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Vibrational Exposure Analysis on Human Body: Road Condition Status in City

Chitranjan Kumar[1], BibhutiBhusansahoo[2] ,Prasant Kumar Sahu[3]
[1,3]Assistant Professor, Department of Mechanical Engineering, Gandhi Institute For Technology (GIFT), Bhubaneswar
[2]Assistant Professor, Department of Mechanical Engineering, Gandhi Engineering College, Bhubaneswar

ABSTRACT
Cars are the most important forms of public transportation worldwide. However, high magnitude whole-body vibration (WBV) that can be associated with car travel may lead to various diseases and health problems, such as lower back pain, in humans. This study gives an account of the Daily Exposure to Vibration A(8) and Vibration Dose Value (VDV) experienced by the train and car passengers, with care taken to elucidate the effects of WBV on the human body. This study was conducted on a Malaysian national car. The WBV exposure was measured for duration of 8 hours, which is equivalent to a typical travel time of a passenger, driver or worker. Data was collected using an IEPE (ICP^{TM}) accelerometer sensor connected to a DT9837 device, capable of effectively measuring and analyzing the vibrations. The vibration results were displayed on a personal computer using a custom graphical user interface (GUI). Matlab software was used to interpret the results and determine the WBV exposure level. The values of Daily Exposure to Vibration A(8) and the Vibration Dose Value during one stretch for car study was 1.0782 m/s^2 and 6.3314 m/s$^{1.75}$. The results here confirm that WBV absorbed by the human body increases with an increase in the duration of vibration exposure and the number of trips taken by a passenger, illustrated by the increase in the value of Daily Exposure to Vibration A(8) and the calculated Vibration DoseValue.

***KEYWORDS**: Whole-body vibration, Daily Exposure to Vibration A(8), Vibration dose value, Low back pain, Vibration.*

I. INTRODUCTION

Ergonomics is the application of scientific principles, methods and data drawn from a variety of disciplines to the development of engineering systems in which people play a significant role. Among the basic contributing disciplines are psychology, cognitive sciences, physiology, biomechanics, applied physical anthropometry and industrial systems engineering (Kroemer et al., 2003). The importance of safety and ergonomics has grown significantly over the past years (Matilla, 1996). The latest technology has allowed for the expanded used of ergonomics and additional safety features in products and equipment. At the same time, new technology has created new risks, and the management of these risks is more complicated. For this reason, it is important for adesigner to use his knowledge of ergonomics during the design process of machines, equipment, products and systems. There is substantial epidemiologic evidence that links physical ergonomics exposures at the workplace, such as lifting, constrained postures, repetitive movements, fast work pace, handling of heavy material, forceful exertions and vibration, to the occurrence of upper extremity musculoskeletal disorders (Bernard, 1997; Grieco et al., 1998; Hagberg et al., 1995; NRCIM, 2001; van der Windt et al., 2000). Ergonomics (also called human factors or human engineering in the United States) can be defined as the study of human characteristics for the appropriate design of the living and work environment. Its fundamental aim is that all human-made tools, devices, equipment, machines, and environments should advance, directly or indirectly, the safety, well-being, and performance of human beings (Kroemer et al., 2003). Several ergonomic interventions, such as employee training, redesign of process tools or workstations and improvement of work conditions, have been suggested and implemented to tackle musculoskeletal problems related to industrial work (Wang et al., 2003; Weestgard and Winkel,1997).

Depending on the source, WBV has been given a variety of definitions. From the Directive 2002/44/EC of the European Parliament and of the Council, the term 'whole-body vibration' refers to the mechanical vibration that, when transmitted to the whole body, entails risks to the health and safety of workers, in particular lower-back morbidity and trauma of the spine (Directive 2002/44/EC). WBV is defined as the vibration that occurs when the greater part of a person's weight is supported on a vibrating surface. WBV principally occurs in vehicles and wheeled working machines. In most cases exposure to WBV occurs when the person is in a sitting position and the vibration is thus primarily transmitted through the seat pan, with additional transmittance through the backrest. WBV may impair performance and comfort. It may also contribute to the development of various injuries and disorders. In many work situations, WBV is a prominent and troublesome occupational health problem (Griffin, 1990).

