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Field Study

An investigation of a cluster of cervical herniated discs among container truck drivers with occupational exposure to whole-body vibration

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Abstract: An investigation of a cluster of cervical herniated discs among container truck drivers with occupational exposure to whole-body vibration: Fan-Yun LAN, *et al*. Department of Occupational and Environmental Medicine, National Cheng Kung University Hospital, Taiwan—Objective: This study aimed to determine if occupational exposure to whole-body vibration is associated with cervical intervertebral disc herniation among container truck drivers. **Methods:** We conducted a walk-through survey among container truck drivers and unexposed workers. We also measured the vibration hazard of the container truck over the driver's back and seat when the driver was loading a container and driving the loaded truck. **Results and Discussion:** Among the 38 workers interviewed, 32 were container truck drivers. Four of them reported cervical herniated discs, and all of these individuals were container truck drivers with a job tenure of greater than 10 years. Self-reported cervical herniated disc, nuchal pain, nocturia, arm/forearm weakness, arm/forearm numbness, and finger numbness were significantly more prevalent as the driver's duration of exposure increased (all p values of test for trend <0.05). The vibration of the truck during and after loading a container was considered the main cause of herniated disc. When a container truck was driven with a loaded container, both the vertical and horizontal vibrating acceleration over the seat and back sites exceeded the 8-hr exposure level based on the ISO 2631-1 criteria. The transient vibration dose values (VDVs) measured during misaligned or unsmooth loading operations were usually greater than the upper bounds of the health guidance caution zone for the 8-hr VDV. **Conclusions:** Our investigation disclosed a cluster of cervical intervertebral disc herniation that was associated with the vibration hazard during long-term container truck driving under full load and possibly aggravated by misaligned loading operations.
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Vibration has been reported to be a health hazard in the past few decades[1–4], and it can be classified as local or whole-body vibration (WBV). Local vibration is often due to vibrating tools, causing health effects such as hand-arm vibration syndrome and carpal tunnel syndrome[5]. Occupational exposure to WBV due to operating vehicles is generally considered a significant risk for illnesses of the lower back[6–11] and is widely accepted as an occupational disease[12, 13]. However, guides for diagnosis and lists of occupational diseases in most countries, such as those used by the European Commission and Denmark, do not include vibration-related cervical illness[12, 13]. Moreover, there are a limited number of studies on the association between hazards from occupational exposure to WBV and cervical illnesses. These pioneering studies provided the initial evidence indicating that occupational drivers operating vibrating motor vehicles may sustain cervical damage if they are exposed to impact shock and have abnormal posture[14–16]. However, the literature has only limited data on the related exposure assessments, and thus

there is as yet no universally accepted value for the permissible exposure limit for WBV-related cervical illnesses.

In May 2014, two patients visited the occupational medical clinic of National Cheng Kung University Hospital with herniated cervical intervertebral discs, requesting a determination of the occupational relatedness of their lesions. Since both of them were from the same truck company and also reported that two other workers were suffering from the same illness, we conducted this cluster investigation to explore possible etiological factors, including occupational exposure to WBV hazard, for the clustered cases with cervical illnesses.

One of the two patients was a 52-year-old man who had suffered from numbness throughout the bilateral upper arms for a two-year period. He complained that this numbness radiated to the posterior neck and was associated with nuchal pain. He visited another medical center in early 2014 and underwent a magnetic resonance imaging (MRI) examination, and the results showed 5^{th}–6^{th} cervical intervertebral disc herniation. Surgical intervention was performed in April 2014, and his symptoms were largely relieved.

