Int Arch Occup Environ Health (1990) 62:109–115

International Archives of
Occupational and Environmental Health

Original articles

Self-reported back pain in tractor drivers exposed to whole-body vibration

Hendriek C. Boshuizen, Paulien M. Bongers, and Carel T. J. Hulshof

Coronel Laboratory, University of Amsterdam, Meibergdreef 15, NL-1105 AZ Amsterdam, The Netherlands

Received May 2 / Accepted October 30, 1989

Summary. A postal questionnaire on symptoms of ill health and exposure to whole-body vibration was completed by 577 workers (response rate 79%) who were employed in certain functions by two companies 11 years before. The relation between the occupational history of driving vibrating vehicles (mainly agricultural tractors) and back pain has been analyzed. The prevalence of reported back pain is approximately 10% higher in the tractor drivers than in workers not exposed to vibration. The increase is mainly due to more pain in the lower back and more pain lasting at least several days. A vibration dose was calculated by assigning each vehicle driven a vibration magnitude, estimated on the base of vibration measurements. The prevalence of back pain increases with the vibration dose. The highest prevalence odds ratios are found for the more severe types of back pain. These prevalence odds ratios do not increase with the vibration dose. This might be due to health-related selection which is more pronounced for severe back pain than for back pain in general. The two components of the vibration dose, duration of exposure and estimated mean vibration magnitude, have also been considered separately. Back pain increases with duration of exposure but it does not increase with the estimated mean magnitude of vibration. This is probably due to the inaccuracy of this estimate. The higher prevalence of back pain in tractor drivers might be (partly) caused by whole-body vibration, but prolonged sitting and posture might also be of influence.

Key words: Back pain – Epidemiology – Tractor drivers – Whole-body vibration

Introduction

Low-back pain presents a common problem in occupational health. Nevertheless, there exists little consensus on the various risk factors and the magnitude of their causal impact on back pain. A risk factor, whose importance has only been recognised during the last decades, is driving vehicles involving exposure to whole-body vibration. Five case-control studies on herniated lumbar disc [5, 14, 15, 19, 21] have reported that professional drivers or truck drivers show an increased risk for herniated lumbar discs. In their study on medically reported low-back pain Frymoyer et al. [9] found that occupations that involve driving automobiles, motorcycles, buses, tractors, trucks and heavy construction equipment were present more frequently in patients with low-back pain than in a reference group without back pain. The excess of back pain in drivers is often considered to be at least partly due to exposure to whole-body vibration [16].

This study investigates the prevalence of back pain in drivers of agricultural vehicles (mainly tractors) in relation to past exposure to whole-body vibration. The study is part of an 11-year follow-up study in which long-term sick leaves and disability pensioning have als been studied. Results of that part will be published separately [4]. The prevalence of back pain was studied through self-reported symptoms in a postal questionnaire as we did not think that inclusion of a clinical investigation would add any validity to the assessment of back pain. Clinical signs are absent in a large number of back pain sufferers, while they are sometimes present in those free of pain [40]. Besides only a few clinical tests achieve a level of inter-observer reliability high enough for use in an epidemiological study [26]. In contrast, self-reported pain is a valid and relevant effect measure that can be measured with sufficient reliability [42].

Materials and methods

Study population. The study population consisted of workers employed on January 1, 1975 by two state companies. In company A the study population comprised all workers employed in the department in charge of the development and cultivation of newly reclaimed land. In company B the study population comprised all workers who performed inspections of roads, dikes, canals or at building sites and who worked in the same district as the workers

Offprint requests to: H. C. Boshuizen

of company A. The selected study population comprised 798 workers. Of these workers, 51 had died before the end of the follow-up period;15 workers could not be located because of incomplete identification, emigration or because no address was available. The workers ($n = 732$) received a questionnaire in 1986, which was returned by 577 workers (response 79%). Because the study population comprises both workers who are presently employed by the companies and workers who left the companies during the follow-up period, selection bias resulting from workers leaving the company will partly be prevented. However, some bias might still be present due to health-related selection before January 1, 1975.

