Journal of Sound and Vibration (2002) **253**(1), 21–29
doi:10.1006/jsvi.2001.4247, available online at http://www.idealibrary.com on IDEAL®

MUSCULOSKELETAL SYMPTOMS AMONG DRIVERS OF ALL-TERRAIN VEHICLES

B. Rehn, I. A. Bergdahl, C. Ahlgren, C. From and B. Järvholm

Occupational Medicine, Department of Public Health and Clinical Medicine, Umeå University, SE-901 85, Umeå, Sweden. E-mail: borje.rehn@niwl.se

R. Lundström

Occupational Medicine, Department of Public Health and Clinical Medicine, Umeå University, SE-901 85, Umeå, Sweden; and National Institute for Working Life, Technical Risk Factors, Umeå Sweden

T. Nilsson

Department of Occupational and Environmental Medicine, Sundsvall, Sweden

and

G. Sundelin

Occupational Medicine, Department of Public Health and Clinical Medicine, Umeå University, SE-901 85, Umeå, Sweden; and Department of Community Medicine and Rehabilitation, Umeå University, Umeå, Sweden

(*Accepted* 19*th October* 2001)

The aim of this cross-sectional study was to characterize the risk of experiencing musculoskeletal symptoms in the region of the neck, shoulders and upper and lower back for professional drivers of various categories of all-terrain vehicles and to assess the association between symptoms and duration of exposure to whole-body vibration (WBV) and shock from driving all-terrain vehicles. The study group consisted of 215 drivers of forest machines, 137 drivers of snowmobiles and 79 drivers of snowgroomers and a control group of 167 men randomly selected from the general population. The subjects were all from one of the four most northern counties in Sweden and they were all men. Musculoskeletal symptoms were assessed by use of a standardized questionnaire. In addition, the questionnaire held items about the driving time with all-terrain vehicles and a subjective estimation of exposure to unpleasant movements (shock, jolt, irregular sway). The job strain was measured according to Karasek's demands/control model. The prevalence ratios were adjusted for age, smoking and job strain. Among drivers, significantly increased prevalence ratios within the range of 1·5–2·9 were revealed for symptoms from the neck–shoulder and thoracic regions during the previous year. None of the driver categories had a statistically significantly increased risk of low back pain. Forest vehicles were those most reported to cause unpleasant movements. In conclusion, drivers of all-terrain vehicles exhibit an increased risk of symptoms of musculoskeletal disorders in the neck–shoulder and thoracic regions. The increased risk is suggested to be related to physical factors such as exposure to whole-body vibration (WBV) and shock, static overload or extreme body postures. However, since symptoms of low back pain were not significantly increased, it appears that factors other than WBV would explain the occurrence of symptoms in the group of all-terrain drivers.

0022-460X/02/$35.00

1. INTRODUCTION

At present, there are approximately 20 000 all-terrain vehicles such as forest machines, snowgroomers, snowmobiles, snowcats, two-wheeled motorcycles and three- or four-wheeled motorcycles used professionally in Sweden. The workers are forest workers, ski slope workers, military personnel, policemen, workers in the energy industry and reindeer herdsmen. Compared to other earth-moving vehicles, all-terrain vehicles can be characterized as bumpy when driving on irregular off-road surfaces.

Drivers of all-terrain vehicles may be exposed to whole-body vibration (WBV), physical load and stress. The magnitude of exposure to WBV is a result of several combined factors such as operating technique, vehicle type, terrain type, tyres, cabin and seat suspension [1]. WBV is transmitted from the seat, the backrest and the foot support in a vehicle [2] and can have an adverse health effect on the musculoskeletal system (e.g., references [3, 4]). A relation between exposure to WBV and low back pain has been found in several studies (e.g., references [4, 5]) but the relationship is more uncertain concerning other body regions [6, 7]. Several studies show that a large number of accidents occur in modern all-terrain vehicles during repair or service but also due to alcohol use, rider inexperience and inattention and excessive speed (e.g., references [8, 9]). There are, however, only few epidemiological studies on musculoskeletal symptoms in drivers of all-terrain vehicles focusing on effects of WBV, shock or other types of physical load [10–12].

The aim of this cross-sectional study was to characterize the prevalence of symptoms of musculoskeletal disorders in the neck, shoulders and upper and lower back among drivers of all-terrain vehicles. Because psycho-social factors also may influence the occurrence of musculoskeletal symptoms, the job strain was also investigated.

