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The Assessment of the Whole-Body Vibration on Health Effects in Automobile Assembly Line Worker in South Korea

Park MS and Kim T*

Department of Occupational Health & Safety Engineering, College of Biomedical Science & Engineering, INJE University, Gimhae, South Korea

***Corresponding author:**

Taegu Kim,
Department of Occupational Health & Safety Engineering, College of Biomedical Science & Engineering, INJE University, 197, Inje-ro, Gimhae-si, Gyeongsangnam-do, 50834, South Korea,
Tel: +82 10 27360561,
E-mail: tgkim@inje.ac.kr

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1. Abstract

1.1. Background: In general, whole-body vibration is one of the potential contributors to the development of back disorders of workers. In particular, it is thought that workers at the automobile assembly line are exposed to mechanically induced vibrations, either Whole-body Vibration (WBV) or Hand-arm Vibration (HAV). However, we can not assess the WBV on health effects in automobile assembly line workers.

1.2. Methods: This paper aims to measure the WBV in three different cars and evaluate the WBV exposure for health effects in automobile assembly line workers by ISO2631-1:1997.

1.3. Results: This study shows that the magnitude of vibration in three different cars was not exceeded 0.5 m/s^2. That means workers driving more than 8hour a day have a low probability of adverse health effects in ISO2631-1:1997. However, when workers are exposed to WBV at 2hour or 4hour, the magnitude of vibration was higher than that of 8hour a day.

1.4. Conclusion: Although this study did not identify the adverse effects of WBV exposure to workers, WBV is still one of the potential contributors to the development of back disorders of workers. Therefore, further study would be needed to investigate this relationship using a more significant number of samples.

2. Introduction

In 2018, according to a report of workplace accidents by the Korean Statistical Information Service (KOSIS), occupational diseases occurred the total number of 11,473 cases. The distribution of the occupational diseases showed that 29.0% (3,322) of physical load, 28.6% (3,281) of back pain, 10.0% (1,153) of cerebral- cardiovascular disease, 12.3% (1,414) of noise-induced hearing loss (NIHL), 12.7%(1,451) of pneumoconiosis, 7.4% (852) of others. In particular, the physical load and the back pain in the status of occupational diseases accounted for 57.6% of the total. We already knew that these two factors were highly related to work-related musculoskeletal disorders (WMSDs) at the workplace [1].

According to the National Institute for Occupational Safety and Health (NIOSH) in the USA, WMSDs are defined as painful injuries and disorders that affect the human body's movement systems (muscle, tendon, and nerve). In general, WMSDs are associated with continual repetition of movements and force concentrated on small parts of the body, vibration exposure, etc.

In order to prevent WMSDs at the workplace, the South Korean government is conducting the legal investigation of risk factors of musculoskeletal disorders(MSDs) under Occupational Safety and Health (OSH) Standard Article 657. The legal investigation of

MSDs is divided into an introductory survey and a detailed survey. The introductory survey comprises three main parts: assessment of physical load, assessment of working posture, and a symptom questionnaire investigation. The detailed survey is conducted similar to an epidemiological survey under Occupational Safety and Health (OSH) Act Article 141.

The previous research for the management and prevention of musculoskeletal disorders showed that the working environment was improved by evaluating the working posture through ergonomic evaluation of workers at the workplace [3]. The previous study was also to measure the muscle loads of workers through electromyogram tests [4]. However, in previous studies, there was hardly any measurement and evaluation of worker response to vibration at the workplace, which is one factor of WMSDs.

Kim SG. [5] pointed out that if workers are exposed to vibration in a sitting posture or working posture for an extended period, they are likely to develop the WMSD. He also noted that further research is needed to investigate how to reduce vibration exposure in the workplace and how to identify the hazardous vibration level associated with WMSD.

This paper aims to measure the WBV in three different cars and evaluate the WBV exposure for health effects in automobile assembly line workers by ISO2631-1:1997.

