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City bus driving and low back pain: A study of the exposures to posture demands, manual materials handling and whole-body vibration

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Abstract

A cross-sectional study was conducted to investigate worker exposure to posture demands, manual materials handling (MMH) and whole body vibration as risks for low back pain (LBP). Using validated questionnaire, information about driving experience, driving (sitting) posture MMH, and health history was obtained from 80 city bus drivers. Twelve drivers were observed during their service route driving (at least one complete round trip) and vibration measurements were obtained at the seat and according to the recommendations of ISO 2631 (1997), for three models of bus (a mini-bus, a single-decker bus, a double-decker bus). The results showed that city bus drivers spend about 60% of the daily work time actually driving, often with the torso straight or unsupported, perform occasional and light MMH, and experience discomforting shock/jerking vibration events. Transient and mild LBP (not likely to interfere with work or customary levels of activity) was found to be prevalent among the drivers and a need for ergonomic evaluation of the drivers' seat was suggested.
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Keywords: Bus; Drivers; Exposure; Vibration; Posture; MMH; Low back pain

1. Introduction

Low back pain (LBP) is a major health issue affecting millions of people world wide (Pope et al., 2002a). It is a problem affecting not only those who suffer from it directly but also society at large. Indeed, LBP has been reported to be the main cause of sick leave in the developing world (Pope and Novotny, 1993). However, despite the large volume of work done to understand the aetiology of LBP, a thorough understanding of the causes remains elusive (Leboeuf-Yde et al., 1997).

Occupational drivers such as bus drivers are one group of workers that have been reported widely as being at an increased risk for LBP. For them, there has been much research work as epidemiological studies and as studies investigating the underlying causes/risk factors involved (Rosegger and Rosegger, 1960; Bovenzi and Betta, 1994; Costa et al., 2001; Jin et al., 2000; Magnusson et al., 1996; Kumar et al., 1999; Keyserling, 2000; Mansfield and Marshall, 2001). Several factors have been identified as being important occupational stressors contributing to the onset and development of back trouble but the two main ones are postural stress and long-term exposure to whole body vibration (WBV). Manual materials handling (MMH) is thought to compound the risks from posture and WBV when it is also performed. Whilst there is general agreement regarding the association of the three factors with prevalence of LBP among drivers, the relative importance of each is yet not well defined. In these regards, clear appreciation of the exposures to the three risk factors for different driving groups is necessary as a minimum requirement, more so if safety and health is to be effectively encouraged (Hannerz and Tuchsen, 2001).

The present study was conducted to investigate the typical exposures of city bus drivers to driving posture demands, MMH and vibration as well as the prevalence and nature of LBP. Possible strategies for controlling the

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risks for LBP are also discussed. Given the nature of their work and their potential for back problems, bus drivers presented a particularly interesting group for study, more so when they have been studied less extensively than other categories of professional drivers.

2. Subjects and methods

2.1. Study design

The study comprised of two parts, self-assessments by a questionnaire and systematic (direct) observation (including measurements). Persons (male and female) who drive buses and/or coaches occupationally represented the source population. Inclusion criteria for the questionnaire assessments was a minimum of 1 year in present job or total of 5 years continuous bus driving experience, while the volunteers included in the observation study constituted a convenience sample of individuals who were willing to be observed. Contact was made by telephone with transport or health and safety management staff of commercial bus companies and adverts were published in newspapers and professional newsmagazines to explain the purpose of the study and to request for volunteers.

2.2. The study group

A sample of 80 drivers employed at one public transport bus company site ($N = 350$) was volunteered for participation. This consisted of all the drivers on off-duty schedule between 11:00 a.m. and 12:00 p.m. of four randomly selected normal workdays (in consultation with the personnel manager). The company's management were informed about the nature of the research prior to its commencement and informed that a summary report would be presented at the end of the study. It could not be established that the sample was representative of the total group of drivers as relevant descriptive (personal characteristics) information for the non-participants could not be obtained by the researchers, but the sample proportions of male and female participants closely approximated those of the entire driver population. Indeed, just over 97% of the driver population were men compared to 95% in the present sample.

Each volunteer was scheduled to attend one of four 40-min seminar meetings (11: 00 a.m.–11: 40 a.m.) during which time, the purpose of the study was explained and copies of the study questionnaire were distributed for completion and immediate return. Participation was voluntary and one person administered the questionnaire at each of the seminar meetings. In all, completed copies of the study questionnaire were received from 68 drivers (85% response ratio), but data for 61 drivers (58 males and three females) that met the inclusion criterion were analysed. These drivers were aged between 19 and 64 years (mean 47.6, standard deviation (SD) (10.41), they weighed 84.9 kg on average, SD 15.72 (range 58.6–129.0 kg) and stood between 154.9 and 192.0 cm in stature (mean 172.9, SD 8.45).