This man has been working as a container truck driver for eleven years. He used to work nine hours a day, 25–26 days a month. His daily routine consisted of driving the unloaded container truck to the harbor to collect cargo and then spending about 6-8 hours driving it to its destination. The container usually weighed 10–24 tons, and the worker stated that smooth loading of the container at the harbor requires a skillful technique. If the container does not fall exactly on the pins at the four corners, then the truck sustains a violent vibrational shock two or three times until the crane operator manages to achieve a good alignment. The driver has to stay in the truck during the loading process to work with the crane operator and move the truck backward and forward to achieve a good alignment. However, there is no convenient communication tool between the truck driver and crane operator, other than their eyes, which often results in shocks and sometimes even causes the driver's head to hit the roof of the truck. The man also complained of occasional whiplash injury to his neck while driving the loaded truck, occurring once or twice a week. In addition, the cushioned seat of the driver's truck had only been replaced with a new one three years previously, and he stated that before this, the vibrations were even more severe. He claimed that he did no other work or daily weight-bearing tasks, and he also stated that he had no history of trauma, arthritis, rheumatological disease, or any other medical history related to neck strain.

Fig. 1. The overhead crane sets the container onto the unloaded container truck. The driver has to stay in the truck to cooperate with the crane operator to move the truck forward/backward. The arrows mark the pins at the four corners, which have to be inserted into (aligned with) the four recesses of the container.

Methods

The Occupational Safety and Health Administration of the Ministry of Labor has contracted with nine medical centers in Taiwan to conduct field investigations for the determination of work-related injuries since 2008, one of which is the Occupational Medicine Department of National Cheng Kung University Hospital. We conducted a workplace visit to figure out possible occupational hazards with regard to container truck drivers' cervical spines. Every worker currently employed in the company was included in the investigation without selection.

The unloaded container trucks were parked in a parking lot about a 15-minute drive from the harbor. The drivers and the officials of the cargo company met at the parking lot every morning for the assignment of cargo. Each driver then drove his truck to the harbor with their assignment sheet to receive the cargo. As mentioned before, we observed that trial and error were inherent in container loading, which occasionally resulted in two or three vibrating impacts to the truck (Fig. 1) with the driver sitting in his seat.

We measured the vibration in the trucks, both over the seat and upper back sites, with an SV 106 Human

Table 1. Vibration measurements at two time points: "unloaded truck entering harbor" and "loaded truck leaving harbor"

Site of measurement	Direction	Unloaded truck entering harbor						Loaded truck leaving harbor					
		Truck A (5 records)			Truck B (4 records)			Truck A (2 records)			Truck B (3 records)		
		RMS (m/s^2)*	Max (m/s^2)**	Exposure limit time (hours)#	RMS (m/s^2)*	Max (m/s^2)**	Exposure limit time (hours)#	RMS (m/s^2)*	Max (m/s^2)**	Exposure limit time (hours)#	RMS (m/s^2)*	Max (m/s^2)**	Exposure limit time (hours)#
Seat	Forward/ backward	0.453	0.622	8	0.481	0.795	8	0.750	0.844	8	0.419	0.507	8
	Leftward/ rightward	0.659	0.867	8	0.526	0.932	8	2.344	2.704	1	0.698	1.029	4
	Upward/ downward	0.658	1.165	8	0.634	1.112	8	1.517	1.752	4	0.704	0.893	8
Upper back	Forward/ backward	0.926	1.124	8	0.557	0.651	8	1.514	2.061	4	1.049	1.283	4
	Leftward/ rightward	1.096	1.411	8	0.905	1.134	8	0.725	0.936	8	0.623	0.923	8
	Upward/ downward	0.917	1.240	8	0.773	0.962	8	0.939	1.266	4	0.479	0.563	8

* RMS: Root mean square. ** Max: Maximum dose measured. # The exposure limit time was determined by the ISO 2631-1:1997 exposure limit value.

Vibration (6-ch) Meter and Analyzer and an SV 38V Seat Accelerometer (Svantek, Warsaw, Poland), which were adjusted to meet ISO 8041:2005. Because we had only one device, we measured either the seat or back site individually until both measurements accomplished. Vibration signals were recorded every second, and data were saved as a file every minute. The setup of the vibration measurement process is shown in a step-by-step flowchart in the Appendix. The measurements were performed during the following three periods: "unloaded truck entering harbor", "loading course", and "loaded truck leaving harbor".