Lower back pain (LBP) is among the most common and costly health problems (Garg and Moore, 1992; Van Tulder et al., 1995). Occupational, non-occupational, and individual risk factors play a role in the development, the duration, and the recurrence of LBP. Several critical reviews have discussed the occupational risk factors that result in back disorders (Wilder and Pope, 1996; Burdorf and Sorock, 1997; Bovenzi and Hulshof, 1999; Lings and Leboeuf, 2000; Waddell and Burton, 2001). All of these reviews conclude that there is strong epidemiological evidence relating occupational WBV exposure to LBP. In five European countries (Belgium, Germany, Netherlands, France, Denmark), LBP and spinal disorders due to WBV are currently recognized as occupational diseases (Hulshof et al., 2002). However, WBV remains a common occupational risk factor for LBP, with high exposures and the resulting injuries affecting 4% to 8% of the workforce in industrialized countries (Palmer et al., 2000). Important high risk groups include drivers of off-road vehicles (such as those used for earth moving, forestry, and agriculture), drivers of forklift trucks, lorries, and buses, crane operators, and helicopterpilots.

II. EXPERIMENTAL DESIGN

WBV measurements were conducted according to ISO 2631-1:1997. The triaxial accelerometer sensor was located between the passenger's contact points and thevibration source. During the test, a randomly chosen passenger sat on the accelerometer, shown in Figure 1.

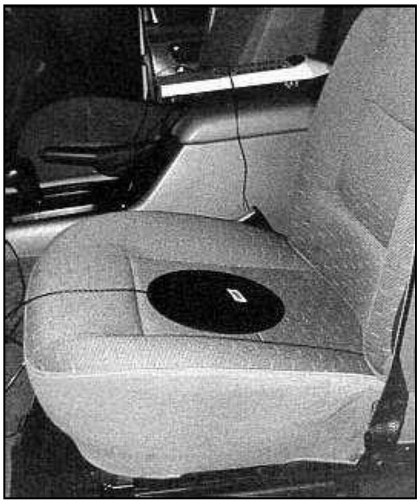


Figure 1: Triaxial accelerometer sensor used for WBV measurement

The two measurement devices used in the study were the IEPE(ICP^{TM}) accelerometer sensor, and a DT9837 instrument. The IEPE(ICP^{TM}) accelerometer sensor (also known as a triaxial seat accelerometer) was a DYTRAN Model 5313A. The sensor was used to assess the vibration level. The DT9837 instrument was a highly accurate five channel data acquisition module that is ideal for portable noise and vibration measurements. In this study, Matlab software was used to analyze the vibration signal gathered by the DT9837 instrument via a USB port. The Matlab Graphical User Interface (GUI) scripts were examined using the *GUIDE* function for ease of measurement and assessment of WBV exposure. Using this Matlab script, three graphs, displaying the three different axes of vibration, were displayed for real time observation. The collected data were also saved in the computer for subsequent analysis. Thus, in this work, the total daily exposure to vibration towards humans was evaluated using an accelerometer sensor, a DT9837 instrument and Matlab software. Excessive exposure of WBV typically occurs when the exposure duration is long and accompanied with a large vibration magnitude. While the road surface circumstance is one of the environmental factors that may contribute to high-level of vibrationmagnitude.

The Malaysian car traveling from the east coast to the southern part of the country was chosen for this study. WBV measurements using a randomly chosen passenger were performed three times at three different locations. The WBV was sampled 1000 times per second. For each experiment, the exposure time was set to 8 hours, which is equivalent to the duration of a typical occupational exposure time. The study was conducted at different locations. After the accelerometer and DT9837 were connected, the data collection began. The total vibration along each axis (x, y, and z) felt by the passenger was displayed in a graph using Matlab. Road surface circumstance is a big dominant parameter towards WBV especially at low frequency. One Malaysian national car was chosen to conduct the study. The car passenger was picked up randomly without consideration of the individual characteristics of the passenger. In this study, WBV measurements were done by changing the road condition passed by the car. Calculationoftheexposuretimewassetto5minand10minrespectively.Thestudywas conducted at different locations with different road conditions. The road circumstances for each experiment is listed in Table 1. WBV measurements explored by the car passenger were conducted three times at three different road conditions. Among the road conditiopns passed by the car were uneven and zigzag road, even and zigzag road, and lastly even and straight road.