2.3. Questionnaire assessment

Information about LBP (current—pain in immediate past 7 days and previous—pain in the last 12 months), driving experience (sitting) posture and MMH was obtained using a validated questionnaire (Pope et al., 2002b). The questions regarding driving experience were in terms of years of driving and daily driving hours, surface and environment of driving, style of driving and discomfort from different modes of vibration. Those regarding posture were in terms of five different possible configurations of the torso (torso against backrest, torso straight, torso bent, torso twisted, and torso bent and twisted simultaneously) and three possible frequencies of occurrence (never, occasionally, and often). In these respects, driving posture stress was evaluated for each respondent. Firstly, severity scores were allocated to the postures and frequencies of occurrence as follows: torso against backrest—1, torso straight—2, torso bent—3, torso twisted—4, torso bent and twisted simultaneously—5; Never—0, occasionally—1, often—2. Secondly, a posture score was computed as the sum total of posture severity and frequency severity scores. The approach reflects suggestions that stress from sitting posture is minimal when the torso is leaned against a back support in neutral upright position and increased as the position adopted increases in complexity (Wilder et al., 1994; Vergara and Page, 2002). The questions regarding MMH were in terms of the weight of load (light load—< 5 kg, medium load—5–10 kg, heavy load—> 10 kg) and frequency (self reported) in a typical workday, for lifting and pushing tasks, whether handling was done in awkward postures, i.e., with bent torso or with twisted torso (never, occasionally, often) and whether handling was done immediately after driving (never, sometime, often).

2.4. Observation study

Twelve drivers were observed in their assigned duty service route driving over the duration of at least one complete round trip—to and from. The observation times ranged between 1 h 21 min and 1 h 44 min. Firstly, the drivers were observed for their sitting posture (i.e., torso against backrest, torso straight, torso bent, torso twisted, and/or torso bent and twisted simultaneously), which was noted and recorded once in every minute for an accumulated 1-h period. Secondly, the drivers were observed for their style of driving as well as the number and duration of stops made. Thirdly, the types of road surfaces driven on were noted and the duration of time spent travelling on each surface was measured using a stopwatch.

For the respondents to the study questionnaire, the company's transport office records were reviewed to obtain information about their daily service route driving allocations, durations of service route driving and bus models

Table 1
The fractions (%) of service route driving time done with different models of bus

	Models of bus driven									D/W
	1	2	3	4	5	6	7	8	9	
Mean	56.5	24.9	14.3	20.9	5.7	18.9	15.9	18.5	3.3	81.4
SD	22.7	16.3	12.5	22.6	3.9	33.1		14.1		21.0
Max	100.0	87.2	42.5	100.0	16.0	100.0	15.9	36.1	3.3	96.2
Min	12.8	6.3	2.1	2.1	1.7	2.0	15.9	3.6	3.3	8.0
N	43	40	19	20	12	8	1	7	1	45.0 (>60% = 40)

1. Volvo B10BLE Wright Renown single-decker bus.
2. Volvo B10BLE Alexander ALX300 single-decker bus.
3. Volvo B7LA Wright Eclipse Articulated 56 seated single-decker bus.
4. Leyland OlympianAleander R type double-decker bus.
5. Volvo B7TL Alexander ALX400 double-decker bus.
6. Mercedes 709D Alexander AM (23 seats Beaver) mini-bus.
7. Volvo B10 M Plaxton Premiere 3.5 bus.
8. Volvo B6 bus.
9. Plaxton Paramount coach.

N—Number of drivers.
D—Time spent in service route driving during daily duty (considered over a month period).
W—Corresponding total duty time (includes break periods).

driven in a previous 1-month period. Vibration measurements in the three orthogonal axes (*x*-fore and aft, *y*-lateral and *z*-vertical) were carried out during simulated service route driving (not including admission of passengers) for three different models of bus, i.e., the most frequently used models (Table 1) and according to the recommendations of the ISO 2631 (1997) standard. Vibrations from a Leyland Olympian Aleander R Type double Decker bus, a Volvo, B10BLE Wrights Renown single Decker bus, and a Mercedes 709D Alexander AM (23 seats Beaver) mini-bus were measured. The ages of the vehicles varied between 2 years and 10 years since first in service, with the oldest being the double-decker bus and the newest the single-Decker bus.

In all, 9 sets of measurements were taken covering the three vehicles, three working conditions (idling, moving on good asphalt, moving on cobble) and driving along one service route (that considered by the drivers to be the most severe for vibration). Only one driver was involved during the vibration measurement exercise. The vibrations were measured at the driver/seat interface using a tri-axial seat pad accelerometer (Liberty Mutual whole-body vibration meter 2.0), which was placed on the seat below the driver's ischial tuberosities when sitting and connected to a portable field computer packaged in a rugged instrument case. For each set of measurements, the case was securely positioned within the cabin of the vehicle and the recorded accelerations were acquired over a 5-min period. Values for four measures (average linear [weighted root-mean-square] acceleration, peak acceleration, crest factor [ratio of peak to average acceleration] and vibration dose value [VDV]) were determined as well as the fatigue-decreasing proficiency (FDP) allowable exposure (hours and minutes). Sample graphs of the measured vehicular vibrations (frequency-weighted rms values) are shown in Fig. 1.

2.5. Data analysis

Statistical analysis of the data was performed using the statistical package SPSS 11.1 for windows. Continuous data were summarised with the average (mean) as measure of central tendency and the SD as measure of dispersion. The difference between two means were tested by Student's *t*-test. In all tests, $p < 0.05$ was accepted as the minimum for significance.