We also conducted a questionnaire survey among container truck drivers and unexposed workers at the workplace. The questionnaire contained items on demographic data (gender, age, body height, body weight, and marital status), medical history (diabetes mellitus, hypertension, cancer, rheumatoid arthritis, gout, ankylosing spondylitis, cervical herniated disc, lumbar herniated disc, carpal tunnel syndrome, mental illnesses, trauma, and so on), current symptoms related to a herniated cervical disc, personal history (including alcohol consumption), and work history (including self-perceived occupational factors related to herniated cervical disc). We conducted detailed interviews with those reporting a medical history of cervical herniated disc to verify that the diagnosis was made by a certified physician based on a physical examination and imaging evidence. All workers completing the questionnaire signed an informed consent form.

Statistical analysis

All data were coded onto a personal computer, and we applied the SAS 9.3 software (SAS Institute Inc., Cary, NC, USA) to conduct statistical analyses. The Mantel extension test for trend[17] was performed to examine if longer durations and different frequencies of exposure to truck vibration and whiplash episodes during the loading process and regular driving are associated with increased risks of symptoms and diseases related to the cervical spine. We also included the following three dummy symptoms for validation of potential false-positive symptoms unrelated to cervical disc herniation: diarrhea, chest pain, and dyspnea.

Results

Vibration measurement

The vibration measurements are summarized in Tables 1 and 2. Although all the measurements were within ISO 2631-1:1997 limits without any container load, both vertical and horizontal vibration acceleration over the seat and back sites exceeded the 8-hr exposure level when two trucks were carrying containers (Table 1). When vibrational shock occurred because of a poor loading process (or a misaligned loading operation), the crest factor (=peak value/rms value) rose to more than 9, and the vibration dose value (VDV) was up to 19.86 $m/s^{1.75}$. The transient VDV was greater than the upper bounds of the health guidance caution zone for 8-hr VDV, which is 17 $m/s^{1.75}$. We made more efforts to measure a total of three trucks. One of them happened to have data for

Table 2. Vibration measured at the time of loading operation stratified by trucks and "aligned versus misaligned" conditions

Vibrating shock during loading course (seat site)		Truck A (Misaligned)	Truck B (Aligned)	Truck C (Aligned)	Truck C (Misaligned)
Forward/backward (X-axis)	RMS (m/s^2)*	9.80	6.68	1.19	6.68
	VDV ($m/s^{1.75}$)#	5.16	3.89	0.68	9.89
Leftward/rightward (Y-axis)	RMS (m/s^2)*	30.20	2.32	1.17	21.32
	VDV ($m/s^{1.75}$)#	9.86	1.45	0.83	11.45
Upward/downward (Z-axis)	RMS (m/s^2)*	12.95	8.41	1.58	25.41
	VDV ($m/s^{1.75}$)#	19.86	6.78	0.98	17.78

* RMS: Root mean square. # VDV: Vibration dose value.

both aligned and misaligned loading operations for self-comparison, and it consistently showed results exceeding ISO limits when the loading process was misaligned, as summarized in Table 2.

