), and a prevalence of shoulder/arm pain of 38.0% (PR vs unexposed: 2.57 (95% CI 2.10–3.14)). Conversely, in an epidemiological survey of the prevalence of neck pain in the British population, no association was found between neck symptoms and driving occupations (Palmer et al. 2001).

Studies of drivers of heavy machines have reported prevalences of neck/shoulder pain from 37% in truck drivers (Magnusson et al. 1996) to 77.4% in drivers of forklift trucks and earth-moving machines (Tola et al. 1988). In this latter study, machine operators showed an excess risk of severe neck troubles over a three-year follow-up period when compared with manual workers (OR 2.5 (95% CI 1.4–4.4)) and office workers (OR 3.9 (95% CI 2.3–6.9)) (Viikari-Juntura et al. 1994).

Among the few cohort investigations of professional drivers, one study reported a cumulative incidence of 25.5% for non-traumatic neck injuries in San Francisco transit vehicle operators over a 7.5-year follow-up (Rugulies and Krause 2005). A retrospective cohort study of Danish active workers (1981–1990) found that male professional drivers (truck, taxi, bus, railway) were more frequently hospitalised for cervical disc prolapse than men working in other occupations (standardised hospitalisation ratio (SHR): 142 (127–160)) (Jensen, Tüchsen, and Orhede 1996). In another 10-year follow-up study conducted in Denmark (1994–2003), drivers of heavy vehicles showed an excess risk of hospitalisation for cervical disc disorders when compared with economically active people in the total Danish population (SHR 116 (101–134)) (Jensen et al. 2008).

4.3. *Risk factors for neck and shoulder pain in the professional drivers*

The relation of NSP to physical work loading has been well documented in either cross-sectional or longitudinal studies (NIOSH 1997; EU-OSHA 1999; Ariëns et al. 2000; van der Windt et al. 2000). Manual materials handling, awkward postures with trunk bent or twisted, and work with hands above shoulder level have been found to be related to the onset and the development of neck and shoulder disorders in both professional drivers and non-driving occupations (van der Windt et al. 2000; Miranda et al. 2001; Viikari-Juntura et al. 2001; Ariëns et al. 2002; Rehn et al. 2002; Hagberg et al. 2006; Mayer, Kraus, and Ochsmann 2012). Awkward body postures caused by poor ergonomic design of the workstation (uncomfortable seat, driver–seat mismatch, inadequate back support, steering wheel stiffness) are considered a major risk factor for neck/shoulder pain in driving professions (Szeto and Lam 2007; Alperovitch-Najenson et al. 2010a). The positive association between neck/shoulder troubles and physical risk factors are confirmed by the findings of this cohort study in which frequent awkward postures during either driving or lifting loads, and over shoulder work were significant predictors of the frequency, duration and/or intensity of NSP over time.

The relation between NSP outcomes and psychosocial risk factors at work is not fully known. The magnitude of the influence of the various dimensions of psychosocial environment (job demand, decision latitude, support from supervisors or co-workers, job satisfaction) on the occurrence of neck and shoulder complaints varies across studies (van der Windt et al. 2000; Ariëns et al. 2001, 2002, 2011; van den Heuvel et al. 2005; Côté et al. 2008; Tornqvist et al. 2011). However, some studies of professional drivers have found an association between NSP and either of these work-related psychosocial factors (Tola et al. 1988; Magnusson et al. 1996; Scutter, Türker, and Hall 1997; Joksimovic et al. 2002; Rugulies and Krause 2005). In the present study, low job decision, poor social support and job dissatisfaction were significantly associated with neck pain but not with shoulder pain, although a tendency of an increased risk for shoulder outcomes with the increase of deteriorated psychosocial environment was observed. Differences in the definitions of NSP and psychosocial factors, the lack of standardisation for the metric used to quantify psychosocial variables and the poor understanding of the underlying pathophysiological mechanisms may account, at least partially, for the heterogeneity of the findings provided by the epidemiological studies which investigated the impact of work-related psychosocial factors on neck and shoulder disorders.