Table 1: Road Circumstances

Experiment	Measurement Time (min)	Road Condition
1	5	Uneven and zigzag road
2	10	Even and zigzag road
3	10	Even and straight road

III. RESULTS AND DISCUSSION

From the two experiments conducted, the Daily Exposure to Vibration A(8) value and Vibration Dose Value (VDV) were evaluated using Matlab features, according to formulas (1) and (2) listed below (Hostens and Ramon, 2003). The results were displayed in the custom made Graphical User Interface (GUI).

The Daily Exposure to Vibration A(8) was calculated as follows;

$$A(8) = vibration\ value\left(\frac{m}{s^2}\right) \times \sqrt{\frac{exposure\ time\ (min)}{480\ (min)}} \qquad (1)$$

The Vibration Dose Value (VDV) was calculated as follows;

$$VDV = \left(\int_0^T a^4(t)\,dt\right)^{0.25} \qquad (2)$$

where,
$a(t)$ = frequency-weighted acceleration (m/s^2)
T = the total period of the day during which vibration may occur(s)

WBV graphs were demonstrated in Figure 2. From the analysis, three different road surface conditions have been passed through for WBV assessment occurred in the car. The first road type was uneven and zigzag road at Golf Kajang. The second condition was even and zigzag road which at University Kebangsaan Malaysia (UKM) areas. While the third road was at Bandar BaruBangi areas which even and straight road. The speed of the car during the study was set to 40km/h. All the data obtained in the experiment are shown in Table 2. Whole-body vibration graphs were demonstrated in Figure 2. For Figure 2(a), the graph of whole-body vibration was collected at uneven and zigzag road, while Figure 2(b) was at even and zigzag road, and Figure 2(c) was even and straightroad.

Table 2: Whole-body Vibration Measurement Data Collected in Car

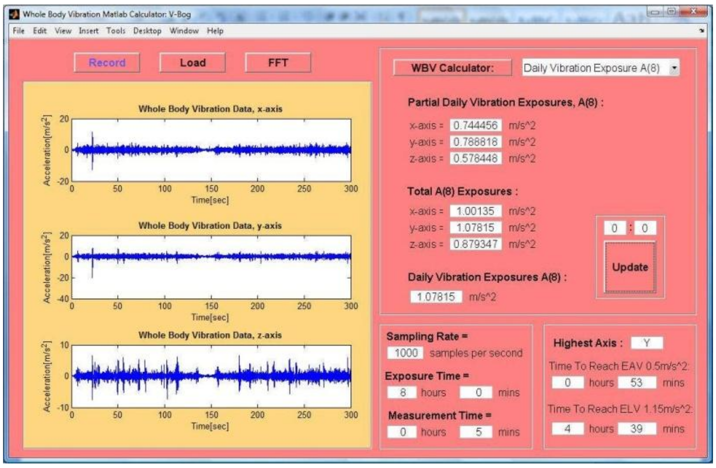
Analysis Method	**Experiment 1 (5 min) Uneven and Zigzag Road**	**Experiment 2 (10 min) Even and Zigzag Road**	**Experiment 3 (10 min) Even and Straight Road**
Daily exposure to vibration A(8)	1.0782 m/s^2	0.8097 m/s^2	0.7928 m/s^2
Exposure points system	464.96 point	262.219 point	251.381 point
Vibration dose value (VDV)	6.3314 $m/s^{1.75}$	4.3958 $m/s^{1.75}$	3.7264 $m/s^{1.75}$
Daily exposure action	53 min	93 min	97 min
Daily exposure limit	279 min	494 min	515 min
Points per hour	58.1201	32.7773	31.4226
Time achieving	812 min	3494 min	6765 min

value time (0.5 m/s^2) value time (1.15 m/s^2)

1.75 $m/s^{1.75}$

WBV risks towards human's health enhanced when the amplitude of the vibration signal absorbed by the human body increased. This situation was proved by the comparison of the three experiments done in the study. In the first experiment, the uneven and zigzag road surface had boost up the vibration amplitude. Thus, the daily exposure to vibration A(8) and the vibration dose value (VDV) absorbed by the passenger was higher compared to experiment 2 and experiment 3 eventhough the measurement time only took 5 min. At the same time, exposure WBV points system value in experiment 1 was high too. In other words, daily exposure action value time (0.5 m/s^2) and daily exposure limit value time (1.15 m/s^2) were at low level than in experiment 2 and3.