Questionnaire survey

After excluding six drivers who had been working for less than one year, we collected self-reports from the 38 remaining workers, all of whom were male: six of them were administration or unexposed workers, while 32 were container truck drivers. There were no significant differences in average age (45.5 ± 6.4 versus 45.0 ± 16.2 years old) and duration of employment (12.7 ± 7.5 versus 11.0 ± 10.6 years) between the exposed and unexposed groups. Fourteen of these drivers had been employed for less than ten years, and 18 had been employed for more than ten years, as summarized in Table 3. Self-reported nuchal pain, nocturia, arm/forearm weakness, arm/forearm numbness, and finger numbness were all significantly more prevalent as the drivers' duration of exposure increased (all of the p values of test for trend <0.05). Four of the 32 reported a medical history of cervical herniated disc, and the test for trend was significant (p value<0.05). All four were container truck drivers with job tenures of greater than 10 years, with the shortest duration being 11 years, but there was no significant difference in mean age between those with and without herniated cervical discs (47.8 ± 3.6 versus 45.2 ± 6.7 years old). Three of these four drivers had undergone surgical treatment with valid medical evidence, while the fourth one was seriously considering the same treatment (Table 3). Despite some missing values in these self-reported data in different categories, we found significant associations between increased frequencies of truck vibration during driving and/or the loading process and prevalence of weakness and numbness throughout the upper extremities (Table 4). However, neither increased frequency of hitting the head on the roof nor whiplash injury during the loading process seemed to be associated with these symptoms. With the assistance of an orthopedic surgeon specialized in spine injury, we carefully reviewed these drivers' medical records and rechecked their diagnoses of cervical disc herniation and spondylosis according to the findings of MRI studies combined with their clinical symptoms of neck pain or radicular pain. Among the three patients with MRI, we could visualize HIVDs (herniated intervertebral discs) at C 5–6 and C 6–7 plus degeneration of facet joints and ligamenta flava, including osteophyte formation, subchondral sclerosis of facet joints, or buckling change of ligamenta flava, and so on. All three suffered from severe pain over the lower cervical neck with and without numbness of the unilateral or bilateral upper extremities. These subjects suffered from both HIVD and spondylosis, and thus they underwent discectomy plus anterior fusion with cage.

Discussion

Despite considerable evidence showing a significant association between lower back diseases and vibration hazard among professional drivers[18–22], there are few reports discussing vibration hazard and cervical spine diseases. Although we found a cluster of four cases with cervical disc herniation in container truck drivers, this does not necessarily indicate that such an association is occupationally related. We have, however, the following arguments to corroborate such a hypothesis: First, since all four cases occurred in drivers with more than 10 years experience of driving container trucks, there is a significant trend of association between duration of exposure and cervical disc herniation, and there was no significant difference in mean ages between those with and without the above illness. Moreover, the same trend was statistically significant for individual cervical spine-related symptoms, including nuchal pain, weakness of arm/

Table 3. Self-reported symptoms and comorbidities among container truck drivers and unexposed workers

	Unexposed workers (N=6)	Container truck drivers with job tenure ≤10 years (N=14)	Container truck drivers with job tenure >10 years (N=18)	Two-tailed *p* value of test for trend
Symptoms				
Headache	0	0	2	0.17
Nuchal pain	0	6	11	0.01*
Frequent urination	0	1	1	0.71
Diarrhea	1	1	0	0.10
Chest pain	0	1	3	0.21
Dyspnea	0	0	0	N/A
Nocturia	0	0	4	0.05*
Urine incontinence	0	0	0	N/A
Stool incontinence	0	0	0	N/A
Shoulder pain	0	8	11	0.10
Arm/forearm pain	1	4	9	0.10
Arm/forearm numbness	0	1	8	0.01*
Arm/forearm weakness	0	0	5	0.02*
Finger numbness	1	2	9	0.04*
Lower extremities weakness	0	0	1	0.34
Cormorbidities				
Hypertension	1	0	3	0.59
Diabetes mellitus	2	0	2	0.36
Cancer	0	0	0	N/A
Rheumatoid arthritis	0	0	0	N/A
Gout	0	0	1	0.34
Ankylosing spondylitis	0	0	0	N/A
Cervical herniated discs[#]	0	0	4	0.05*
Lumbar herniated discs[#]	0	0	1	0.34
Carpal tunnel syndrome	0	0	0	N/A
Mental illnesses	0	0	0	N/A

*p value <0.05. [#] Detailed imaging, laboratory, and surgical intervention records were collected and confirmed if the worker reported such diseases. N/A: not available.