3. Method

3.1. The evaluation of WBV using ISO2631-1:1997

The ISO 2631:1997 (International Organization for Standardization) standard guides “Mechanical vibration and shock-evaluation of human exposure to whole-body vibration." The purpose of ISO 2631-1:1997 is to identify methods for measuring periodic, random, and transient whole-body vibrations. This standard guide evaluates the effects of vibration on health, comfort, perception, and motion sickness [6-8].

3.1.1. Basic evaluation method: Frequency weighted r.m.s: The evaluation of vibration is calculated using the weighted r.m.s. acceleration defined by equation (1) from ISO 2631-1, as shown below

$$a_w = \left[\frac{1}{T} \int_0^T a_w^2(t)dt \right]^{1/2} \text{-----------------------------} (1)$$

Where ; a_w : the root-mean-square(r.m.s) , $a_w(t)$: the frequency-weighted acceleration (m/s²) , T : the measurement duration(seconds)

3.1.2. Crest Factor: Crest Factor is defined as the weighted r.m.s. value of the frequency signals to the maximum instantaneous peak of the signal for the weighted mean value. ISO 2631-1:1997 suggests that if the crest factor is less than 9, the weighted r.m.s. is ordinarily sufficient to evaluate vibration. However, when the crest factor is higher than 9, one additional method should be used, such as VDV (Vibration Dose Value) or MTVV (Maximum Transient Vibration Value).

$$C.F = \frac{max(a_w(t) \ :(peakvalue)}{r.m.s(\ a_w)} \text{-----------------}(2)$$

In this study, the crest factor is less than 9. Thus, this study considered the primary evaluation method.

3.1.3. Combining vibrations in more than one direction : There are vibrations in more than one direction, the total vibration value of weighted r.m.s. acceleration, determined from vibration in orthogonal coordinates, is calculated as follows:

$$a_v = \sqrt{k_x^2 a_{xw}^2 + k_y^2 a_{yw}^2 + k_z^2 a_{zw}^2} \text{----------------------}(3)$$

Where, a_v (vector sum) : The actual value used to evaluate the frequency weighted acceleration

$k_x = k_y = 1.4$, $k_z = 1$ indicates the frequency weighting

3.1.4. Equivalent continuous acceleration throughout 8hour: The daily vibration exposure level (A(8)) in ISO2631-1:1997/And 1: 2010, expressed as eight-hour energy equivalent continuous, frequency-weighted r.m.s. acceleration (A(8)) may be derived as follows:

$$A(8) = k * \left[\frac{1}{T_0} \int_0^T a_w^2(t)dt \right]^{1/2} \text{--------------------} \quad (4)$$

Where ; $a_w(t)$: the frequency-weighted acceleration (m/s²) , T : total duration of exposure within any period of 24 hours, T_0 : reference duration of 8hours, $k = k_x = k_y = 1.4$, $k_z = 1$ indicates the frequency weighting

3.1.5. Guidance on the effects of vibration on health: ISO 2631-1:1997 expressed as the health guidance caution zone in Figure 1. If someone were exposed to whole-body vibration for 8 hours per day, this provides the health guidance caution zones presented in ISO 2631-1. (A(8) <0.5 m/s²: Low potential health risk, 0.5 m/s² < A(8) <0.8 m/s² : Potential health risk , A(8) >0.8 m/s² : High potential health risk) (Figure 1).

3.2. Measurement condition

Vibration measurement was performed in the driving inspection course at the automobile assembly line in Figure 2. There are speed bumps in some parts of the driving inspection course. The choice of the measurement place was that the worker felt the vibration when driving the vehicle on the driving inspection course and felt the burden on the body (Figure 2).

Measurement equipment used in the measurement was a three-axis piezoelectric accelerometer (ACOEM Group, 01dB) and a data recorder(ACOEM Group, 01dB) in Figure 3. A three-axis piezoelectric accelerometer (ACOEM Group, 01dB) is mounted on the seat surface (Figure 3).