This study finds that, the frequency-weighted acceleration value associated with car travel in Malaysia is close to the permissible exposure limit stated in ISO 2631- 1:1997. Hence, the high magnitude of WBV experienced by the passenger of a moving car may cause musculoskeletal disorders. The basic method discussed in ISO 2631-1 involves a frequency-weighted root-mean-square (r.m.s.) calculation that is primarily applicable to the assessment of health risks from stationary vibrations and does not account for severe single or multiply occurring shock events. Single shocks events can be analyzed with additional methodology that involves a running r.m.s. calculation as described in 2631-1, although no information on the health risk levels of single event shocks is provided in the literature. This additional method involves a (frequency- weighted fourth power vibration dose value (VDV)), and is more sensitive to shocks than the basic method. However, the VDV method will underestimate the health risks of vibration that contains severe shocks in comparison to the health risks of vibration that does not containing severe shocks. The EU Physical Agents Directive uses the basic method for the assessment of health risks, with VDV as an alternative. The two methods give different assessment results (Kjell and Miltek,1999).



WBV Calculator: Daily Vibration Exposure A(8)

Partial Daily Vibration Exposures, A(8) :
x-axis = 0.744456 m/s^2
y-axis = 0.788818 m/s^2
z-axis = 0.578448 m/s^2

Total A(8) Exposures :
x-axis = 1.00135 m/s^2
y-axis = 1.07815 m/s^2
z-axis = 0.879347 m/s^2

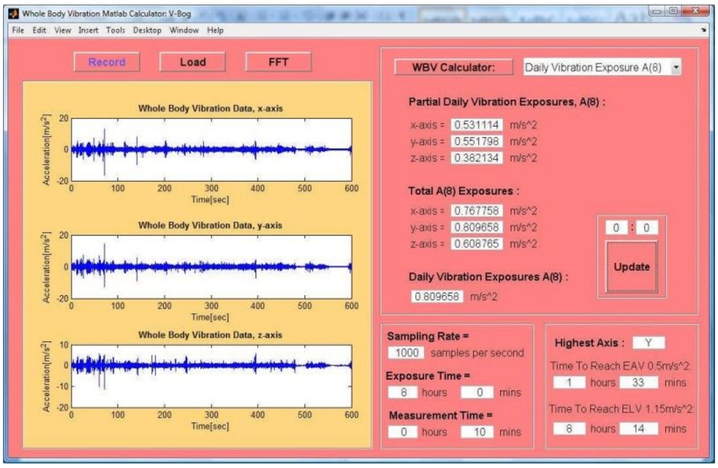
0 : 0

Daily Vibration Exposures A(8) :
1.07815 m/s^2

Sampling Rate = 1000 samples per second
Exposure Time = 8 hours 0 mins
Measurement Time = 0 hours 5 mins

Highest Axis : Y
Time To Reach EAV 0.5m/s^2: 0 hours 53 mins
Time To Reach ELV 1.15m/s^2: 4 hours 39 mins

(a)



WBV Calculator: Daily Vibration Exposure A(8)

Partial Daily Vibration Exposures, A(8) :
x-axis = 0.531114 m/s^2
y-axis = 0.551798 m/s^2
z-axis = 0.382134 m/s^2

Total A(8) Exposures :
x-axis = 0.767758 m/s^2
y-axis = 0.809658 m/s^2
z-axis = 0.608765 m/s^2

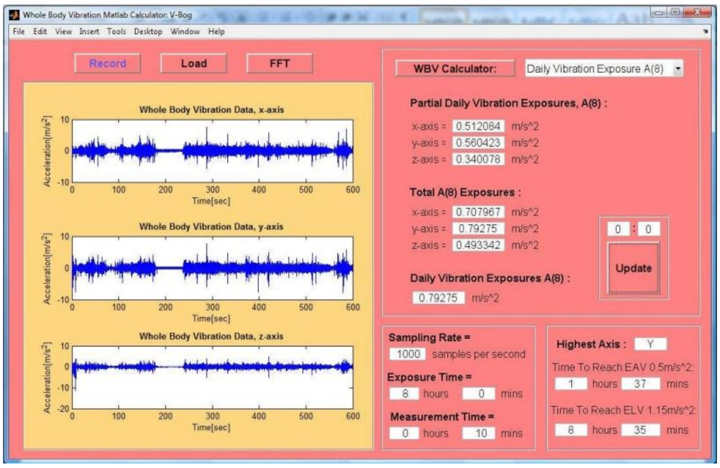
0 : 0

Daily Vibration Exposures A(8) :
0.809658 m/s^2

Sampling Rate = 1000 samples per second
Exposure Time = 8 hours 0 mins
Measurement Time = 0 hours 10 mins