3. Results

3.1. The exposures

From the questionnaire data, the drivers spent (on average) 7 h and 36 min driving, 1 h and 15 min sitting without vibration and 50 min standing or walking about in the typical workday. From the company's transport office records, it was determined that the drivers' normal daily work lasted 7 h 36 min and ordinarily consisted of two service route driving allocations with at least 30 min break in between, though three and even four route allocations were not uncommon. Over the 1 month review period, the service route driving times of the drivers range from 35 min to 4 h 30 min while their daily duty work times were from 2 h 12 min to 14 h and 38 min. In the longer daily duty work times (>10 h) there was at least one long rest period (> 1 h). Observation of the drivers during service route driving determined that on average, 61.6% of the time was spent driving (actually travelling) and about 5% of the time was spent standing or walking, which occurred during occasional long duration stops (between 8 and 15 min) at main bus terminuses. Thus, in the typical 7 h and 36 min work time, a driver may spend about 4 h and 40 min actually driving, about 2 h and 33 min sitting with the bus

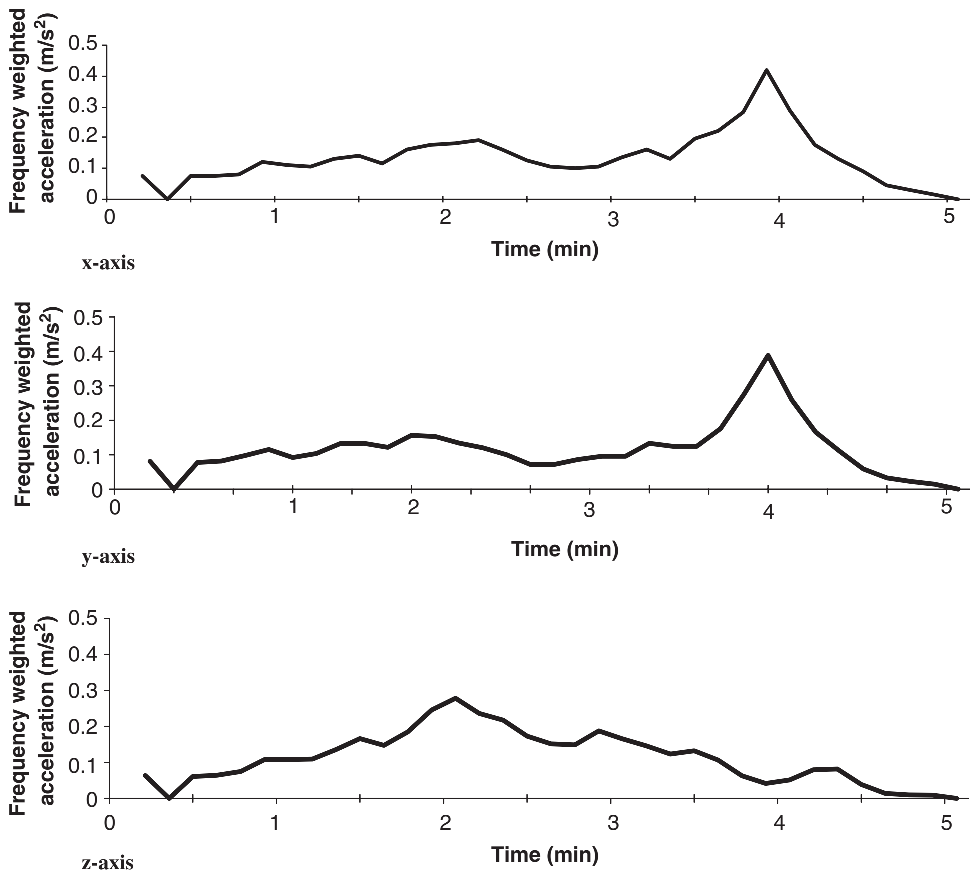

Fig. 1. Sample graphs of the measured vehicular vibrations.

stationary and the engine idling and about 23 min standing or walking about.

3.1.1. Posture and MMH

The questionnaire assessment determined that 23 drivers (37.7%) experienced discomfort from sitting during driving, of which 11 said that they used seats with bad back rest/support, and all but one said they checked the seat settings prior to driving. None of these drivers needed to use a separate back support when driving. Five drivers (8.2%) indicated that the 'torso bent' posture was often adopted during driving, and thirty-five (57.4%) indicated the 'torso against backrest' posture (Fig. 2). Only eight drivers (13.1%) and one driver, respectively, indicated that the 'torso twisted' posture and the 'torso twisted and bent simultaneously' posture were often adopted.

From observation of the drivers during service route driving, the 'torso straight' posture was most often sampled and the 'torso twisted' postures least often sampled. Torso twisting with or without bending was seen adopted when the driver reached across the body to operate the ticket machine with the right hand, or reached back with the left hand to remove items from his jacket (hung on the right side of the drivers cabin back wall). The 'torso bent' posture showed to occur when stationary, at a T-junctions prior to moving into a major road from a minor road. The driver bent (flexed) forward over the steering wheel of the bus to view the side roads and showed to spend between 10 and 20 s in this position before negotiating the road (Fig. 3).

Concerning MMH, the questionnaire data showed that eight drivers (13.1%) performed lifting tasks in their jobs. While, three of the drivers indicated that lifting was occasional, occurring only when wheel chair access ramps needed to be positioned or when elderly passengers needed to be assisted with placing and retrieving their luggage during embarking/disembarking, five said that they lifted only when working on inter-city service routes. In the lifting activities, six drivers indicated that they handled only medium loads, one driver indicated handling light loads and one driver indicated heavy loads (Fig. 4). Five drivers (8.2%) indicated that they lifted loads immediately after driving (of which two reported they did so often) and four reported that they lifted with awkward posture of the torso (which was often done by one driver). Only two drivers (3.3%) indicated they performed pushing tasks, which for one, involved medium loads and for the other heavy loads. On the other hand, observation of the drivers during service route driving determined that apart from carrying their bag of personal belongings on and off the bus at the start and end of a shift, no MMH activities were performed.

