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MEASUREMENT OF WHOLE-BODY VIBRATION EXPOSURE FROM GARBAGE TRUCKS

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Japanese garbage truck drivers are exposed to mechanical whole-body vibration during their work. Some drivers have suffered from low back pain from this vibration. However, there is no evidence of a relationship between the whole-body vibration from the garbage trucks and the low back pain or occupational disease, due to the lack of investigations. A field study was conducted in order to characterize the health risks associated with garbage truck work. Three different types of truck were tested at different loadings and on different road surfaces, with the vibrations measured at the driver/seat interface (x, y, and z-axes). The vibrations were comparaed with the health risk guidance according to Annex B of ISO 2631 [1]. The findings of this study indicated that Japanese garbage truck drivers should not operate trucks for 2.5 h in a day, under current working conditions.

1. INTRODUCTION

Low back pain disorders occurring among professional drivers have been investigated in several studies [2, 3]. Bovenzi and Zadini [4] and Bovenzi [5] investigated the prevalence of several types of low back symptoms among the bus drivers employed at a public transport company. Most of the studies were not informative because the data were poorly documented, except for Bovenzi's study [5].

Garbage truck drivers are exposed to mechanical whole-body vibration during their work and some drivers suffer from low back pain due to their driving work in Japan. In order to predict the health risk for garbage truck drivers from vibration, it is necessary to evaluate the oscillatory motion of the garbage trucks so as to make a correlation between vibration directed into the body and occupational disease associated with the vibration. However, it was not possible to apply the results reported by Bovenzi to predict the health risk, as the working conditions of garbage truck drivers are complex compared with those of bus drivers. Garbage collection entails a variety of working conditions: truck loading, discharging, and driving with or without garbage. Thes conditions cause various vibration exposures of the drivers. To date there has been no research regarding whole-body vibration of garbage trucks.

The objective of the study was to measure the whole-body vibration on the driver's seat of garbage trucks, before, during and after collecting garbage, with different road conditions. The results were evaluated according to the health risk guidelines in Annex B of International Standard ISO 2631-1 [1].

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TABLE 1

Garbage trucks used in this study

Type of garbage truck	2 ton dump	2 ton truck	4 ton truck
Type of engine	diesel	diesel	diesel
Idling r.p.m.	650	650–750	650–750
Engine capacity (cc)	3560	4334	4334
Fuel type	light oil	light oil	light oil
Type of garbage	rough garbage	garbage	garbage
Truck length (mm)	5150	5170	6600
Truck width (mm)	1800	1800	2200
Truck height (mm)	2230	2230	2650
Truck weight (kg)	3400	3500	5000
Total truck weight (kg)	3400	5700	7900
Capacity number	3	3	3
Garbage capacity dimension (L × W × H)	—	2560 × 1690 × 1200	3010 × 2000 × 1440
Garbage input height (mm)	—	750	790
Garbage input dimension	—	1300 × 730	1500 × 830
Garbage tank capacity (l)	—	60	75
Type of garbage discharge	—	dump type	dump type

2. EXPERIMENTAL METHOD

2.1. GARBAGE TRUCKS AND SUBJECT

Three garbage trucks that are commonly used in Japan were used as shown in Table 1 for characterizing the vibration in the different garbage trucks. Seven different runs were chosen so as to give a wide variety of various intensities, frequencies and dominant directions. The running speed was the usual daily garbage truck speed. Only one driver participated in this study. The driver was 42 years old, 165 cm tall and weighted 80 kg. He had approximately 15 years of operation time (experience) of the garbage trucks. In Japanese garbage truck work, the driver does not get out of the truck to lift the loads.

2.2. VIBRATION MEASUREMENT AND ANALYSIS

Vibration measurements were performed on the three garbage trucks as shown in Table 1. Vibrations were measured under actual working conditions according to the recommendations for the International Standard ISO 2631-1. The whole-body vibration for the different work conditions of the garbage trucks was measured at the driver/seat interface (x-, y-, and z-axes). Table 2 shows the different measurement conditions.

TABLE 2

Vibration measurement conditions used with each garbage truck

	Measurement conditions
1	Idling without load
2	Normal road without load
3	Rough road without load
4	Idling with load
5	Normal road with load
6	Rough road with load
7	Discharge garbage

Whole-body vibration was measured at the driver/seat interface by using a triaxial seat pad accelerometer (B&K type 4322). The vibration measurements were performed by using a HVLab field computer system. The three recorded acceleration signals for each of the conditions of Table 2 were acquired on a digital computer for 30 s at 500 samples s^{-1} using 167 Hz anti-aliasing filters. Frequency weighted accelerations were calculated by using the weighting factors suggested by ISO 2631-1. A Fast Fourier Transform was performed by using HVLab software [6] on the time domain data.