The questionnaire. The questionnaire contained items on exposure to whole-body vibration, symptoms of ill health (focussing on symptoms of the musculoskeletal system) and potentially confounding factors.

Exposure to whole-body vibration was assessed by asking for the types of vehicles driven (both while working with the company and before joining it or after leaving it); period of driving (specified per vehicle), the number of weeks that were driven yearly (specified per vehicle) and the number of hours driven daily (for tractors) or weekly (for cars, vans and trucks). Drivers of agricultural tractors were also asked which part of the time they drove on roads and which part of the time they drove in the fields.

The most important questions on back pain are presented in Table 1. Based on these questions "frequent or long lasting back pain" is defined as back pain lasting several weeks or longer, or back pain occurring more than five times a month, which lasted several days or longer. The prevalence of "prolapsed disc" also includes workers with no present back pain but with a history of prolapsed disc.

The items on potentially confounding factors included smoking behaviour, age, climatical conditions, experienced mental stress and part of the working day one was walking, sitting, sitting with a twisted spine, stooping or kneeling, standing or lifting.

Table 1. Questionnaire items on back complaints

1. Do you regularly have pain or stiffness in the back?
2. Can you tick the place in the back where you have pain or stiffness?
3. How long do the back complaints usually last?
4. How often do you have back complaints?
5. Do you have or have you ever had a prolapsed disc?
6. Have you been treated for this?
   If yes, what kind of treatment?
7. Have you been treated for back pain, other than a prolapsed disc?

Table 2. Estimates of vibration magnitude per vehicle used in the analysis (only the most commonly used vehicles are listed)

Vehicle i	a_i (in m/s^2)	No. of workers who used this vehicle
Tractor on the road	1.1	363
Tractor in the fields	0.6	
Caterpillar tractor (only used in fields)	0.6	217
Combine harvester	0.3	197
Other reapers	0.3	18
Trencher	0.5	38
Bulldozer	0.6	40
Van	0.4	29
Car	0.3	15
Excavator	0.4	27
Shovel	1.1	10

Construction of exposure measures. For the calculation of a vibration dose both the duration of exposure and a magnitude of vibration are needed. The duration of driving was calculated from the questionnaire per type of vehicle, and for tractor drivers separately for driving on the road and in the fields. For each type of vehicle a mean magnitude of vibration was estimated based on measurements made at the two companies in 1985. The measurements were carried out by the Institute for Mechanical Constructions TNO according to the international standard ISO-2631 [17] on measuring vibration.

Tractors, especially in the field, vibrate in all three directions with about equal intensity. Therefore we decided to use the vector sum of the root mean square (r.m.s.) of the frequency-weighted accelerations in x-, y- and z-directions as measure of vibration magnitude.

Table 2 presents the estimates of the vibration magnitude for the most commonly driven vehicles. These estimated vibration magnitudes per vehicle were used to calculate an "equivalent vibration magnitude" and a vibration "dose" for each worker.

The equivalent vibration magnitude is calculated as:

$$a_{eq} = \sqrt{\sum (a_i^2 t_i)/t_i}$$

where t_i = time (in full-time working years) driven on vehicle i and a_i = estimated vectorsum of the r.m.s. acceleration in x-, y-, and z-direction (Table 2).
Vibration dose is calculated as:

$$\text{vibration-dose} = \sum_i a_i^2 t_i ,$$

using the same time-dependence as the ISO-2631 uses for exposure within a single working day.

Other dose measures suggested in the literature are the Vibration-Dose-Value, roughly proportionate to $\sum_i a_i^4 t_i$, proposed by Griffin [11]; $\sum_i a^{10} t$, derived by Sandover, assuming that recovery processes are absent, from data on fatigue failure of bone [31, 32]; and the absorbed energy [13] roughly proportionate to $\sum_i a_i^2 t_i$. Since no supportive epidemiologic evidence exists for any of these, we used the commonly applied energy equivalence principle. Although the vibration dose does not incorporate shocks explicitly, recent research has shown that this dose predicts the discomfort caused by shocks as well as, or even better, than shock oriented measures [41].