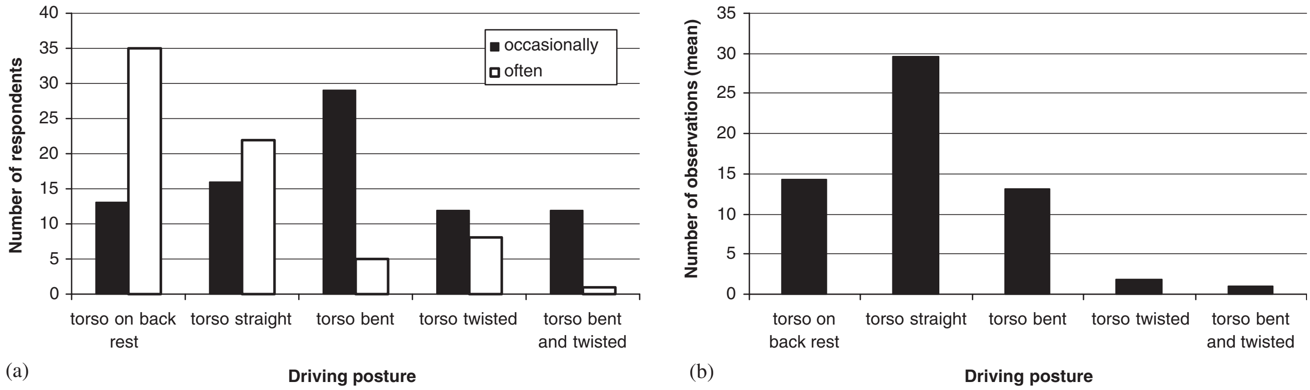

Fig. 2. The summarised data for driving posture: (a) questionnaire assessment ($N = 61$) and (b) observation study ($N = 60$).

Fig. 3. The typical postures adopted during service route driving.

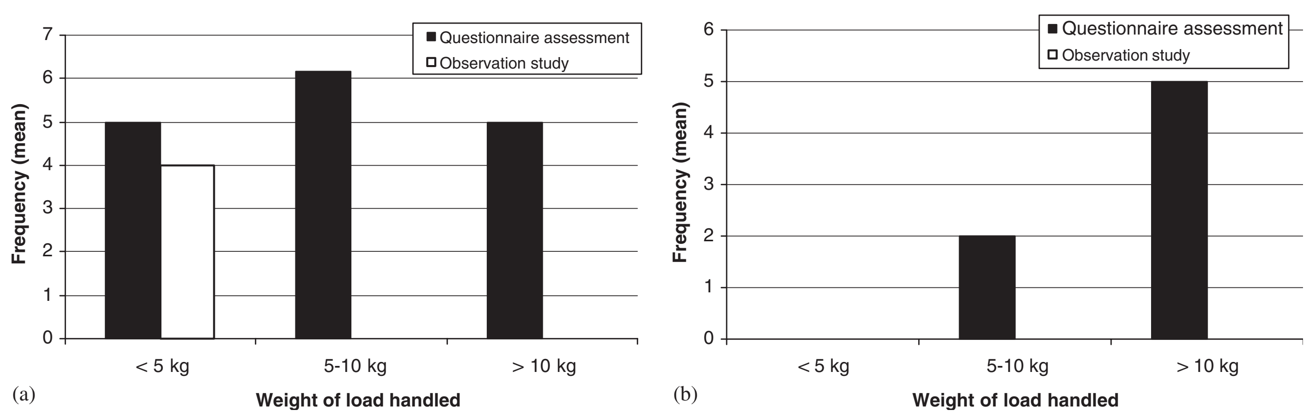

Fig. 4. The summarised data for MMH activities: (a) lifting tasks and (b) pushing tasks.

3.1.2. Vibration

The questionnaire data showed that good asphalt, poor asphalt and cobble were the driving surfaces most frequently traversed, which was often in a city environment (Fig. 5) and the daily driving time on each surface averaged 5 h 22 min, 2 h 36 min and 1 h 48 min respectively. Forty-two drivers (68.8%) indicated discomfort from vibration of any kind, of which 31 indicated discomfort from vertical vibration, 16 indicated discomfort from fore–aft vibration, 15 indicated discomfort from lateral vibration and 23 indicated discomfort from shock and jerking events. Furthermore, 58 drivers said that they drove buses with automatic transmissions and, as can be seen from Fig. 5, most indicated that they adopted a smooth style of driving.

On the other hand, data from the observation study showed that (on average) about 90.8% of the service driving time was spent travelling on asphalt (good and poor), 8% was spent travelling on asphalt roads with speed bumps/cushions, and about 3.8% travelling on cobble (Table 2). It was difficult to separate duration of travel on poor asphalt from duration of travel on good asphalt for each service route, as travel on poor asphalt often was not continuous for an appreciable length of time. Six of the 12 observed service routes showed to include travel over cobble and three to include travel over speed bumps/