In this study there was evidence for a strong association between NSP outcomes and psychological/psychosomatic problems in the professional drivers. This finding supports the opinion of several researchers who suggest that psychological distress is an important predictor of both specific and non-specific musculoskeletal disorders in the neck and upper limbs (Leclerc et al. 1999; Miranda et al. 2001; Palmer et al. 2001; Côté et al. 2008). It is worth noting that in this study negative feelings and psychosomatic symptoms were more frequently reported by bus drivers than by machine drivers employed in the industry. Traffic-related mental stress, rigid work shift time schedules and the relations, often conflicting, with the public may explain the high occurrence of psychological distress in the bus drivers (Alperovitch-Najenson et al. 2010b). These stressors may induce an increase of muscle tension and a lowering of the threshold for pain perception, which, combined with individual vulnerability, may facilitate the onset and the development of neck/shoulder disorders (Leclerc et al. 1999).

The role of vibration exposure in the etiopathogenesis of neck/shoulder disorders is controversial. Some studies have reported significant associations between NSP outcomes and hand-arm vibration generated by hand-held power tools (Stenlund et al. 1993; Ariëns et al. 2000; van der Windt et al. 2000; Åström et al. 2006; van Rijn et al. 2010; Tornqvist et al. 2011; Mayer, Kraus, and Ochsmann 2012), while others did not support such an association (Palmer et al. 2001; Viikari-Juntura et al. 2001). The relation of NSP to WBV exposure is also uncertain. In epidemiological studies of professional drivers, nearly all with a cross-sectional design, there was some evidence that exposure to WBV was related to an excess risk for neck/shoulder complaints (Tola et al. 1988; Magnusson et al. 1996; Johanning et al. 2006; Szeto and Lam 2007; Raanaas and Anderson 2008). However, in these studies WBV exposure was expressed in a rough way, using proxy variables such as job title (drivers vs non-drivers) or years of professional driving. Very few studies reported metrics of WBV exposure, combining measures of vibration magnitude at the driver–seat interface with daily or cumulative duration of exposure, as required by the international standard ISO 2631-1 (1997) or the EU Directive (2002) on mechanical vibration. In a study of New Zealand farmers and rural workers using quad bikes (Milosavljevic et al. 2012), there was evidence for a strong association between the prevalence of 12-month neck pain and measures of daily vibration exposure and mechanical shock exposure (OR 3.42 (95% CI 1.41–8.96)). On the contrary, in the Swedish arm of the EU VIBRISKS project no significant associations were observed between the prevalence of neck pain or neck pain combined with arm pain and measures of daily or cumulative vibration exposure in a group of professional drivers of forest machines, although the cases with neck pain complained more often uncomfortable shocks and jolts during driving (Rehn et al. 2009).

Biodynamic investigations have shown that WBV can be transmitted from a seat surface to the head, cervical spine and shoulder area (Dupuis and Zerlett 1986; Griffin 1990). For vertical vibration, the peak seat-to-head transmissibility factor (acceleration at the head/acceleration at the seat) has been observed around 4–5 Hz. At these frequencies, the greatest head displacement occurs with vibration amplification in the range 1.8–3.0 (Dupuis and Zerlett 1986; Griffin 1990). There is intra- and inter-subject variability in the seat-to-head transmissibility of vibration: in addition to age, gender and anthropometric characteristics, vibration transmissibility depends on the posture of the subject, muscle tension and the contact with backrest (Paddan and Griffin 1988a, 1988b). The biodynamic behaviour of the cervical spine has been studied during exposure to vertical sinusoidal vibration with frequencies of 0.5–5.5 Hz and displacement magnitudes of 7–20 mm, using a roentgencinematographic technique (Christ and Dupuis 1963; Dupuis and Zerlett 1986). The cervical spine showed a resonance peak at 3.5 Hz and marked compression-extension motions of the cervical segment were observed in the frequency range 2.5–5 Hz. The shoulder also showed a resonance response between 2 and 5 Hz during vibration exposure in a seated posture (Dupuis and Zerlett 1986). Electromyographic measurements during simultaneous exposure to low-frequency vibration (2–6 Hz) have evidenced an increase activity of the paravertebral cervical muscles and the remaining neck musculature which has been interpreted as a defence mechanism to stabilise the cervical spine under vibration stress (Berthoz and Wisner 1968; Cursiter and Harding 1974).