Analysis. For initial inspection of the data, the smoothing algorithm proposed by Fowles [10] was used to plot the prevalence of a complaint for each exposure category as function of age. When no important interaction with age was spotted, asymptotic maximum likelihood point estimates of the odds ratio were calculated for different categories of exposure after stratification for age [30]. The Mantel Haenszel extension test [25] and logistic regression were used to test for a trend with vibration dose.

Logistic regression (BMDP LR) was also used to adjust for several confounders. Not all potential confounders could be used in the regression.

One set of covariates was selected for all types of back pain other than prolapsed disc, small enough for the type with the smallest prevalence. Selection was based on the literature [2, 9, 20, 38, 39], on data of a group of (non-vibration exposed) military officers who completed a similar questionnaire for another study by our laboratory and on analyses of the data of this study.

Age was included as a quadratic term as studies [3, 12] have shown that the prevalence of low-back pain initially increases with age but declines after the fifth or sixth decade.

To study the relation between exposure and the prevalence odds ratio unrestricted by assumptions of the model, the exposure measure was entered in the model as a categorial covariate [6]. When a monotonic trend was observed, its significance was assessed by testing the coefficient of the exposure measure entered in the model as a continuous covariate.

Results

Figure 1 shows the smoothed prevalence of pain or stiffness in the back for different exposure groups as a function of age. It does not show consistent interaction between age and vibration exposure. Of the tractor drivers younger than 40 years, 61% had left the study company at the time the questionnaire was sent, against only 46% of the referent workers younger than 40 years. Most of the tractor drivers who had left the company had received a vibration dose less than 2.5 years m^2/s^4. Figure 2 shows the smoothed prevalence of pain or stiffness in the back for only those workers who no longer worked at the study companies at the time the questionnaire was sent. It shows that tractor drivers who had left the company after a short exposure had a high prevalence of pain or stiffness in the back, which indicates significant health based selection.

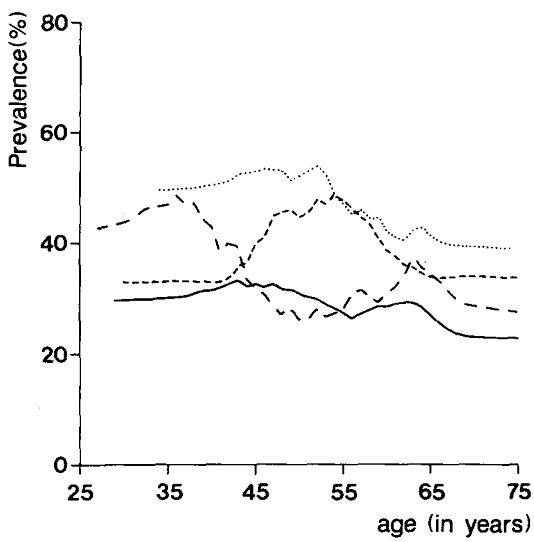

Fig. 1. Smoothed prevalence of back pain as a function of age for the different categories of received vibration dose. —— not exposed ($N=110$); – – – WBV-dose 0–2.5 years m^2/s^4 ($N=214$); ----- WBV-dose 2.5–5 years m^2/s^4 ($n=118$); ········· WBV-dose > 5 years m^2/s^4 ($N=118$)

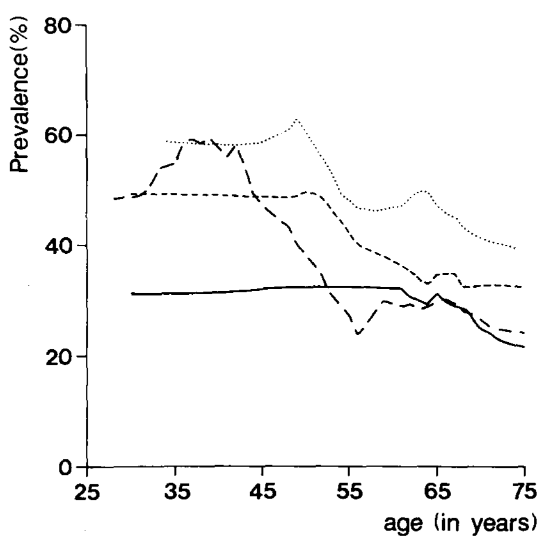

Fig. 2. Smoothed prevalence of back pain as a function of age for the different categories of received vibration dose for only those workers who had left the company. —— not exposed ($N = 49$; – – WBV-dose 0–2.5 years m^2/s^4 ($N = 103$); ---- WBV-dose 2.5–5 years m^2/s^4 ($N = 54$); ········ WBV-dose > 5 years m^2/s^4 ($N = 54$)