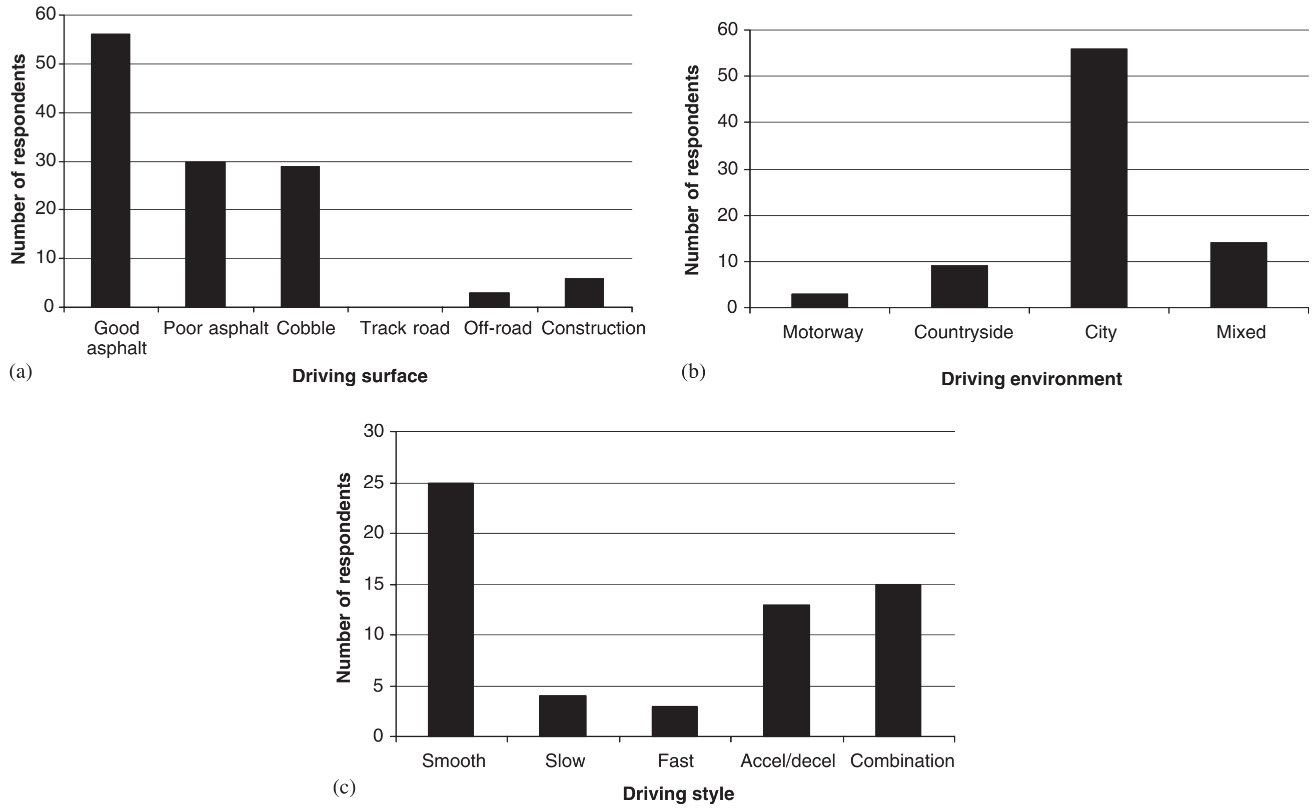

Fig. 5. Driving surface, driving environment and driving style of the bus drivers ($N = 61$).

Table 2
The travelling times (in seconds), stationary or crawling times (in seconds), number of stops made, driving style and road surfaces traversed during service route driving tasks

Driver/gender	Travelling time	Time stationary or crawling in traffic			Number of stops	Driving style	Road surfaces (%)
		Total	Max	Min			
1—M	3620	2200	180	3	86	Smooth	Asphalt (100)
2—M	4546	1574	128	3	73	Fast	Asphalt (99.4) Cobble (0.6)
3—M	3683	1717	87	3	86	Smooth	Asphalt (97.8) Speed bumps (1.6) Cobble (0.6)
4—M	2861	1999	158	4	63	Smooth	Asphalt (100)
5—M	2725	2135	420	3	69	Fast	Asphalt (99.3) Cobble (0.7)
6—M	3498	2142	143	3	93	Smooth	Asphalt (98.8) Cobble (1.2)
7—F	3527	2713	840	5	83	Smooth	Asphalt (91.1) Speed bumps (8.9)
8—M	2965	2555	549	2	74	Smooth	Asphalt (98.2) Speed bumps (1.8)
9—M	3310	2150	302	3	67	Smooth	Asphalt (89.7) Cobble (10.3)
10—M	2881	2279	686	4	72	Smooth	Asphalt (100)
11—M	3705	1815	279	3	68	Smooth	Asphalt (100)
12—M	3551	2029	94	3	94	Fast	Asphalt (96.8) Cobble (3.2)

cushions. All the drivers needed to decelerate and accelerate often during the service route driving tasks but most displayed a smooth driving style.

The measured average r.m.s. accelerations ranged between 0.029 and 0.449 m/s^2 in the x-axis, between 0.046 and 0.470 m/s^2 in the y-axis and between 0.100 and 1.01 m/s^2 in the z-axis (Fig. 6). The lowest values were seen during idling and the highest values generally occurred in the z-axis during travel on cobble, particularly for the single-decker bus. While the idling accelerations were highest for the mini-bus, the asphalt and cobble accelerations were lowest for this vehicle. It can be seen from Fig. 6 that during travelling, the double-decker bus generated highest x-axis average acceleration and the single-decker bus highest z-axis average acceleration.

Based on the vector sum values, the European directive limit was exceeded by the single-decker bus during travelling on asphalt and by the three buses during travelling on cobble. The double-decker bus and single-decker bus associated with high CF values (>9.0) and VDV ($>15\,m/s^{1.75}$) during travelling on cobble particularly in the y- and z-axes (Table 3), which is an indication that the vibration exposures in these conditions included severe shock events. Also, from the point of fatigue-decreasing proficiency (FDP) allowable exposure, the results indicated that bus drivers should not travel on cobble surfaced roads for more than 1 h and 36 min in an 8-h workday.