2. METHODS

2.1. STUDY DESIGN

In 1999, a self-administered questionnaire was sent to 875 registered drivers of all-terrain vehicles in the four most northern counties in Sweden. All 394 workers registered as drivers of forest machines in the region were included together with 304 workers randomly selected from jobs known to comprise work with snowmobile driving and all 177 workers listed as drivers of snowgroomers. Since the vehicles are mostly operated by men, only men were included in this study. The same questionnaire was sent to 800 male controls. The controls were a random sample from the general population in the same region, with an age restriction of 20–60 years. Two reminders of the questionnaire were sent to those who failed to answer by a specific time. In total, the response rates were 75·4, 73·0, 78·5, 65·5% for the drivers of forest machines, snowmobiles, snowgroomers and control group respectively. No information was collected about the non-responders. In the analysis, only drivers who had worked professionally with all-terrain vehicles for at least 3 years were included. Several controls had used all-terrain vehicles, especially snowmobiles. In the present analysis only respondents with no more than 1 year of exposure to driving of any other type of all-terrain vehicle were included. There were 215 drivers of forest machines, 137 drivers of snowmobiles, 79 drivers of snowgroomers and 167 controls included in the final data analysis.

2.2. QUESTIONNAIRE

Each individual estimated their exposure duration time in total number of hours of driving a terrain vehicle. Based on description of job titles and work duties, the controls' occupations were classified according to the Swedish standard for classification of

TABLE 1

Number of subjects (*n*), *age*, *cumulative exposure duration during all years* (*lifetime*) *and during the previous year in hours* (*h*) *for drivers of all-terrain vehicles and controls*, *mean*, *range. Smoking habits and the percentage of subjects with jobs exposed to WBV or ergonomic risk factors* (*job exposure*) *are also given*

	Driver categories and controls			
	Forest machine	Snowmobile	Snowgroomer	Controls
n	215	137	79	167
Age	49 (26–69)	44 (22–62)	42 (23–60)	44 (22–62)
Cumulative exp. duration (*h*)				
Lifetime	41 865	4898	8980	0·6
(range)	(4330–135 860)	(80–39 080)	(684–36 120)	(0–64)
Previous year	1711	298	635	1·3
(range)	(0–3996)	(0–1600)	(32–1540)	(0–96)
Smoking (%)				
Current user	13	11	10	14
Never used	53	68	62	64
Used earlier	30	18	25	20
Unknown	4	3	3	2
Job exposure (%)				
Current job	100	100	100	29
Previous job	82	53	57	30

occupations, which is based on the international standard ISCO-88. If the current employment duration was less than one year, the previous job was also classified. The same procedure was undertaken for the drivers' previous employment. After classification the jobs were rated as (1) exposed to WBV or ergonomic risk factors and (2) not exposed. The respondents also gave details about their smoking habits (Table 1).

Subjective symptoms were asked for using a Swedish version of the general Nordic Questionnaire [13], which includes items with dichotomized response alternatives regarding symptoms (ache, pain or discomfort) originating from different regions of the musculoskeletal system at some point during the previous 12 months. Those who reported symptoms also answered additional items on the consequences of each symptom for their working capacity, such as not being able to manage daily work at some point during the past 12 months (severe symptoms). Further, the questionnaire comprised items on whether the workers had symptoms they believed were associated to operating all-terrain vehicles. They also gave their subjective estimation of exposure to unpleasant movements (shock, jolt, irregular sway). The job strain was measured according to Karasek's demands/control model [14]. This was achieved through a Swedish version of the model, which was included in the questionnaire [15]. The version includes five items about psychological job demands and six items about control over work. All items have response categories that are scored on a categorical scale of 1–4, ranging from "never" to "almost always". Job strain was computed as the ratio between the weighted sum scores of psychological demands and control for each subject.

2.3. STATISTICAL ANALYSIS

A generalized log-linear model was utilized to determine the prevalence rate ratio (PRR) of musculoskeletal symptoms adjusted for age, smoking and job strain. Significance refers to

the 95% confidence interval, not including 1·0. *P*-values for trends were formed by cumulative exposure duration all years. Job strain was compared between groups using one-way ANOVA, followed by post hoc multiple comparisons.

3. RESULTS

The prevalence of symptoms was larger in the neck, shoulder and thoracic regions in drivers of all-terrain vehicles compared to the control group. Compared to controls, the driver groups also showed increased prevalence of severe symptoms in the neck, shoulder and lower back.