forearm, and numbness of the finger and arm/forearm (Table 3). There was only one driver with herniated disc who also complained of nocturia. To control for potential biased reports from exposed workers, we deliberately included three dummy symptoms in the questionnaire: diarrhea, chest pain, and dyspnea. None of them showed a similar trend, indicating that the above association is probably valid. Second, direct vibration measurements at the driver's seat and upper back indicate strong vibrations in all directions when the truck is normally carrying a loaded container. In addition, ISO-2631-1:1997 recommends that drivers should work for less than 8 hours under such conditions. This implies that the longer the duration of exposure, the higher the likelihood of developing WBV-related illness, even if all loading operations are performed with perfect alignments. Table 4 shows that the drivers reported truck vibration during the loading process as the most important factor associated with cervical herniated discs and related weakness and numbness, while neither hitting the head on the roof nor whiplash injury during the loading process were associated with it. As increased frequencies of truck vibration during regular driving are also associated with increased symptoms of weakness and numbness of upper extremities, we suspected that such a chronic hazardous vibration (for periods of over 10 years) may at least partially contribute to nuchal pain and HIVD, leading to weakness and numbness of upper extremities. Thirdly, our survey of the subjects' medical histories did not reveal any alternative causes for the illness of the four drivers with herniation of the cervical disc. As there is also the possibility of a healthy worker effect for such a cross-sectional

Table 4. Frequency distributions of self-perceived occupational factors and health outcomes

	<1 time/week	1–3 times/week	1 time/day	>3 times/day	*p*-value of test for trend
Truck vibration					
Regular driving (No. cases)	10	5	2	17	
Nuchal pain	3	2	2	10	0.12
Nocturia	0	1	1	2	0.44
Arm/forearm numbness	0	1	1	7	0.02*
Arm/forearm weakness	0	0	0	5	0.02*
Finger numbness	0	2	1	7	0.12
Cervical herniated discs	0	1	0	3	0.24
Loading process (No. cases)	10	5	1	15	
Nuchal pain	3	1	1	9	0.08
Nocturia	1	0	0	2	0.66
Arm/forearm numbness	0	0	0	8	<0.01*
Arm/forearm weakness	0	0	0	5	0.02*
Finger numbness	1	1	0	8	0.02*
Cervical herniated discs	0	0	0	4	0.04*
Head hitting roof					
Regular driving (No. cases)	15	1	1	7	
Nuchal pain	7	1	1	4	0.55
Nocturia	0	0	0	1	0.13
Arm/forearm numbness	1	1	0	3	0.06
Arm/forearm weakness	1	1	0	1	0.65
Finger numbness	2	1	0	4	0.05*
Cervical herniated discs	1	1	0	2	0.22
Loading process (No. cases)	15	4	3	6	
Nuchal pain	7	2	3	2	0.99
Nocturia	1	1	1	0	0.99
Arm/forearm numbness	3	1	2	2	0.31
Arm/forearm weakness	2	0	2	0	0.99
Finger numbness	4	2	2	2	0.52
Cervical herniated discs	2	0	1	1	0.66
Whiplash injury					
Regular driving (No. cases)	13	5	2	11	
Nuchal pain	4	3	2	6	0.21
Nocturia	0	1	0	1	0.48
Arm/forearm numbness	0	2	1	5	0.01*
Arm/forearm weakness	0	1	1	3	0.06
Finger numbness	2	3	1	5	0.15
Cervical herniated discs	0	1	0	3	0.07
Loading process (No. cases)	11	2	3	12	
Nuchal pain	3	1	3	8	0.04*
Nocturia	0	1	1	1	0.58
Arm/forearm numbness	1	1	2	4	0.18
Arm/forearm weakness	1	0	1	2	0.50
Finger numbness	2	2	3	4	0.44
Cervical herniated discs	1	0	0	3	0.29

*$p<0.05$.

survey of currently working individuals, we tentatively concluded that the cluster of cases examined in this work is probably occupationally related and that our estimate of four out of 32 truck drivers with herniated intervertebral disc of the cervical spine is thus an underestimation. A qualitative study of insightful stories told by the workers also corroborates this claim, as there have been at least two people who left this job because of cervical symptoms.