2.3. EXPERIMENTAL PROCEDURE

The experiments for each garbage truck were carried out separately because it was not possible to instrument all three garbage trucks at the same time. Each experiment—one driver testing one truck on each of the 6 or 7 conditions—took half a day. The driver was required to adjust the seat as he so wished at the start of the experiment and to sit comfortably. The duration of each condition run was about 60 s. Each truck was run on the same road before and after garbage collecting.

3. RESULTS AND DISCUSSION

3.1. FREQUENCY WEIGHTED ACCELERATION FROM GARBAGE TRUCKS

Table 3 shows the frequency weighted r.m.s. acceleration of the different road conditions of garbage trucks at the driver/seat interface (x-, y-, and z-axes) according to ISO 2631-1.

TABLE 3

Frequency-weighted r.m.s. acceleration (ms^{-2}) *magnitude from garbage trucks*

Type of garbage truck	Measurement conditions	x	y	z
2 ton dump	1	0·35	0·23	0·35
	2	1·23	0·93	0·93
	3	0·86	1·72	1·64
	4	0·31	0·29	0·3
	5	0·29	0·32	1·04
	6	1·31	1·5	1·12
	7	none	none	none
	average	0·73	0·83	0·9
2 ton garbage truck	1	0·31	0·21	0·3
	2	0·92	0·45	0·8
	3	1·67	0·93	1·32
	4	0·31	0·24	0·36
	5	0·32	0·25	0·64
	6	1·43	0·62	0·91
	7	1·49	1·09	1·34
	average	0·92	0·54	0·81
4 ton garbage truck	1	0·53	0·6	0·93
	2	0·57	1·04	1·7
	3	0·74	0·56	1·71
	4	0·5	0·71	0·37
	5	0·56	1·98	2·1
	6	0·94	1·36	2·45
	7	0·63	0·74	1·93
	average	0·64	1	1·6
	Grand average	0·76	0·79	1·1

From Table 3, the grand average x-, y-, and z-axes whole-body vibration magnitudes measured on trucks were 0·76 ms^{-2} r.m.s. (range 0·31–1·67 ms^{-2} r.m.s.), 0·79 ms^{-2} r.m.s. (range 0·21–1·98 ms^{-2} r.m.s.), and 1·1 ms^{-2} r.m.s. (range 0·30–2·45 ms^{-2} r.m.s.). These values are in the range of those of off-road vehicles and industrial vehicles and machines [7]. In the normal and rough road running of a 2 ton dump truck and a 2 ton garbage truck, the seat vibration magnitude without a garbage load was greater than with a garbage load. Therefore, the drivers experience large vibrations before collecting the garbage. On the other hand, in a 4 ton garbage truck, the seat vibration magnitude without a garbage load was smaller than with a garbage load. Also, from Table 3, the vibration magnitude of the discharge of garbage of 2 ton and 4 ton garbage trucks has a large vibration magnitude. This is a typical vibration in the garbage truck work. It was also clear that the drivers of the garbage trucks had a large vibration from the discharge work.

3.2. PREDICTING THE HEALTH RISK

Annex B of the ISO 2631-1 provides guidance for the assessment of whole-body vibration with respect to health. It applies to people in normal health who are regularly exposed to vibration. It applies to vibrations along the x-, y- and z-basicentric axes of the human body. The health guidance caution zone is indicated by dotted lines in Figure B.1 of Annex B of the ISO 2631-1. The r.m.s. value of the frequency weighted acceleration can be compared with the zone shown in Figure B.1 at the duration of the expected daily exposure. In this study, the z-axis vibration data of Table 3 were plotted as in Figure B.1 of the ISO 2631-1 (see Figure 1).

