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A review on WBV and its effects in automobile drivers

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Abstract: *The whole-body vibration (WBV) experienced by automobile drivers and the effects of WBV have been widely investigated. There exists a need to review the research literature investigating the evidence of WBV in automobile drivers and the effects of WBV. The aim of this review is to determine whether WBV exists in automobile drivers and then to find out the effects of WBV. Low Back Pain (LBP) is the most common musculoskeletal disorder (WMSD) resulting from WBV. Studies have shown that there exists a relationship between WBV exposure and LBP. Apart from LBP, several other WMSD were also identified by various researchers.*

Keywords: *Whole body vibration (WBV), WMSD, Low Back Pain.*

I. INTRODUCTION

Whole-body vibration (WBV) is transmitted through the seat or feet of employees who drive mobile machines, or other work vehicles, over rough and uneven surfaces as a main part of their job. Automobile drivers of vehicles are subjected to vibrations due to the vibrations generated from its engine, improper structural design of the vehicle and the bad road/surface conditions. Many studies on effects of whole-body vibration have been carried out in the past. Further low intensity frequency, medium intensity frequency and high intensity frequency may lead to increase or decrease the comfort and health related issues. Exposure to high levels of whole-body vibration can present risks to health and safety and can cause or aggravate back injuries to automobile drivers.

II. WHOLE BODY VIBRATION PARAMETERS

Whole body vibration (WBV) refers to the transmission to the human body of low frequency environmental vibration in the range of 0.5 to 80 *Hz* through a broad contact area, such as the feet when standing, the buttocks when sitting, or the reclining body when in contact with the vibrating surface. Occupational WBV exposure, especially when chronic, is suspected to cause adverse health effects such as fatigue, lower back pain, vision problems, interference with or irritation to the lungs, abdomen, or bladder, and adverse effects to the digestive, genital/urinary, and female reproductive systems. Mandatory standards for regulation and monitoring of worker exposure to WBV exist in Europe; in the U.S., there are reference standards but no specific regulations.

Vibration is measured as the variation with time of the magnitude of a quantity (eg. distance) about a point that describes the motion or position of a mechanical system (Griffin, 1990). With simple addition, the positive and negative distances traveled from the reference point would cancel each other and equal zero. For this reason, vibration is expressed as the root-mean-square (*RMS*) of the vibration accelerations (m/s^2) and is calculated by finding the square root of the arithmetic mean of the squares of individual vibration wave values. Measurement should last long enough to adequately describe or estimate the typical daily exposure of a worker and may require separate analyses of variable exposures during work tasks (ISO, 1997;ANSI, 2002). A complete assessment of exposure to vibration requires the measurement of the following.

1. Vibration acceleration in meters per second squared (m/s^2).
2. Vibration exposure direction in a well-defined directions.
3. Vibration frequencies and duration of exposure.

A typical vibration measurement system includes a device to sense the vibration (accelerometer), and an instrument to measure the level of vibration. This equipment also has settings for measuring frequency. As outlined in the ISO 2631-1 Standard, when crest factors are greater than 9, transient shocks may be presented in the vibration data and the average weighted vibration (A_w) should be interpreted with caution since the vibration exposures may be underestimated. In these cases, the vibration dose value (VDV) can be used to further characterize the vibration exposures.[1]

The most widely used document on this topic is Guide for the Evaluation of Human Exposure to Whole Body Vibration (***ISO 2631***). According to the ISO standard, WBV on a person in the seated position needs to be measured at all the supporting surfaces (seat, back, and feet) along the three axes. The *ISO 2631-1* standard defines a basic evaluation method for determining weighted *rms* acceleration to evaluate the impact of WBV. The following equation (1) is used to calculate the weighted *rms* acceleration:

$$r.m.s = \left[\frac{1}{T} \int_0^T a_w^2(t)\ dt \right]^{1/2} \qquad (1)$$

where, *aw(t)* = the weighted acceleration as a function of time measured in m/s^2
T = the duration of the measurement in seconds

The weighted *rms* acceleration needs to be determined for each axis of vibration on the surface that supports the person. The *ISO* standard defines the comfort reactions to vibration environments as shown in TABLE-1 below.

Table-1

Measured Vibration Level of Comfort (m/s^2)	**Level of Comfort**
Less than 0.315	Not Uncomfortable
0.315 to 0.63	A little comfortable
0.5 to 1	Fairly uncomfortable
0.8 to 1.6	Uncomfortable
1.25 to 2.5	Very uncomfortable
Greater than 2	Extremely uncomfortable

For certain types of vibrations, particularly those with occasional shocks, the basic method may not be sufficient. In those cases, the ISO standard provides alternative methods such as the running *rms* or fourth-power ***Vibration Dose Value*** which is expressed below.

$$VDV = \left[\frac{1}{T} \int_0^T a_w^4(t)\ dt \right]^{1/4} \qquad (2)$$

These 4th power methods reflect an increased human sensitivity to high amplitude acceleration events [2]. The ISO 2631-5 standard uses raw, continuously collected tri-axial WBV exposure data to calculate a daily equivalent ***static compressive dose*** ($\mathbf{S_{ed}}$) on the lumbar spine[1]. The threshold values for adverse health effects over a lifetime of exposure, based on an average 8-hour daily equivalent exposure, are shown on the right side of TABLE- 2.