The prevalence ratios, even when adjusted for age, smoking and job strain, were increased for the neck, shoulder and thoracic regions for the drivers of all-terrain vehicles. There were no significantly increased risks of low back pain for any of the driver categories. There were statistically significant associations with age and job strain for forest machine operators concerning shoulder and lower back and the associations for these body regions was included in the statistical model. No other associations were found (Table 2).

In general, the exposure–response relation between symptoms of musculoskeletal disorders and duration of operating an all-terrain vehicle was weak. The only significant trend was established in the group of snowmobile drivers for symptoms in the upper back (Table 3).

The drivers reported that driving an all-terrain vehicle negatively influenced their health. Between 35 and 48% of the driving groups reported that present (previous 3 months) and earlier episodes of illness and disorders were related to driving an all-terrain vehicle.

TABLE 2

Prevalence, given as percentages of musculoskeletal symptoms [*severe symptoms in brackets*] *for neck, shoulders, upper and lower back during the previous* 12 *months among the drivers of terrain vehicles and control group. Prevalence rate ratios* (*PRR*) *and* 95% *confidence intervals* (*CI*) *for symptoms the previous* 12 *months are compared to the control group*

	Drivers of all-terrain vehicles and control group			
Anatomical region	Forest machine ($n = 215$)	Snowmobile ($n = 137$)	Snowgroomer ($n = 79$)	Control group ($n = 167$)
Neck				
Prevalence	61 [10]	48 [9]	58 [14]	27 [5]
PRR(CI)†	2·3 (1·7–2·9)	1·8 (1·3–2·4)	2·2 (1·6–2·9)	
PRR(CI)‡	1·9 (1·4–2·5)	1·9 (1·4–2·5)	2·2 (1·6–2·0)	
Shoulders				
Prevalence	56 [9]	44 [7]	52 [13]	29 [4]
PRR(CI)†	1·9 (1·5–2·5)	1·6 (1·1–2·1)	1·8 (1·3–2·5)	
PRR(CI)‡	1·6 (1·2–2·1)	1·5 (1·2–2·1)	1·8 (1·3–2·4)	
Upper back				
Prevalence	20 [4]	23 [7]	23 [5]	8 [4]
PRR(CI)†	2·4 (1·4–4·2)	2·8 (1·6–5·0)	2·7 (1·4–5·2)	
PRR(CI)‡	2·2 (1·2–3·9)	2·9 (1·6–5·2)	2·7 (1·4–1·9)	
Lower back				
Prevalence	47 [13]	53 [17]	52 [14]	42 [8]
PRR(CI)†	1·1 (0·9–1·4)	1·3 (0·9–1·6)	1·2 (0·9–1·6)	
PRR(CI)‡	0·9 (0·8–1·2)	1·3 (1·0–1·6)	1·2 (0·9–1·6)	

†Crude value.
‡Adjusted for age, smoking and job strain.

TABLE 3

Prevalence rate ratios, adjusted for age, smoking and job strain, for symptoms from the neck, shoulders, upper and lower back in relation to cumulative exposure duration in hours during all years (h). Stratification using four exposure bands, arranged in approximate quartiles of the number of respective driver subjects. P-values for trends illustrating the exposure–response relationship

Driver category exposure duration	*n*	Neck	Shoulders	Upper back	Lower back
Forest machine	215				
⩽ 24 000 h	54	1·7	1·3	1·5	1·2
24 001–36 000 h	54	1·9	1·6	2·9	1·1
36 001–58 000 h	53	2·4	1·3	1·3	0·9
> 58 000 h	54	2·2	1·3	1·9	1·1
p-value for trend		0·308	0·626	0·453	0·789
Snowmobile	137				
⩽ 1000 h	33	1·3	1·2	2·2	1·3
1001–2500 h	38	2·1	1·6	1·9	1·2
2501–5600 h	32	1·6	1·5	3·4	1·2
> 5600 h	34	2·4	1·8	3·9	1·4
p-value for trend		1·000	0·554	0·038	1·000
Snowgroomer	79				
⩽ 4000 h	19	1·8	1·2	2·1	1·3
4001–7800 h	21	2·3	1·7	2·1	1·4
7801–12 200 h	19	2·2	1·7	2·2	1·5
> 12 200 h	20	1·8	1·9	4·2	1·4
p-value for trend		0·996	0·259	0·186	0·609

Experience of unpleasant movements at some point per hour or more was most common among forest machine drivers (40%) compared to 14 and 16% among snowmobile and snowgroomer drivers respectively.