Highest Axis : Y
Time To Reach EAV 0.5m/s^2: 1 hours 33 mins
Time To Reach ELV 1.15m/s^2: 8 hours 14 mins

(b)



WBV Calculator: Daily Vibration Exposure A(8)

Partial Daily Vibration Exposures, A(8) :
x-axis = 0.512084 m/s^2
y-axis = 0.560423 m/s^2
z-axis = 0.340078 m/s^2

Total A(8) Exposures :
x-axis = 0.707967 m/s^2
y-axis = 0.79275 m/s^2
z-axis = 0.493342 m/s^2

0 : 0

Daily Vibration Exposures A(8) :
0.79275 m/s^2

Sampling Rate = 1000 samples per second
Exposure Time = 8 hours 0 mins
Measurement Time = 0 hours 10 mins

Highest Axis : Y
Time To Reach EAV 0.5m/s^2: 1 hours 37 mins
Time To Reach ELV 1.15m/s^2: 8 hours 35 mins

(c)

Figure 2: Whole-body vibration custom data acquisition system (a) Uneven and zigzag road, (b) Even and zigzag road, and (c) Even and straight road

The (r.m.s) vibration magnitude is expressed in terms of the frequency-weighted acceleration at the seat of a seated person or the feet of a standing person, in units of meters per second squared (m/s^2). The r.m.s vibration magnitude represents the average acceleration over a measurement period. The vibration exposure is assessed using the highest of the three orthogonal axes values ($1.4a_{wx}$, $1.4a_{wy}$ or a_{wz}). A frequency- weighted acceleration value less than $0.45 m/s^2$ mean that no negative health effect should be expected. A frequency-weighted value between $0.45 m/s^2$ and $0.90 m/s^2$ implies the possibility of negative health effects. A frequency-weighted acceleration value greater than $0.90 m/s^2$ suggests high risks of negative health problems. Table 3 shows the r.m.s acceleration value limits for exposures up to 8 hours. Vibrations experienced by the train and car passengers must not exceed the given limits, or they risk the development of vibration-related healthproblems.

Table 3: Standard value of RMS acceleration

Exposure Limit	**8 hrs**	**4 hrs**	**2.5 hrs**	**1 hr**	**30 min**	**5 min**	**1 min**
RMS acceleration	2.8 m/s^2	4.0 m/s^2	5.6 m/s^2	11.2 m/s^2	16.8 m/s^2	27.4 m/s^2	61.3 m/s^2

A study in 1983 looked at exposure to accident risk, including characteristics of the amount of travel, conditions of travel and characteristics of the driver and vehicle undertaking the travel (Ziari and Khabiri, 2006). The high WBV exposure may result in musculoskeletal disorders to the drivers. Musculoskeletal disorders continue to be a major source of disability and lost work time (Ghasemkhani et al., 2006). There are several examples in the literature that relate WBV exposure from occupational vehicles to musculoskeletal disorders. The term musculoskeletal disorder refers to conditions that involve the nerves, tendons, muscles, and supporting structures of the body (Bernard, 1998).

Exposure to WBV is another occupational risk factor that may cause LBP in participants of occupational vehicles (Bovenzi and Hulshof, 1999). In western countries, an estimated 4–7 percent of all employees are exposed to potentially harmful doses of WBV. Experimental studies have found that resonance frequencies of most of the organs or other parts of the body lie between 1 and 10 Hz, which are in the range of frequencies found in occupational machines and vehicles. Six million workers are exposed to WBV, typically while in a seated position. Workers at risk include delivery vehicles drivers, forklift operators, helicopters pilots, and construction equipment operators (Griffin, 2006). Tractor drivers have reported a 61–94% prevalence of LBP and pathological changes in the spine, and heavy-equipment drivers report a 70% prevalence of LBP. WBV is recognized as an important risk factor for occupational LBP in a variety of occupational groups (Joubert and London, 2007). At least four European countries have placed WBV injury on their official lists of occupational diseases (Hulshof et al., 2002). Among such physical exposures encountered in working conditions, WBV has repeatedly been identified as a risk factor for LBP (Santos et al., 2008). Several epidemiologic studies conducted in the past several years have found strong evidence of a correlation between WBV exposure and the onset of LBP (Noorloos et al., 2008). Joubert and London (2007) studied the association between back belt usage and back pain among forklift drivers that were frequently exposed to WBV. LBP has been identified as one of the most costly disorders among the working populationworldwide,andsittinghasbeenassociatedwiththeriskofdevelopingLBP(Lis et al., 2007). It was shown that sustained truck sitting postures maintained by mining vehicle operators generates back muscle fatigue and postural balance issues (Santos et al., 2008).