Considering confounding factors, it was noticed that the age of the tractor drivers increases with received vibration-dose, but the mean age of the tractor drivers was lower, although not significantly, as that of the reference group. There were no significant differences in height between tractor drivers and the reference group, but tractor drivers weighed significantly more, maybe due to their less active jobs. Tractor drivers spent more time sitting and sitting with a twisted spine that the reference group, and lifted and carried less. Tractor drivers found the climatic conditions on the job (and especially the cold) more often disagreeable than the reference group. Smoking behaviour did not substantially differ between the groups.

Table 3 shows that the prevalence of back pain was higher in the tractor drivers than in the non-vibration exposed reference group. This difference was most pronounced for the more severe "frequent or long lasting" pain. In the tractor drivers the pain was located more often in the lower back. The complaints in this table are not independent: someone with low-back pain also has back pain in general and could have had medical treatment. When the non-exposed workers are excluded from the analysis (not shown), a significant ($P<0.05$, both Mantel-Haenszel extension test and logistic modeling) increase with vibration dose is observed only for the three most common types of back pain (numbers 1, 2 and 6). When duration of exposure is used instead of vibration dose to form exposure categories (results not shown) the trend of increasing prevalence with increasing vibration exposure becomes weaker for all types of back pain with the exception of treated back pain. However, all associations, except that for back pain radiating to a leg, are still significant according to the Mantel-Haenszel extension test.

The odds ratios found from logistic regression, adjusting for more confounders than age (results not shown), are similar but have wider confidence intervals. When the duration of driving is used instead of vibration dose as measure of exposure (not shown), this association becomes weaker. When the non-exposed workers are again excluded from the analysis (results not shown) no significant increase of back pain prevalence with vibration dose is observed.

In addition to the relation between vibration-dose and back pain, the separate contributions of equivalent vibration magnitude and duration of exposure were also studied. Table 4 shows the odds ratios for equivalent vibration magnitude and Table 5 shows those for duration of exposure. When studying equivalent vibration magnitude (as a categorical variable), adjustment was made for duration of exposure (included in the model as

Table 3. Crude prevalences, age-adjusted maximum likelihood point-estimates of odds ratios (in brackets 90% test-based confidence intervals) for several types of back pain. As statistical tests for linear trend: 1. the Mantel-Haenszel extension test. 2. the Wald-statistic of vibration dose as a continuous covariate in a logistic model, including also age and age^2 as covariates

Type of back pain	Prevalence in % Vibration dose in years m^2s^4				Odds ratio (90% confidence intervals) Vibration dose in year m^2s^4			*P*-value (one-sided) of trend test	
	0 $n = 110$	0–2.5 $n = 214$	2.5–5 $n = 118$	>5 $n = 118$	0–2.5	2.5–5	>5	Mantel-Haenszel extension test	Logistic modeling
1 Back pain	27.3	34.6	38.1	45.8	1.37 (0.88–2.1)	1.57 (0.97–2.5)	2.3** (1.38–3.8)	0.002	0.009
2 Back pain, lasting several days or longer	18.2	29.4	31.4	38.1	1.76* (1.08–2.9)	2.0* (1.17–3.4)	2.8** (1.58–4.9)	0.0008	0.006
3 Back pain, treated	14.5	22.3	23.7	22.9	1.58 (0.93–2.7)	1.77 (0.99–3.2)	1.71 (0.91–3.2)	0.09	0.16
4 Back pain, radiating to a leg	12.7	15.9	21.2	22.9	1.36 (0.76–2.4)	1.69 (0.91–3.1)	1.59 (0.84–3.0)	0.03	0.12
5 Frequent or long lasting back pain	4.5	17.3	19.5	23.7	4.3** (2.0–9)	4.5** (2.0–10)	5.5*** (2.4–12)	0.009	0.01
6 Low-back pain	19.1	29.4	28.0	38.1	1.80* (1.11–2.9)	1.78* (1.04–3.1)	2.8** (1.64–5.0)	0.001	0.005
7 Frequent or long lasting low-back pain	3.6	14.0	15.3	18.6	4.3** (1.84–10)	4.7** (2.0–12)	6.0** (2.4–15)	0.003	0.02
8 Has had a prolapsed disc	4.5	5.6	11.0	10.2	1.58 (0.62–4.0)	2.8* (1.15–6.9)	2.7* (1.01–7.1)	0.02	0.04