The job strain was found to be significantly higher for forest machine drivers, compared to the control group ($p < 0{\cdot}001$). Snowmobile drivers and snowgroomer drivers had no significantly altered job strain compared to the control group.

4. DISCUSSION

The outcomes show an increased risk of neck, shoulder and thoracic symptoms for drivers of the various all-terrain vehicles in this study. There were, however, no increased risks of low back pain. The exposure–response relation between symptoms of musculoskeletal disorders and duration of driving a terrain vehicle was weak.

4.1. CONSISTENCY WITH OTHER STUDIES

4.1.1. *Neck/shoulder*

The findings of an increased risk of neck/shoulder symptoms for the group of forest machine operators are in accordance with some previous findings. The most recent study

reported an odds ratio of 3·37 for neck/shoulder disorders among forest machine operators compared to administrative personnel [10]. An early Swedish investigation reported that only one out of five drivers of forest machines between the year 1974 and 1978 had symptoms mostly from the neck, but the drivers were not compared to any control group [16]. Another Swedish study revealed a 12 months prevalence of 65% for symptoms in the neck and shoulders for drivers of forest machines [12]. No distinction between drivers of different categories of forest vehicles was found. This study exhibited a prevalence of 61% for neck symptoms among drivers of forest machines and the risk was significantly increased compared to the control group. Another study on mechanized logging operators indicated that prevalence of "overload syndrome", characterized by complaints and injuries to the neck, arms and cervical spine was around 50% in a study group of 1174 subjects [11]. This study had, however, no external control group but compared prevalence of symptoms in relation to age and years of work as a machine operator.

4.1.2. *Upper back*

This study has indicated an increased risk of symptoms from thoracic region irrespective of type of all-terrain vehicle. This section of the spine has rarely been reported as susceptible for exposure to WBV. One investigation of forest employees reported a 12 months prevalence of complaints to around 8% in the thoracic region [11]. The results from that study did not distinguish between machine operators and other employment categories, which could explain the low prevalence in relation to our findings.

4.1.3. *Lower back*

Only one previous study has compared the risk of low back pain between forest machine operators and an external control group [10]. That study showed an increased risk of low back pain among a subgroup of forest machine drivers that also exhibited large psychological demands according to Karasek's demand/control questionnaire. The increased risk was shown in comparison to a control group of administrative workers. There was no increased risk for low back pain among the operators with medium and low psychological demands. Jonsson and co-workers performed a study on forest machine operators who exhibited a 49% prevalence of low back pain [12]. That study compared the prevalence among drivers of different types of forest vehicles but not with an external control group. The prevalence of low back symptoms among the general population in the current study is slightly lower (42%).

The present results do not indicate any increased risk of low back pain among drivers of all-terrain vehicles. Other authors have discussed spinal injuries in the neck and back among drivers of snowmobiles [17, 18] and proposed that shock impulses should be considered when analyzing the reason for spinal injuries among drivers of snowmobiles. A study by Nayha *et al*. showed that drivers of snowmobiles (reindeer herders) reported a prevalence of back complaints of 42% [19]. No external control group was included in that study but revealed an increased risk of symptoms in the locomotive organs for those who had a large exposure time. Research on musculoskeletal health and spinal disorders in relation to long term exposure for ergonomic load among drivers of snowgroomers is lacking.

4.2. CAUSATIVE FACTORS

Exposure to shock and vibration that should occur in both horizontal and vertical directions for all-terrain vehicles may be of particular importance, in developing symptoms

of musculoskeletal disorders, as the worker has to have tensed muscles to maintain balance during exposure and to be able to handle the lever at the same time. Also a sustained elevated arm position could cause symptoms in the neck and shoulder due to static overload of the muscles. Drivers of forest machines have restricted visibility partly due to the frames of the windows obstructing their view [20]. Drivers of snowgroomers may also have this problem. This can influence head postures and force the neck into strenuous and extreme positions outside the optimal range of motion. The region of neck and shoulders is often considered as one functional entity by virtue of the anatomical proximity and because musculoskeletal disorders in the neck often include symptoms in the shoulder regions and *vice versa*. The two regions were distinguished by means of a sketched figure carried in the questionnaire, with marked anatomical regions. There are anatomical differences, in that the thoracic part has more synovial joints in relation to other parts of the spinal column. Typically, the joint movements in the thoracic spine are relatively small due to the anatomical construction with links to the nearby protecting rib cage preventing large range of motions. The steering passive units of the columna and the zygopophysial joints are oriented differently compared to the neck, which may alter the susceptibility from WBV and shock. Symptoms from the thoracic region might hypothetically originate from joint structures.