Occupational drivers suffer from many musculoskeletal health problems, such as lower back pain, sciatica, lumbar vertebral early degeneration, and herniated intervertebral discs. The main etiology is thought to be vibration hazard, especially whole-body vibration[23, 24]. Many researchers have found that specific vibration frequencies can cause a resonance effect with the body's vertebral system[25–27], and this resonance energy may cause damage to the vertebral system[28].

Epidemiological study and outbreak investigations also seem to corroborate the above hypothesis. An epidemiological cohort study from Denmark revealed a higher standardized hospitalization ratio (SHR) due to prolapsed cervical discs among male drivers registered as working for shipping companies, harbors, and so on (SHR, 2.03; 95% CI, 1.18–3.24), and those working with haulage contractors, freight forwarders, and similar organizations (SHR, 1.04; 95% CI, 0.69–1.52)[14]. Another study found a borderline positive association between acute prolapsed cervical intervertebral discs and time spent operating motor vehicles[15]. There was also an outbreak investigation of two cases that examined occupational exposure to repetitive vibrational impact and its association with cervical herniated discs. The two cases in this earlier study were dump truck drivers sustaining extreme nuchal over-flexion and accelerating forces during the process of dumping[16].

ISO 2631-1 and ISO 2631-5 are often used as health caution guidelines to determine occupational exposure to WBV hazard, and these standards were developed due to concerns with regard to WBV-related health risks for vertebral systems and nearby nerve structures. These risks include degenerative changes of the vertebrae, damage to intervertebral discs, and various gastrointestinal and genitourinary concerns[29, 30]. We mainly used ISO 2631-1:1997 as the reference in this cluster investigation, and this standard applies the method of frequency-weighted acceleration, or root mean square (RMS) during the measurement period, as the basic evaluation of WBV. Such a method takes different frequencies and accelerations along different dimensions into consideration. However, RMS values may not catch the effects of sudden vibrational impacts, like those that occur with the misaligned loading of cargo. Therefore, ISO 2631-1:1997 suggests using the 4th power VDV or other methods when the crest factor (=peak value/rms value) is greater than 9.

As shown in the results of our investigation, although the samples were limited and the variations were large, an episode of VDV of up to 19.86 $m/s^{1.75}$ was noted. The transient VDV observed was greater than the upper bounds of the health guidance caution zone for 8-hr VDV, which is 17 $m/s^{1.75}$. Moreover, when the container trucks were driven under full load, our measurements showed significant vibration hazard not only over the seat site but also over the upper back site. This indicates that upper back vibration hazard should not be ignored, since the cervical vertebral structure is no less vulnerable than the lumbar spine[31–36]. As there were two episodes of misalignment out of four loading operations during our measurements and the truck vibration during the loading process is reported to be the most important factor related to cervical illness and relevant symptoms, we suspect that such impact may be relatively common and thus requires immediate attention. Moreover, since four out of eighteen of the current workers developed cervical disc herniation after at least 10 years of container truck driving, we also recommend avoiding overtime driving under full load.

This cluster investigation report has the following limitations: First, although we collected data for almost all workers from the company (38 out of a total of 44 workers), the sample size was still relatively small, and we did not adjust for potential confounders, such as body mass index and so on. Second, this study made a limited number of measurements with large variations in occupational exposure to whole-body vibration during the loading process, and thus the results might not represent daily exposures among the container drivers. We tried to obtain the value of upper back vibration during loading impact but failed because it was very difficult to keep the measuring equipment fixed over the upper back site when the impact shock occurred. However, the impact shock resulting from misaligned loading operations should not be lower at the upper back site than that at the seat site, with the former associated with neck whiplash and occasional episodes of the driver's head hitting the truck roof.