3.2. Low back pain

The questionnaire data showed that 36 drivers (59.0%) experienced LBP during the last 12 months of which, 19 also reported current LBP (i.e., pain in immediate past 7 days). For these persons, more than six episodes of LBP were experienced, each typically lasting between a few minutes and 2 days and for which considerable but not severe pain was perceived, i.e., between 3 and 7 on a scale from 1 [little pain] to 10 [very bad pain] (Fig. 7).

Back pain only and back pain with radiating pain to the leg were the two common symptoms and seven of the drivers needed to take time off work because of LBP. For the bus drivers, muscle stiffness, muscle sprain and trapped nerve, were the three reported medically diagnosed underlying problems and actions such as standing after a long period of driving, flexing the torso and twisting, tended to initiate and/or aggravate pain. Furthermore, the questionnaire data indicated that back pain had little effect on ability to work and on ability to take part in recreational/social activities. As can be seen in Table 4, the drivers who reported LBP were (on average) older as well as heavier and they lifted medium loads more frequently than the drivers who did not report LBP. However, the indicated differences did not reach significance level.

4. Discussion

The work undertaken was concerned with exposure of city bus drivers to vibration, posture demands, and MMH. It investigated the three occupational risk factors using both self-reported questionnaire assessment and objective observation and measurements. By complementing questionnaire assessment with direct observations of drivers during their work and measured vehicular vibrations, a clearer picture of the exposures was enabled than had previously been made available.

Some caution may, however, be needed when considering the wider application. Firstly, the sampling approach used during direct observations means that aspects of the risk factors occurring between sampling points were overlooked. Secondly the investigation of prevalence was based on a relatively small sample size of subjects and it

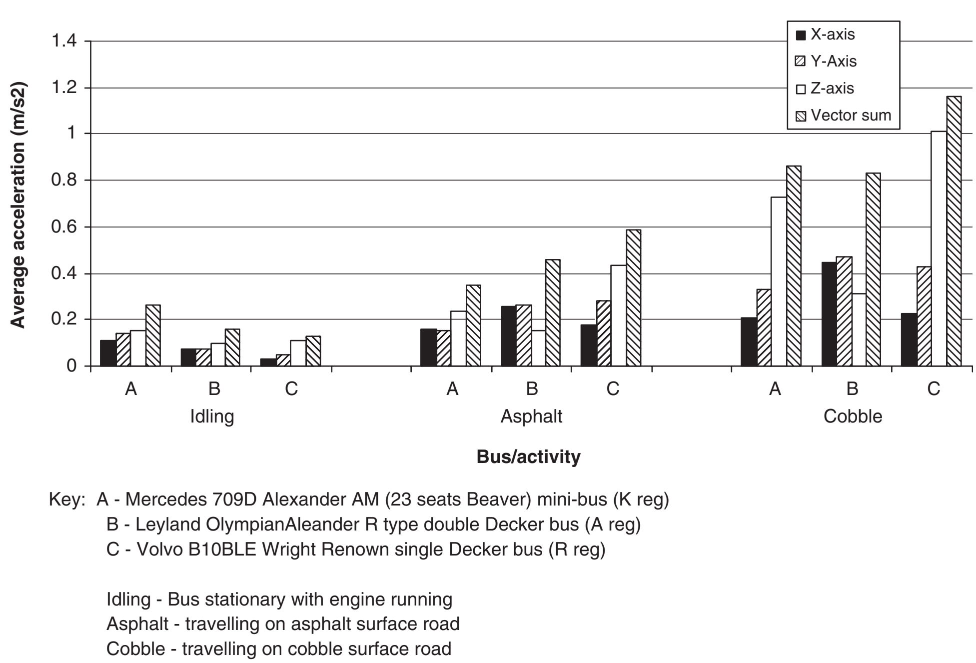

Fig. 6. The summarised average r.m.s. acceleration data for the measured bus vibrations.

Table 3
The values of peak acceleration, vibration dose and crest factor for measured bus vibrations

Test /bus	Peak acceleration (m/s^2)			Vibration dose value ($m/s^{1.75}$)			Crest factor		
	x-axis	*y*-axis	*z*-axis	*x*-axis	*y*-axis	*z*-axis	*x*-axis	*y*-axis	*z*-axis
Idling									
Mini	1.464	2.104	7.510	5.119	6.889	11.778	13.583	14.835	48.924
D/Decker	0.699	0.565	1.568	3.148	3.150	5.258	9.909	7.530	16.146
S/Decker	0.269	0.756	1.055	1.187	2.390	3.550	9.251	16.364	9.506
Moving on asphalt									
Mini	1.168	1.107	2.733	5.237	4.910	8.288	7.274	7.119	11.752
D/Decker	0.644	0.652	0.593	6.417	6.498	4.570	2.499	2.499	3.887
S/Decker	1.064	4.799	7.024	6.721	15.862	19.233	9.050	16.983	16.128
Moving on cobble									
Mini	1.357	2.242	4.506	6.289	10.845	21.624	6.464	6.796	6.215
D/Decker	13.153	13.559	19.110	36.722	38.525	38.873	29.290	28.841	61.156
S/Decker	2.913	7.885	12.849	10.120	27.043	37.597	12.705	18.358	12.728

Mini—Mercedes 709D Alexander AM (23 seats Beaver) mini-bus.
D/Decker—Leyland OlympianAleander R type double-decker bus.
S/Decker—Volvo B10BLE Wright Renown single-decker bus.