The results of these experimental investigations suggest that exposure to low-frequency vibration may affect the cervical spinal structures and the connected musculature in the neck–shoulder area, supporting the epidemiological findings of an increased occurrence of neck and shoulder disorders in professional drivers exposed to WBV. In our previous studies of the same population of professional drivers, frequency analysis of the vibration generated by most of the machines/vehicles showed that the vibration frequencies with the highest r.m.s. acceleration magnitudes were 1.25–5 Hz (vertical axis), i.e. the frequency range at which the highest vibration transmission to the head and neck was observed in laboratory experiments (Bovenzi 2009, 2010). Overall, these findings seem to provide biodynamic and pathophysiological plausibility to the dose–response relationship between WBV exposure and NSP outcomes found in the present study. Moreover, multivariable analysis of longitudinal data with time-lag models suggested that cumulative WBV exposure contributed to the occurrence of NSP over time independently of other work-related risk factors. Physical overload, poor psychosocial environment and psychological distress were also significant predictors of NSP outcomes, suggesting a multifactorial origin of these disorders in professional drivers.

4.4. Limitations of the study

Uncertainties and limitations of this study have already been discussed in our previous papers in which the relationship between low back pain and measures of daily and cumulative WBV exposure was investigated in the same sample of professional drivers (Bovenzi 2009, 2010).

Briefly, the lifetime vibration dose cumulated by the professional drivers, i.e. $\Sigma(a_{wsi}^2 t_i)$, was calculated from the exposure duration (total hours, t_i) in current jobs and this may have lead to underestimation of vibration exposure in drivers with previous jobs with WBV exposure. To adjust, at least partially, for this exposure bias, prior employment as a driver was included as a time-independent variable in multivariable data analysis. A further uncertainty in the estimation of lifetime vibration dose may arise because vibration measurements were made on currently available machines or vehicles, even though a limited number of vibration measurements were also performed on old machinery, mainly in the forklift trucks used in dockyards (Bovenzi, Pinto, and Stacchini 2002; Bovenzi 2009). Nevertheless, the weighted r.m.s. acceleration magnitude of vibration measured in the vehicles of the present study are comparable with those reported in recent and past investigations (Dupuis and Zerlett 1986; Griffin 1990; Griffin et al. 2006).

Quantification of duration of WBV exposure may be difficult because recall bias cannot be ruled out when daily driving time is estimated by means of questionnaire or direct interview of employees and employers. To reduce this bias, a survey was conducted in the field to compare subjective estimates of daily exposure duration with objective measurements of actual driving time during typical working days (Pinto and Stacchini 2006). Systematic observations of the variability of work tasks over a one-week period indicated that drivers tended to overestimate the duration of their actual exposure to WBV in the range 5–13% (mean 11%). This finding is broadly consistent with the results of a national survey in Great Britain (Palmer et al. 2000) which showed a good agreement between reported and observed duration of exposure to WBV in a sample of drivers of industrial and agricultural machines (median ratio of reported to observed time: 1.1; interquartile range: 1.0–1.2).

In this study, work-related physical loading other than mechanical vibration was evaluated by a mixed approach based on both direct observation of working conditions and subjective judgement of the frequency and duration of awkward postures and heavy manual work. Since the association between NSP outcomes and physical load risk factors was evaluated mainly on the basis of self-reported working postures and manual materials handling, and not by means of quantitative observation methods, potential bias for spurious associations between exposures and symptoms cannot be ruled out. However, previous studies have found that individuals with musculoskeletal disorders did not tend to overestimate their physical workload when questionnaire data were compared with systematic observations (Hollmann et al. 1999). Moreover, ergonomic investigations have shown a good agreement between self-reported and observed frequency, duration and magnitude of physical demands (Pope et al. 1998).

Longitudinal studies involving outcomes and exposure variables that vary over time may be affected by feedback bias: drivers with NSP may modify their exposure to either physical load or WBV (Eisen 1999). This potential bias cannot be excluded, but information on driving activities gathered from repeated interviews of the drivers did not reveal substantial changes in exposure associated with NSP during the follow-up period.

5. Conclusions

The findings of this prospective cohort study highlighted the multifactorial nature of NSP outcomes in a population of professional drivers. Multivariable data analysis suggested that cumulative WBV exposure, physical load factors and adverse psychosocial environment at the workplace, as well as individual-related psychological/psychosomatic problems, are significant predictors of the occurrence of neck and shoulder disorders in driving occupations.

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