Conclusion

Our investigation examined the occupational exposure to WBV hazard among container truck drivers, and the vibrations that occurred during loading and driving with full loads are probably responsible for the drivers' cervical herniated discs and related weakness and numbness of upper extremities. However,

there is currently limited scientific evidence on this issue, and thus further longitudinal follow-up studies are warranted to determine the causal relationships among vibration, shock impact, and cervical herniated intervertebral discs.

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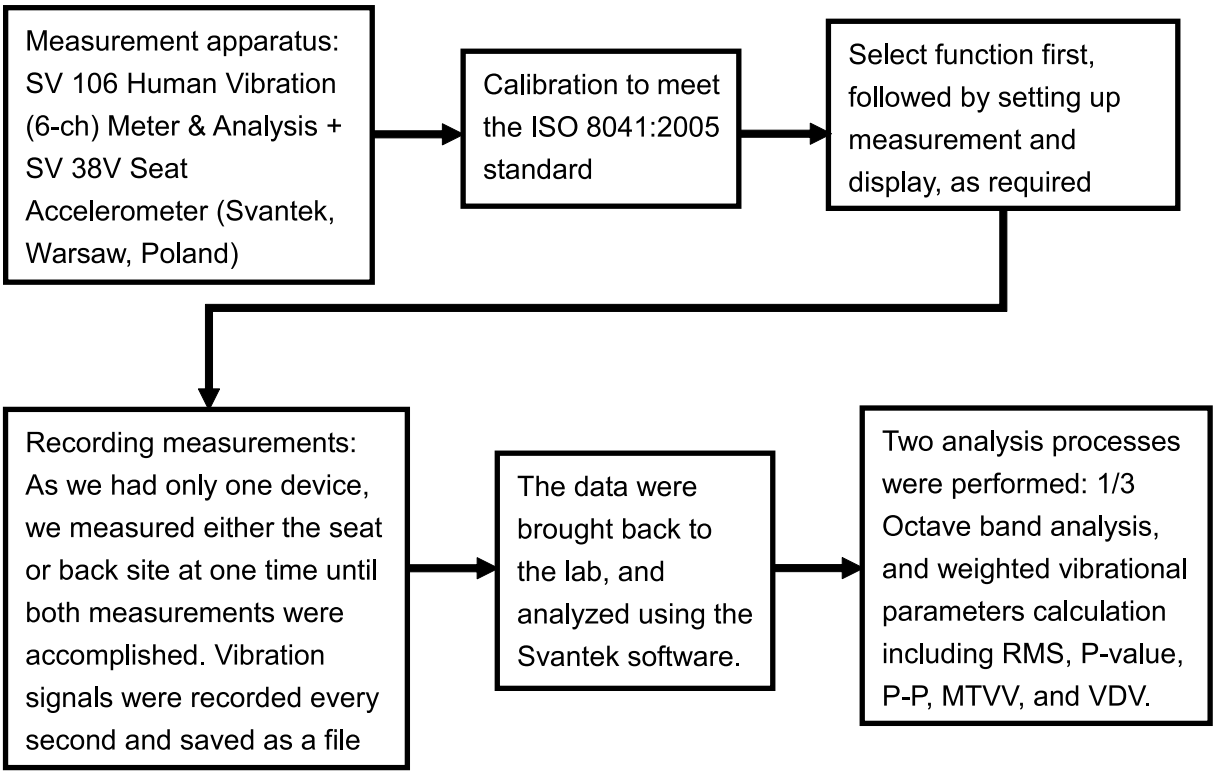
Appendix Table. Demographic data of container truck drivers with/without cervical HIVD and non-exposed workers

	Driver		Non-exposed workers	One-way ANOVA *p* value
	With cervical HIVD*	Without cervical HIVD		
Case number	4	28	6	
Age (year-old)	47.8 ± 3.6	45.2 ± 6.7	45.0 ± 16.2	0.85
Job tenure (year)	16.8 ± 4.1	12.1 ± 7.8	11.0 ± 10.6	0.50

*HIVD: herniated intervertebral disc.



Appendix Figure. Setup of the vibration measurement expressed as a step-by-step flowchart