* $P < 0.05$ (one-sided)
** $P < 0.005$ (one-sided)
*** $P < 0.0005$ (one-sided)

Table 4. Odds ratios resulting from logistic modelling using equivalent vibration magnitude (a_{eq}) categories, while correcting for duration of exposure, age, age^2, height, smoker/non-smoker, twisting, lifting, experienced mental workload, employing company. (For prolapsed lumbar disc only age, smoker/non-smoker, lifting, twisting and duration of exposure)

Type of back pain	Odds ratio (90% confidence interval) a_{eq} in m/s^2			
	0.3–0.55 $n = 66$	0.55–0.7 $n = 121$	0.7–0.9 $n = 117$	>0.9[a] $n = 22$
1 Back pain	1.22 (0.62–2.42)	1.33 (0.70–2.54)	1.46 (0.78–2.71)	1.27 (0.51–3.14)
2 Back pain, lasting several days or longer	1.39 (0.66–2.9)	1.84 (0.91–3.7)	1.60 (0.81–3.1)	2.03 (0.80–5.2)
3 Back pain, treated	1.54 (0.69–3.4)	1.73 (0.82–3.7)	1.52 (0.74–3.2)	1.52 (0.55–4.2)
4 Back pain, radiating to a leg	1.68 (0.70–4.0)	1.61 (0.69–3.7)	1.60 (0.71–3.6)	3.0* (1.07–8.3)
5 Frequent or long lasting back pain	3.9* (1.19–13)	5.2** (1.64–16)	6.1*** (1.97–19)	5.3* (1.38–20)
6 Low-back pain	1.98 (0.97–4.0)	1.66 (0.82–3.4)	2.10* (1.07–4.1)	1.38 (0.52–3.7)
7 Frequent or long lasting low-back pain	5.8 (1.48–23)	6.3 (1.63–24)	8.4*** (2.24–32)	7.4* (1.58–34)
8 Has had a prolapsed disc	3.9 (0.94–17)	3.5 (0.81–15)	3.9 (0.91–16)	2.10 (0.35–13)

* $P < 0.05$ (one-sided)
** $P < 0.005$ (one-sided)
*** $P < 0.0005$ (one-sided)
[a] In the logistic regression only respondents without any missing covariates could be included ($n = 395$)

a continuous variable) and vice versa. Table 4 shows no association between the equivalent vibration magnitude and the prevalence of back pain. Table 5, however, shows some association between duration of exposure to vibration and the three most common types of back pain. The association observed between vibration dose and back pain prevalence therefore is mainly due to the association between duration of exposure and back pain.