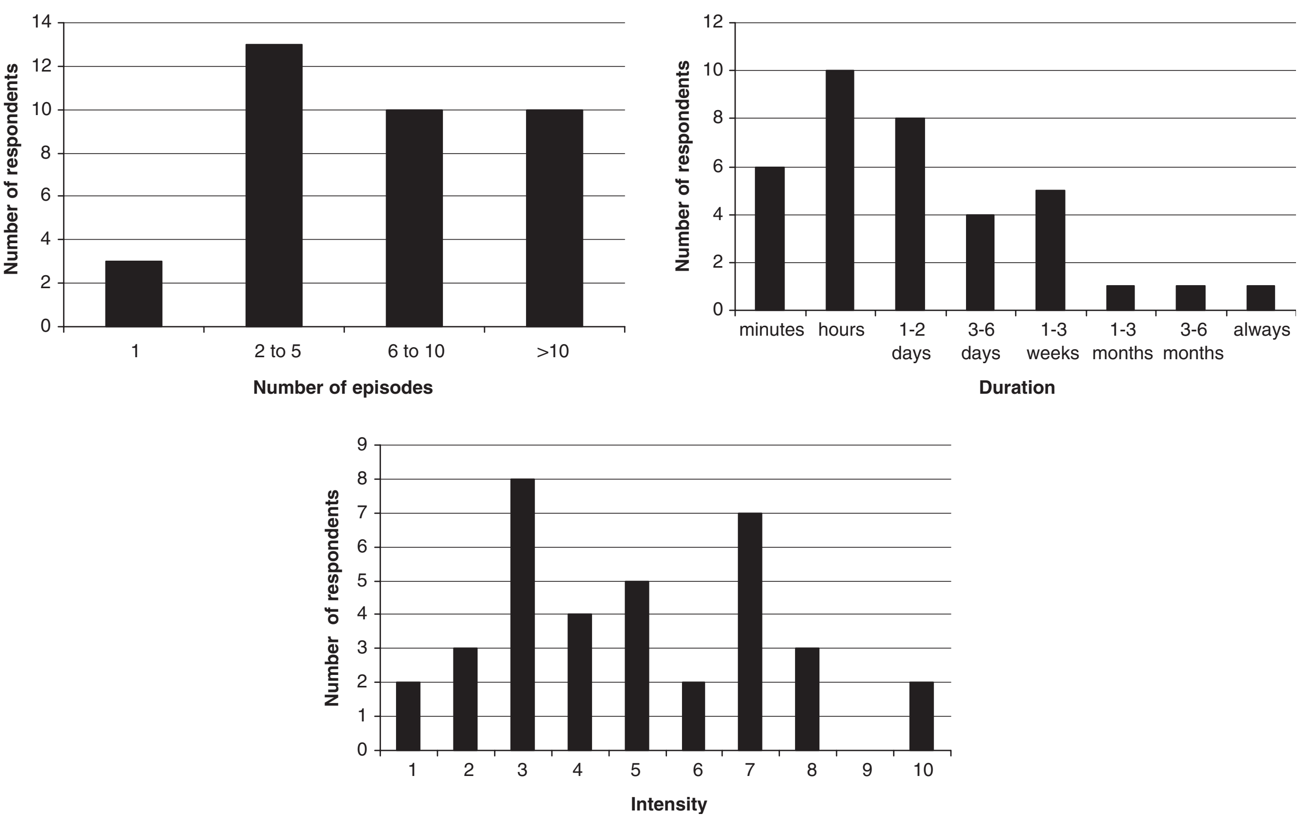

Fig. 7. Number of episodes, duration and intensity of LBP ($N = 36$).

was not clear whether the characteristics of these persons compared favourably with the wider population from which they were drawn. As such prevalence of LBP might have been underestimated. However, considering that the drivers were drawn from one company and that they were selected randomly based on a common off-duty schedule with 76.3% response rate, the sample can be considered as homogeneous, representative of the population (at least in respect of the drivers' work practices) and with low selection bias.

4.1. Evaluation of the exposures

Both the self-reported questionnaire assessment and direct observation indicated exposure to low levels of driving posture stress and exposure to little or no MMH

Table 4
The summarised values of personal and risk factors (mean and SD) for the drivers with LBP and without LBP

Variable	Drivers LBP ($N = 36$)	Drivers no LBP ($N = 25$)
Age (years)	48.1 (9.73)	46.8 (11.48)
Height (cm)	172.9 (7.49)	172.9 (9.82)
Weight (kg)	85.1 (13.29)	84.7 (19.10)
BMI	28.5 (4.04)	28.1 (4.87)
Driving postures score	7.9 (5.37)	8.7 (5.32)
MMH—between 5 and 10 kg (frequency)	6.3 (2.50)	6.0 (5.66)
Daily driving hours	7.5 (1.43)	7.6 (1.78)
Driving years in current job	14.3 (7.82)	17.9 (12.21)

Frequency = number of lifts per day.

stress. The two sets of data also indicated that the bus drivers were exposed to discomforting levels of vibration stress, particularly, vertical vibration and shocks/jerking events. There were however, some discrepancies. Firstly, while the questionnaire data indicated more frequent adoption of the 'torso against back rest' posture during driving than the 'torso straight' posture, the observation data, indicated that the 'torso straight' posture was more frequently adopted than the 'torso against back rest' posture (Fig. 2). Secondly, the self-reported driving times were often higher than the driving times determined from observation. The discrepancies between reported and observed driving times may be attributed to overtime work done by the drivers or to the fact that some shifts were extended shifts, i.e., the drivers worked the normal duty hours but had extended breaks between driving periods. The reason for the discrepancy concerning driving posture is not very clear, but using seats with poor back rests appears to have been a real problem, which probably encouraged that the torso was held straight for most of the driving periods. This is seen in the fact that 23 drivers reported discomfort from sitting and that none of the buses driven was used exclusively by any one driver. Notwithstanding the concerns identified, it is clear from the results that city bus drivers (such as were studied here) are typically exposed to prolonged holding of the torso straight or unsupported, occasional and light MMH, and discomforting shock/jerking events.