Previous studies of the effects of WBV have often included drivers of heavy vehicles, e.g., fork lift trucks and trucks, and have consistently found an increased risk of low back pain [21–23]. There are currently no WBV exposure data for all-terrain vehicles but such measurements are underway. However, it seems reasonable that shocks caused by uneven terrain surfaces may be transmitted to the drivers of off-road vehicles. Such vibration may have a quite different character with respect to magnitude, direction, frequency content, and prevalence of shocks compared to vibration in other vehicles. Our findings are also in contrast to our hypothesis that shock/vibration in all-terrain vehicles should cause an increased risk of low back pain. The group that reported most frequent occurrence of unpleasant movements (shock, jolt, irregular sway), i.e., the forest machine drivers, had no increased risk of low back pain.

4.3. ASPECTS OF VALIDITY

This is a cross-sectional study, which may have underestimated the risk of serious musculoskeletal symptoms, as such problems may have caused the individual to change job. The so-called "healthy worker effect" may be the cause for the weak exposure–response relationship. We have not measured the intensity of exposure in the different terrain vehicles in this study and the exposure may differ within the groups, which is why the exposure–response relationship was not determined. The exposure will have a complex variation and interaction. Since the exclusion criteria in this study would be most relevant for cumulative effects of operating a terrain vehicle, but not for acute ones, a parallel analysis was performed which included all potential subjects irrespective of driving time. The results exhibited relative ratios (PRR) of 1·7 (CI; 1·4–2·1) for symptoms from the neck and 1·1 (CI; 0·9–1·3) for the lower back for drivers of forest machines and 1·2 (CI; 1·1-1·5) for the lower back for drivers of snowmobiles. These results do not differ substantially from the results obtained using the present inclusion criteria. No information was collected about other physical risk factors besides from unpleasant movements, but the exposure duration in the various vehicles indicates, apart from exposure to WBV, a working environment with prolonged static seating and repetitious armwork. We did not ask about occurrence of trauma in the past, which could have affected the outcome. The purpose of this study was to

investigate whether a larger cumulative exposure duration from operating an all-terrain vehicle is associated with an increased risk of musculoskeletal symptoms. The awareness of a risk may have influenced the way the worker answered to the questionnaire. However, there were no economical gains from reporting a symptom in this study. Furthermore, it seems unlikely that they should have reported a high prevalence of symptoms from the neck/shoulder and not from the low back if awareness of risk could have influenced the answers. We also asked about symptoms from the knees (data not reported here) and there was no difference between any of the groups (the prevalence varied between 27 and 32%). Thus we consider that a biased reporting of symptoms due to awareness of risk is unlikely.

5. CONCLUSION

The results indicate that drivers of all-terrain vehicles have an increased risk of symptoms from the neck, shoulder and thoracic regions. In contrast, there was no increased risk of low back pain. This indicates that other factors than WBV may be an important factor in determining the risk of symptoms in the neck, shoulder and thoracic regions.

ACKNOWLEDGMENT

The National Institute for Working Life, Technical Risk Factors, Sweden, provided financial support for this work.