Table 5. Odds ratios resulting from logistic modelling using categories of duration of exposure (t) while correcting for equivalent vibration (a). Model contains also as covariates: age, age^2, height, smoker/non-smoker, twisting, lifting, experienced mental workload, employing company. (For prolapsed lumbar disc only age, smoker/non-smoker, lifting, twisting, equivalent vibration magnitude)

Type of back pain	Odds ratio (90% confidence interval) t in years of full time exposure		
	0–5 $n = 125$	5–10 $n = 94$	>10 $n = 107$
1 Back pain	1.44 (0.52–4.0)	1.69 (0.59–4.8)	2.34 (0.83–6.6)
2 Back pain, lasting several days or longer	1.68 (0.57–5.0)	1.91 (0.63–5.8)	2.40 (0.79–7.3)
3 Back pain, treated	1.79 (0.56–5.7)	1.79 (0.54–5.9)	1.77 (0.53–5.9)
4 Back pain, radiating to a leg	1.25 (0.36–4.4)	1.15 (0.31–4.2)	1.42 (0.40–5.1)
5 Frequent or long lasting back pain	4.4* (1.00–19)	4.4 (0.97–20)	4.1 (0.92–18)
6 Low-back pain	2.44 (0.84–7.1)	2.5 (0.85–7.6)	3.6* (1.21–11)
7 Frequent or long lasting low-back pain	5.4* (1.02–29)	5.7* (1.04–31)	4.3 (0.79–24)
8 Has had a prolapsed disc	4.0 (0.63–25)	5.3 (0.81–34)	6.8* (1.05–44)

* $P < 0.05$ (one-sided)

Discussion

In Table 6 the prevalence of (low)back pain observed in the present study is compared to that in 11 other studies of tractor drivers. The different methods of data acquisition and the different age distributions of the study populations make it difficult to compare these prevalences. Only Schulze and Polster [34] used a reference group not exposed to vibration (agricultural workers, mean age 38 years); this reference group had more back pain than the tractor drivers. In contrast with the results of Schulze and Polster [34], the present study shows an increased prevalence of back pain in tractor drivers compared to the reference group not exposed to vibration. In agreement with the data of Rosegger and Rosegger [29] and Seidel and Tröster [35], but in disagreement with the results of Jürgens et al. [18], the prevalence of back pain increases with the number of driving years, although this increase is not statistically significant in all analyses. The present study also shows that health-based selection is an important factor. In the present study bias by this selection was partially prevented by studying workers employed 11 years before the time of the study. In the other studies health-based selection might have influenced the results more.

This study examines prevalence at the end of follow-up and not incidence of back pain. The implicit assumption made using this design is that damage by vibration, once present, will continue to cause complaints. When repair mechanisms or pain-reducing adaptions exist, the effect of vibration will be underestimated in this design and the observed dose-response relation will be distorted. However, the results do not suggest such a distortion very much.

The response in this study was 79%. We used sick-leave data to explore the possible influence of the non-response. The rate ratio of a first back-related long-term sick leave for tractor drivers versus referents is 1.4 for respondents and 1.5 for non-respondents. This suggests that the effects of tractor driving on back pain might be slightly underestimated due to the non-response.

The increase of the prevalence of back pain with the number of driving years and accumulated vibration dose suggests that back pain is caused by tractor driving. The absence of an association between vibration dose and the more severe types of back pain might be due to selection. Workers with severe back trouble may have stopped

Table 6. Prevalences of low-back pain found in studies on tractor drivers

Year of publication	Complaint	No. of tractor drivers	Mean age	Prevalence %	Source
1960	Back pain	310	26	29.9	Rosegger and Rosegger [29]
1966	Low-back pain	± 400	?	36	Kübik [23]
1970	Back pain	60	34	42	Seidel and Tröster [35]
1972	Back pain, 1961	211	17	20.4	Dupuis and Christ [8]
1972	Back pain, 1971	106	28	56.5	Dupuis and Christ [8]
1966	Back pain	13000	?	43	Zimmerman: cited by Dupuis and Christ [8]
1975	Back pain	561	35	61	Köhl [22]
1979	Back pain	103	39	24	Schultze and Polster [34]
1982	Back pain, sometimes, often or always	281	41	75.5	Sjøflot [37]
1982	Back pain, often or always			36.1	Sjøflot [37]
1984	Back pain	521	39	31.3	Jürgens [18]
1984	Low-back pain	50	44	48	Cabanas Espero and Gil Ribes [7]
1986	Low-back pain	85	43	47	Perleau et al. [27]
1988	Back pain	450	52	38.4	This study
1988	Low-back pain			31.3	This study

working on tractors, and therefore have stopped accumulating vibration dose or driving years. This causes the dose-effect relationship to dissolve.