As shown in Figure 1, in this study, the z-axis acceleration data were compared with the lower bound of the zone given by equation (B.2) in Figure B.1 of the ISO 2631-1. Because, although the exact values are given by equation (B.2), these values are not given by equation (B.1). This study only considered the daily vibration dose $eVDV = 8{\cdot}5\ \mathrm{ms}^{-1{\cdot}75}$,

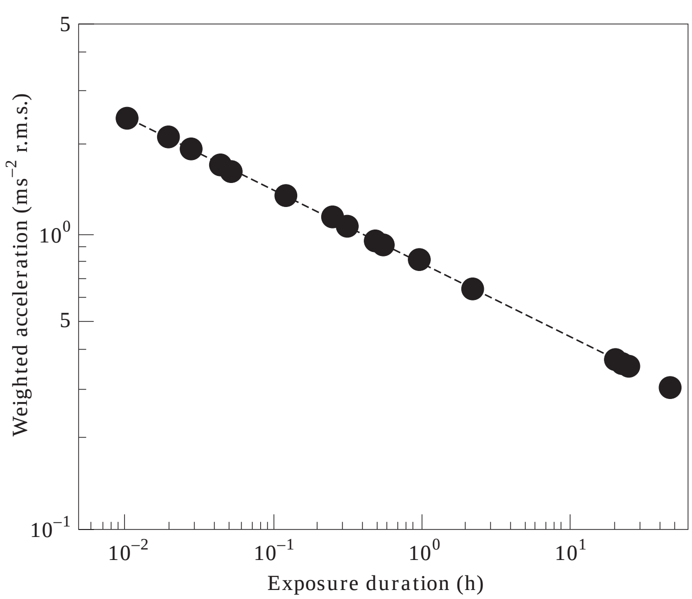

Figure 1. Comparison of the measured frequency weighted r.m.s. acceleration values on the z-axis of the seat of the garbage trucks and the health risk guidance line of the ISO 2631-1 Standard (1997). Key: ●, measured data; - - - -, health hazard ($eVDV = 8{\cdot}5\ \mathrm{ms}^{-1{\cdot}75}$).

dependent on the frequency-weighted acceleration a_{wz} and the daily vibration exposure T. The daily vibration exposure time T was calculated by the equation

$$T = (8{\cdot}5^4)/(1{\cdot}4^4 a_{wz}^4). \tag{1}$$

As shown in Figure 1, for most of the seat vibration, it was clear that the drivers of the garbage trucks cannot work 8 hours in a day in safe condition.

In Japan, the common daily operating time of the garbage truck drivers is 2·5 hours in a day from personal data. Even though the common daily working time is 2·5 hours, the estimated vibration dose values ($eVDV = 1{\cdot}4 a_{wz} T^{1/4}$) were 15 $ms^{-1{\cdot}75}$, from the grand average vibration magnitude on the z-axis shown in Table 3. This $eVDV$ value exceeds the daily vibration dose $eVDV = 8{\cdot}5\ ms^{-1{\cdot}75}$. Also, according to the guide to effect of vibration dose values of the BS 6841 standard [8], it is known that vibration magnitudes and durations which produce vibration dose values in the region of 15 $ms^{-1{\cdot}75}$ will usually cause severe discomfort. It is reasonable to assume that increased exposure to vibration will be accompanied by increased risk of injury. It is clear that the Japanese garbage truck drivers are exposed to serious vibration magnitudes. Therefore, new suspension mechanisms for the garbage trucks, without and with a garbage load, or new work–rest schedules for the garbage truck drivers should be considered.

4. CONCLUSIONS

This field study was conducted to evaluate the ergonomic hazards associated with the use of garbage trucks to collect garbage. One male driver performed garbage work using three different garbage trucks. Whole-body vibration measurements and the health risk assessments were performed. The study was carried out in accordance with the measurement and the health risk assessment outlined in the ISO 2631-1 standard. The following findings were obtained from this study.

(1) The grand average x-, y-, and z-axes whole-body vibration magnitudes measured on the driver seat of garbage trucks were 0·76 ms^{-2} r.m.s. (range 0·31–1·67 ms^{-2} r.m.s.), 0·79 ms^{-2} r.m.s. (range 0·21–1·98 ms^{-2} r.m.s.), and 1·1 ms^{-2} r.m.s. (range 0·3–2·45 ms^{-2} r.m.s.), respectively.

(2) The estimated vibration dose values ($eVDV = 1{\cdot}4 a_{wz} T^{1/4}$) were 15 $ms^{-1{\cdot}75}$, from the grand average vibration magnitude on the z-axis in Table 3. This $eVDV$ value exceeds the daily vibration dose $eVDV = 8{\cdot}5\ ms^{-1{\cdot}75}$. Even though the common daily working time is 2·5 hours, it is clear that the drivers should not be allowed to work their 2·5 hours a day in Japan under the current vibration magnitude conditions.

(3) It is thus clear that a new suspension mechanism for the garbage trucks is required, without and with garbage loads, or the work-rest schedules of the garbage truck drivers should be considered.

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