Two healthy male subjects participated in this measurement, and they worked in the driving inspection course. Before the measurement, the purpose of this study was explained to all subjects, who then gave their consent to participate. The vibration level was measured for different vehicle types such as cars, vans, and trucks. It is necessary to investigate how the vibration level differs when a worker drove different vehicle types from health viewpoints. Three different types of vehicles are measured for 5 minutes in the workplace. The vibration dose is evaluated by ISO2631-1:1997.

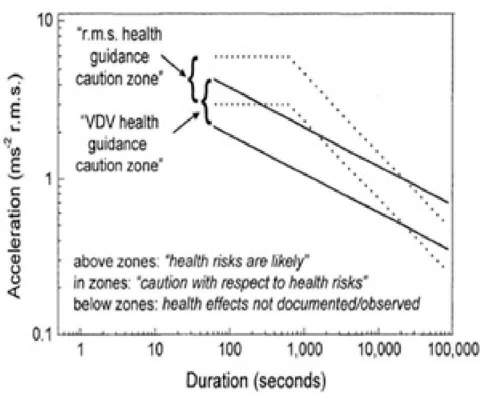

Figure 1: Health Guidance Caution Zone

Figure 2: Measurement Course

Figure 3: Measurement Device

4. Results

4.1. Vibration level of different vehicles under Measurement duration

The vibration level was measured for the different types of vehicles such as car, van, and truck, and the vibration level for different types of vehicles was compared in Table 1. The vibration level of the Z-axis has the largest regardless of the different types of vehicles. This means that the vibration level of up and down movements has more considerable than the other movements during vehicle driving. The second significant vibration level occurs in the left-right movement (Y-axis). On the contrary, the vibration level of the front and back movement (X-axis) was less than other axes. By comparing the vibration level of the different types of vehicles, the vibration level of the van (0.671 m/s^2) and that of the truck (0.690 m/s^2) have larger than that of the car (0.594 m/s^2). This trend has a similar result in previous studies [8-12] (Table 1).

Table 1: Magnitude of vibration at three different cars during the measurement time

No.	Car	Van	Truck
X-axis	0.184 m/s^2	0.227 m/s^2	0.270 m/s^2
Y-axis	0.301 m/s^2	0.308 m/s^2	0.282 m/s^2
Z-axis	0.594 m/s^2	0.671 m/s^2	0.690 m/s^2

4.2. Comparison of vibration level of different vehicles for 8hours of vibration exposure

IF worker is exposed to WBV for 8hours at the workplace, we evaluated how much work is exposed to the health risk by the health guidance caution zone of ISO2631-1:1997. To utilize the health guidance caution zone of ISO2631-1:1997, the total vibration level was calculated from the vibration level of each axis and evaluated according to equation (4). When automobile assembly line workers were operating the vehicle for 8 hours in the driving inspection course, the vibration level was not exceeded 0.5 m/s^2 regardless of the different vehicle types in Table 2. This means there is a low potential health risk in the health guidance caution zone of ISO2631-1:1997. Although the vibration level is low, the Z-axis movement (up-down) is larger than the other axis, and preventive measures are needed to reduce the Z-axis movement (up-down) (Table 2).

Table 2: Magnitude of vibration at three different cars for 8 hours

No.	Car	Van	Truck
X-axis (8Hour)	0.091 m/s^2	0.112 m/s^2	0.134 m/s^2
Y-axis (8Hour)	0.149 m/s^2	0.152 m/s^2	0.140 m/s^2
Z-axis (8Hour)	0.21 m/s^2	0.237 m/s^2	0.244 m/s^2
Total (8Hour)	0.332 m/s^2	0.355 m/s^2	0.364 m/s^2