If vibration causes the higher prevalence of back pain in drivers, an association between the equivalent vibration magnitude and the prevalence of back pain is expected. Such an association was not observed. However, the validity of the equivalent vibration magnitude as used in this study can be questioned in several ways.

Firstly, vibration magnitude as used here might not represent the actual harmful entity. The concept is not based on long-term health damage but stems from experiments on all sorts of short-term effects. Secondly, the estimate of the vibration magnitude is based on measurements in a limited number of situations of vehicles used in 1985, while most exposure took place in earlier years on smaller tractors with less comfortable seats, diagonal tyres, less power, driving at lower speeds, etc. Thirdly, the vibration magnitude of a vehicle depends on the type of soil or surface that is driven on, the state of maintenance of the vehicle, the style and velocity of driving, the type of tyres, the type of seat, etc. The vibration magnitude of one type of vehicle will therefore show considerable variation; thus the vibration magnitude will be subjected to considerable misclassification.

The lack of association between the vibration magnitude and back pain is most likely due to these inaccuracies. Because of this no extensive evaluation of the vibration dose used in this study was possible. Nevertheless, the results show that the vibration dose measure performs slightly better as a measure of exposure than the number of driving years.

In the same study population the long-term sickness absenteeism ($\geqslant 28$ d) was also investigated [4]. The incidence of a long-term period of sickness absence because of a back disorder was 50% higher in tractor drivers who had received a vibration dose of more than 2.5 years m^2/s^4 than in workers with almost no exposure. Although this difference was not seen when analysing the workers of the largest company separately, it supports the results observed in the present study. A high incidence rate ratio was observed for long-term sickness absenteeism of disorders of the intervertebral discs (including prolapsed lumbar disc). This agrees with the increased risk of self-reported prolapsed lumbar discs observed in this study. In the present study the existence of back pain, as stated in the questionnaire, is seen to exist in lower exposure categories than in the study of long-term sickness absenteeism. This is not surprising, as symptoms of ill health may develop long before they result in absenteeism.

Whether the difference in back disorders and back pain observed in both studies should be contributed to exposure to vibration or to other factors connected with driving cannot be inferred from this study. Tractor driving also involves, in addition to exposure to whole-body vibration, prolonged sitting in a fixed and often poor posture and frequent twisting of the spine when looking backwards.

The epidemiological data on sitting as a risk factor for back pain are conflicting, possibly because both workers who sit for most of the day and workers who sit very little, have a higher prevalence of back pain [24]. Sitting is often said to harm the spine due to a higher intradiscal pressure and compressive stress on the annulus when sitting than when standing [28]. However, Adam and Hutton [1] have pointed out that the stress on the most vulnerable part of the annulus (the posterior part) and on the apophyseal joints is reduced. The importance of prolonged sitting as a cause of back pain therefore is still questionable.

Kelsey et al. [21] showed that twisting alone did not present a risk factor for prolapsed lumbar discs, but that twisting while lifting did.

Sandover and Dupuis [33] estimated that $6\,m/s^2$ r.m.s. harmonic vibration may lead to fatigue-induced failure of the annular fibres. In our measurements peak values of 8 to $13\,m/s^2$ were observed in tractors driving on asphalt roads. These peak values are the maximum peak values within a 10-min period, whereas the calculations of Sandover and Dupuis [33] are based on a 5 Hz vibration containing 3000 peaks in a 10-min period. Although the calculations of Sandover are based on biomechanical data that contain many shortcomings and some of the assumptions can be questioned [36], these calculations suggest that vibration-induced fatigue failure of spinal structures is possible by the actual occupational exposure in our study.

From the biomechanical and epidemiological data discussed we conclude that the excess of back pain, suffered by the tractor drivers, is likely to be partly due to the whole-body vibration and shocks to which tractor drivers are exposed. The twisting of the spine and the static posture may also have contributed to the development of this back pain.

Acknowledgements. The study was funded by the Dutch Ministry of Social Services and Employment.

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