4.2. Prevalence and nature of back problems

In the present work, the questionnaire assessment data showed that LBP typically lasting between a few minutes and 2 days and generally attributable to muscle stiffness/sprain was suffered by the bus drivers (59.0%). Also, back pain showed to have little effect on ability to work and ability to take part in recreational/asocial activities. In these regards, Anderson (1992) reported for a sample of motor coach company workers that 66.4% of the bus drivers experienced LBP compared to 44.8% of the non-drivers and that most of these persons experienced mild pain (i.e., not interfering with work or customary levels of activity). Indeed, the drivers were found to suffer more from postural syndromes (involving no true anatomical abnormality and correctable by a simple change in posture/movement) than mechanical disorders (associated with definite injury of the musculoskeletal system). Magnusson et al. (1996) reported 60.0% prevalence of LBP for their group of American and Swedish bus drivers, which required on average, 18 days of sick leave period. Compared to a complementary group of truck and sedentary workers, the bus drivers experienced far more mild episodes of back pain than did none drivers. Benavides et al. (2003) found during a 2-year surveillance of workers at a bus company, higher proportion (78.0%) of sickness absence spells from non-work related diseases than from work related diseases (including LBP), and significant association between sickness absence and non-work related disease for bus drivers. It can then be concluded that during their work, city bus drivers (such as were surveyed in the present work) suffer LBP that is transient (lasting <3 days) and mild (not interfering with work or customary levels of activity) rather than permanent and severe.

4.3. Strategies for controlling risks of LBP

This work was not designed to establish the relative role of posture demand, MMH and vibration as risk factors for LBP. However, based on the determined exposures, the results do suggest strategies of control that may be applied.

Firstly, the results showed that drivers with LBP had lower posture scores (maintaining upright posture) than those without LBP (though not significantly), sitting was done for a high proportion of the service route driving task and long duration driving (>2 h) was generally reported as initiating/aggravating pain. These findings indicate that efforts to eliminate or minimise the need to hold the torso straight or to minimise the duration of sitting done during driving can contribute to reduce the incidences of LBP. One direct way might be to encourage drivers to take regular breaks during service route driving for relieving sitting stress, stretching and exercise as has previously been suggested by Anderson (1992) in respect of motor coach operators. However, since some of the drivers who reported discomfort from sitting during driving also identified that they often used seats with poor back rest/support, there is also a suggested need for ergonomic evaluation of the drivers' seat in buses.

Secondly, the results identified that the bus drivers tended to perform two specific MMH tasks during their service route driving, i.e., positioning access ramps at the entrance for use by disabled passengers and assisting elderly passenger with placing luggage in storage areas. Though tending to occur sparingly and involving only light and medium loads, the highly structured nature of city bus driving and characteristic rigid time schedules (Michaels and Zoloth, 1991; Rydstedt et al., 1998) suggests the possibility of instantaneous injury from undue rapid performance of the handling tasks. These point to a strategy of control that eliminates the need for any MMH. Thus, buses could be fitted with automatically retracting assess ramps and lift platforms which are operated from the driver's cabin by lever/push button.

Thirdly, travel on cobble (and over road obstructions including speed bumps/humps), showed to generate high peak accelerations and to associate with high VDVs, but cobble was in most cases traversed for $<1\%$ of the service route driving time. Bus drivers showed to make more than 60 stops during service route driving, which tended to occur with rapid or sharp deceleration and acceleration of the vehicle and speed humps (which could readily be straddled by the buses during travel) were installed on some bus routes. Since several respondents reported discomfort from shock/jerking events, these observations indicate that a strategy, which seeks to reduce the level of shock/jerking events occurring with deceleration and acceleration of the vehicle, could be benefiting. One direct way might be to encourage increased use of buses fitted with manual transmissions over buses fitted with automatic transmissions, more so when automatic transmissions are showing to be less capable of smooth gear changes than manual transmissions (Holgerson, 1997; Haj-Fraj and Pfeiffer, 2001).

5. Conclusion

This study investigated exposure to driving posture, MMH and vibration, as risks for development of LBP among city bus drivers and the results indicated the need for systematic observation of the exposures alongside any subjective questionnaire assessment, particularly driving duration and daily work time. The following conclusions are made.

(1) City bus drivers clock up considerable hours of daily work time, and spend about 60% of the time actually driving. They often drive with the torso straight or unsupported, perform occasional and light MMH, and experience discomforting shock/jerking vibration events.
(2) LBP is prevalent among city bus drivers (such as were considered in the present study), but largely transient and mild LBP, which is not likely to interfere with work or customary levels of activity.
(3) Taking regular breaks from sitting during driving and fitting buses with remotely operated retracting assess ramps and lift platforms and use of buses with manual transmissions rather automatic transmissions are strategies that can help control precipitation of LBP.

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