REFERENCES

1. L. TABELL 2000 in 8*th European Conference of ISTVS Umeå June* 18–22, *International Society for Terrain–Vehicle Systems*, 181–188. A review of whole-body vibrations in forest machines.
2. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION 1997 *ISO* 2631-1. Mechanical vibration and shock—Evaluation of human exposure to whole-body vibration. Part 1: general requirements.
3. B.-O. WIKSTRÖM, A. KJELLBERG and U. LANDSTRÖM 1994 *International Journal of Industrial Ergonomics* **14**, 273–292. Health effects of long-term occupational exposure to whole-body vibration: a review.
4. M. BOVENZI and C. T. J. HULSHOF 1998 *Journal of Sound and Vibration* **215**, 595–611. An updated review of epidemiologic studies on the relationship between exposure to whole-body vibration and low back pain.
5. C. HULSHOF and V. B. V. ZANTEN 1987 *International Archives of Occupational and Environmental Health* **59**, 205–220. Whole-body vibration and low-back pain—A review of epidemiological studies.
6. G. ARIENS, W. VAN MECHELEN, P. M. BONGERS, M. BOUTER and G. VAN DER WAL 2000 *Scandinavian Journal of Work, Environment and Health* **26**, 7–19. Physical risk factors for neck pain.
7. M. BOVENZI and C. T. J. HULSHOF 1999 *International Archives of Occupational and Environmental Health* **72**, 351–365. An updated review of epidemiologic studies on the relationship between exposure to whole-body vibration and low back pain (1986–1997).
8. D. GANOS, S. CRADY, S. POORTENGA, G. HOFFMAN and R. MANN 1998 *American Surgeon* **54**, 429–433. Trauma associated with three- and four-wheeled all-terrain vehicles: is the four-wheeler an unrecognized health hazard?
9. S. M. SMITH and J. P. MIDDAUGH 1986 *The Journal of the American Medical Association* **255**, 2454–2458. Injuries associated with three-wheeled, all-terrain vehicles, Alaska, 1983 and 1984.
10. K. B. HAGEN, P. MAGNUS and K. VETLESEN 1998 *Ergonomics* **41**, 1510–1518. Neck/shoulder and low-back disorders in the forestry industry: relationship to work tasks and perceived psychosocial job stress.

11. S.-Å. AXELSSON and B. PONTÉN 1990 *International Journal of Industrial Ergonomics* **5**, 267–273. New ergonomic problems in mechanized logging operations.
12. B. JONSSON, C. BRULIN, B. E. ERICSSON and C. HAMMAR 1983 *Investigation Report No*. 1983:13, Research Division, Industrial Welfare Government. Besvär från rörelseorganen bland skogsmaskinförare (in Swedish). Musculoskeletal complaints among forestry machine drivers (summary in English).
13. I. KUORINKA, B. JONSSON, Å. KILBOM, H. VINTERBERG, F. BIERING-SORENSEN, G. ANDERSSON and K. JÖRGENSEN 1987 *Applied Ergonomics* **18**, 233–237. Standardised Nordic Questionnaires for the analysis of musculoskeletal symptoms.
14. R. A. KARASEK 1979 *Administrative Science Quarterly* **24**, 285–311. Job demands, job decision latitude, and mental strain: implications for job redesign.
15. T. THEORELL, A. PERSKI, T. ÅKERSTEDT, F. SIGALA, G. AHLBERG-HULTÉN, J. SVENSSON and P. ENEROTH 1988 *Scandinavian Journal of Work, Environment and Health* **14**, 189–196. Changes in job strain in relation to changes in physiological state.
16. C. HAMMAR, I. ERIKSSON, U. SUNDBÄCK and B. TINGVALL 1980 *Technical Report No*. 1980:45 *T. Luleå College*. Helkroppsvibrationer i skogsmaskiner-skördare (in Swedish).
17. B. TOSTRUP 1994 *Arctic Medical* **53** (Suppl. 3), 45–54. Ergonomic aspects on snowmobile driving.
18. H. ANTTONEN and J. NISKANEN 1994 *Arctic Medical Research* **53**, 24–28. Whole body vibration and the snowmobile.
19. S. NAYHA, H. ANTTONEN and J. HASSI 1994 *Arctic Medical Research* **53**, 41–44. Snowmobile driving and symptoms of the locomotive organs.
20. J. EKLUND, P. ODENRICK, S. ZETTERGREN and H. JOHANSSON 1994 *Ergonomics* **37**, 623–639. Head posture measurements among work vehicle drivers and implications for work and workplace design.
21. H. RIIHIMÄKI, S. TOLA, T. VIDEMAN and K. HÄNNINEN 1989 *Spine* **14**, 204–209. Low-back pain and occupation. A cross-sectional questionnaire study of men in machine operating, dynamic physical work, and sedentary work.
22. H. C. BOSHUIZEN, P. M. BONGERS and C. T. J. HULSHOF 1992 *Spine* **17**, 59–65. Self-reported back pain in fork-lift truck and freight-container tractor drivers exposed to whole-body vibration.
23. H. C. BOSHUIZEN, P. M. BONGERS and C. T. J. HULSHOF 1990 *International Archives of Occupational and Environmental Health* **62**, 117–122. Self-reported back pain in tractor drivers exposed to whole-body vibration.