Table-2 -Daily (8-h) action and exposure limits for whole body vibration

	European Union Directive		**ISO 2631-1**		**ISO 2631-5**	
	$\mathbf{A_w}$	**VDV**	$\mathbf{A_w}$	**VDV**	$\mathbf{S_{ed}}$	**Probability of an adverse health effect**
	m/s^2	$m/s^{1.75}$	m/s^2	$m/s^{1.75}$	*Mpa*	
Action limit	0.5	9.1	0.5	9.1	0.5	***Moderate***
Exposure limit	1.15	21	0.8	14.8	0.8	***High***

The longer a person is exposed to a vibrating environment, the greater the risk of health effects. However, it generally takes years for health issues due to WBV to occur. To avoid long-term health risks associated with WBV, the continued exposure to vibration on the human body needs to be accurately measured and analyzed.

III. EVIDENCE OF EXISTENCE OF WBV IN AUTOMOBILE DRIVERS

Ornwipa Thamsuwan in his study [1] tried to find out the differences exist in WBV exposures between two buses commonly used in long urban commuter routes: a high-floor coach and a low-floor city bus.

Each bus was driven over a standardized test route which included four road types: a newer smooth freeway, a rougher old freeway, a city street segment, and a road segment containing several speed humps. WBV exposures were calculated per ISO 2631-1 (1997) and ISO 2631-5 (2004) standards. WBV exposures were significantly higher in the highfloor coach bus on the road segment containing speed humps. There were primarily small differences between buses in WBV exposures encountered on the city street and freeway segments. With respect to the ISO 2631-1 and European Union's A(8) and VDV(8) action limit values, both buses could be operated on the smooth freeway without exceeding the 8-hour action limits but would have to be operated less than 8 h when operating on the other road types.

Ramakrishnan Mani in his study [3] suggests that balance deficits may exist immediately following exposure to occupational seated WBV and may predispose driver/operator to low back injury during manual material handling tasks immediately post driving.

Bazil Basri in his experimental study [4] investigated the discomfort arising from whole-body vertical vibration when sitting on a rigid seat with no backrest and with a backrest inclined. He found out that at frequencies greater than about 8 Hz, the backrest increased vibration discomfort, especially when inclined to 30°, 60°, or 90°, and there was greater discomfort at the head or neck and at frequencies around 5 and 6.3 Hz there was less vibration discomfort when sitting with an inclined backrest.

S. Rakheja studied [5] the data on biodynamic responses of the seated and standing human body exposed to whole-body vibration along different directions and systematically reviewed in an attempt to identify datasets that are likely to represent comparable and practical postural and exposure conditions. Syntheses of datasets, selected on the basis of a set of criterion, were performed to identify the most probable ranges of biodynamic responses of the human body to whole-body vibration.

IV. EVIDENCE OF EFFECTS OF WBV IN AUTOMOBILE DRIVERS

The survey based study conducted by Shyamal Koley [6] was on the severity of low back pain in 169 male tractor drivers from Ludhiana, Punjab, India, aged 21- 60 years. Of these 169 tractor drivers, a total of 29 (17.16%) had reported their complications regarding low back pain and the rest 140 (82.84%) had no complications for their back pain. To assess the severity of pain, the modified Oswestry Pain Questionnaire was used. The findings of the present study indicate a gradual increase of pain scores with the increased exposure to whole-body vibration with the increase of age. The result showed that tractor drivers were exposed to low frequency whole body vibrations making them vulnerable to low back pain. Because tractors do not have suspension system, the vibration levels are high as compared to other road vehicles. The experimental study conducted by K. Melemez, M. Tunay [7] presents exposure to whole-body vibration during occupational operation of loading tractor. Whole-body vibration was analysed at the seat-operator interface using a tri-axial accelerometer at 145 forestry loading operations in Turkey. The mean total vibration value was found 1.38 ms^{-2} at loading equipment mounted tractors and 1.06 ms^{-2} at original loading machines. The regression analysis was performed in order to determine the most important factors that affect total vibration value transmitted to the tractor operator. Based on the data analysis, it was identified that the most important factors that affect the total vibration value were machine type, ground roughness condition, ground type, wheel pressure, seat condition and operator weight. He proposed that the use of original loading machines should be encouraged. Also, he suggested that the operator seats having an automatic mass adjustment mechanism should be used.

The objective of the study made by E.K. Gillin [8] was to determine if the exposure to whole body vibration of scraper operators exceeded the 1997 ISO Standard 2631. The operator completed five distinct tasks: 1) traveling fully loaded with dirt, 2) dumping and distributing dirt, 3) traveling empty, 4) idling while waiting to be pushed by a bull-dozer to scrape more dirt, 5) scraping a new load of dirt. Twenty-minute vibration samples that included at least three work cycles were taken using 33 scrapers. The average rms acceleration of the z-axis was 1.21 m/s2. The dominant axis for which the vibration acted through the seat was the z-axis (vertically through the seat pan). Vector sum values were 2.08 m/s2. This leads one to conclude that all scrapers will expose the operator to excessive levels of whole body vibration that may lead to injury or illness. The results showed that WBV values obtained demonstrate that a major health hazard exists for the operators of scrapers.

Researcher Silviu Nastac [9] studied the whole-body vibration in trains which constitutes one aspect of the physical environment that can cause discomfort to passengers. The results indicated that the vibration in trains is not severe, but could occasionally cause some discomfort.

V. CONCLUSION

Based on the literature review conducted, it leads to the conclusion that WBV exists in automobile drivers exceeding the permissible limits as laid in the standards. The extent of WBV is so severe that it leads not only to musculoskeletal disorders but can also leads to mental related issues to the drivers. The solution for reduction of WBV lies in the designers' hands. A better seat design might can enable a decrease of floor to seat WBV transmissibility. Modifying the automobile suspension, cab vibration absorption and automobile engine mounts will keep the solution at the source of the problem rather than at the driver.

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