4.3. Comparison of vibration level with vibration exposure time

Workers working in driving inspections at automobile assembly lines may have different exposure to WBV depending on the number of vehicles shipped per day. Therefore, the vibration level was evaluated by assuming that the worker was exposed to WBV for 2 hours, 4 hours, and 8 hours in Table 3. When workers are exposed to WBV at 2hour (Car: 0.644 m/s^2, Van: 0.711 m/s^2, Truck: 0.728 m/s^2) or 4hour (Car: 0.456 m/s^2, Van: 0.504 m/s^2, Truck: 0.515 m/s^2) the magnitude of vibration was higher than that of 8hour (Car: 0.322 m/s^2, Van: 0.355 m/s^2, Truck: 0.364 m/s^2) a day. This trend has a similar result in the health guidance caution zone of ISO2631-1:1997. This means that the vibration exposure time of workers is short. They are exposed to a high vibration level. However, when a worker is exposed to WBV for 2 hours, there is a low potential health risk in the health guidance caution zone of ISO2631-1:1997. Although the adverse effects of WBV on workers are small based on the health guidance caution zone of ISO2631-1:1997, in the case of a van or truck, it is necessary to pay attention to vibration because the vibration level is 0.7 m/s^2 or more (Table 3).

Table 3: Change of the magnitude of vibration at three different cars with exposure time

No.	2Hour	4Hour	8Hour
Car (Total)	0.644 m/s^2	0.456 m/s^2	0.322 m/s^2
Van (Total)	0.711 m/s^2	0.504 m/s^2	0.355 m/s^2
Truck (Total)	0.728 m/s^2	0.515 m/s^2	0.364 m/s^2

5. Discussions

In general, WMSDs are associated with continual repetition of movements and force concentrated on small parts of the body, vibration exposure, etc. [2]. However, the reports of the legal investigation of risk factors of MSDs in South Korea were hardly evaluated of worker response to vibration at the workplace, which is one factor of WMSDs. In order to find the reports of WBV in South Korea, we looked at the reports of the Occupational Safety and Health Research Institute (OSHRI). The OSHRI is a research institution that suggested the policies and development related to Occupational Safety and Health. According to a report released by OSHRI since 2000, three are three reports on vibration in industrial sites: OSHRI (2005) published "A Study on Whole-Body Vibration (WBV) of Drivers Operating Dump Trucks in a Tide Embankment and a Tunnel," OSHRI (2006) published "A Study on the Exposure Level of Whole-Body Vibration of urban Bus Drivers" and OSHRI (2011) published "Research on the Actual Vibration Exposure of Workers Engaging in Vibration Induced Works" [13-15]. We thought that the research on the effects of the human body on vibration at the workplace in South Korea was not actively conducted. In addition, we could not found that there is no assessment method of vibration in the OSH Act. When we look at the contents for prevention of vibration in the OSH Act, for workers exposed to vibration at the workplace, the employer provides the personal protective equipment (PPE), the health risk of vibration is informed, and inspection of the vibrating machines.

However, the ISO 2631:1997 guides evaluate the effects of vibration on health, comfort, perception, and motion sickness. The vibration level is displayed according to each evaluation item, and it helps the user quickly evaluate when workers are exposed to vibration at the workplace. Therefore, the government in South Korea should be provided to divide the evaluation item of vibration under Occupational Safety and Health (OSH) Standard as ISO2631-1:1997 and suggest the vibration level from health viewpoints of the worker.

6. Conclusions

The purpose of this paper is to measure the WBV in three different cars and to evaluate the WBV exposure for health effects in automobile assembly line workers by ISO2631-1:1997. This study shows that the vibration level of the Z-axis has the largest regardless of the different types of vehicles during the measurement time. The magnitude of vibration in three different cars was not exceeded 0.5 m/s^2. That means workers driving more than 8hour a day have a low potential health risk in ISO2631-1:1997. When workers are exposed to WBV at 2hour or 4hour the magnitude of vibration was higher than that of 8hour a day. It is thought that the research on the effects of the human body on vibration at the workplace in South Korea has not been actively conducted in the Discussions part. Although this study did not identify the adverse effects of WBV exposed to workers, whole-body vibration is still one of the potential contributors to the development of back disorders of workers. Therefore, further study would be needed to investigate this relationship using a more significant number of samples. This paper is also expected to evaluate the WBV exposure for health effects in automobile assembly line workers and develop the policy that concerns the prevention of WBV exposure to workers at the workplace.

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