IV. CONCLUSION

In this work, it was found that the exposure of the human body to WBV increased with an increase in the vibration exposure magnitude and duration, as illustrated. The increase in the Daily value of Exposure to Vibration A(8) values and Vibration Dose Values (VDV) with increasing travel time and trip quantity. In this work, the frequency-weighted acceleration value recorded on the Malaysian car was found to be close to the accepted exposure limit set in ISO 2631-1:1997. Hence, most of the passengers on these cars are being subjected to potentially dangerous levels of WBV during their travel. WBV exposure is known to cause health problems in humans. Empirical studies have shown that drivers that are exposed to WBV while in occupational vehicles often have musculoskeletal disorders. However, in Malaysia there is currently insufficient research dedicated to the problem. Because the general public is unaware of the seriousness of WBV, car drivers are often not given information concerning WBV exposure and the related health risks. In conclusion, more studies are needed to provide clear evidence of the association between WBV and musculoskeletal disorders, especially involving to Malaysian occupational vehicles. A future study should focus on an occupational vehicles driver's exposure to WBV and the consequent healthproblems.

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REFERENCES

[1]. Bernard, B.P. 1997. Musculoskeletal disorders and workplace factors: A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. National Institute for Occupational Safety and Health, Cincinnati, OH.
[2]. Bernard, B.P. 1998. Musculoskeletal disorders and workplace factors: a critical review of epidemiologic evidence for work-related disorders of the neck, upper extremities, and low back. NASA no. 19980001289.
[3]. Bovenzi, M. and Hulshof, C.T.J. 1999. An updated review of epidemiologic studies on the relationship between exposure to whole-body vibration and low back pain. Int. Arch. Occup. Environ. Health, 72(6): 351–365.
[4]. Burdorf, A. and Sorock, G. 1997. Positive and negative evidence of risk factors for back disorders. Scand J Work Environ Health, 23: 243–56.
[5]. Directive 2002/44/EC of the European Parliament and of the Council of 25 June 2002, Official Journal of the European Communities, pp.13−19.
[6]. Garg, A. and Moore, J.S. 1992. Epidemiology of low-back pain in industry.
[7]. Occupational Medicine, 7: 593–608.
[8]. Ghasemkhani, M., Aten, S. and Azam, K. 2006. Musculoskeletal symptoms among automobile assembly line workers. Journal of Applied Sciences, 6(1): 35-39.
[9]. Grieco, A., Molteni, G., De Vito, G. and Sias, N. 1998. Epidemiology of musculoskeletal disorders due to biomechanical overload. Ergonomics, 41: 1253–1260.
[10]. Griffin, M.J. 1990. Handbook of human vibration. London: Academic Press, pp.171- 220.
[11]. Griffin, M.J. 2006. Health effects of vibration – the known and unknown. Conference on Human Vibration, Morgan Town, pp.3–4.
[12]. Hagberg, M., Silverstein, B., Wells, R., Smith, M.J., Hendrick, H.W., Carayon, P. andPerusse, M. 1995. In: Kuorinka, I., Forcier, L. (Eds.), Work related musculoskeletal disorders (WMSDs): a reference book for prevention. London: Taylor & Francis.
[13]. Hostens, I. and Ramon, H. 2003. Descriptive analysis of combine cabin vibrations and their effect on the human body. Journal of Sound and Vibration, 266: 453–464. doi: 10.1016/S0022-460X(03)00578-9.
[14]. Hulshof, C., Van Der Laan, G., Braam, I. and Verbeek, J. 2002. The fate of Mrs. Robinson: criteria for recognition of whole-body vibration injury as an occupational disease. Journal of Sound and Vibration, 253: 185–194.
[15]. Joubert, D.M., and London, L. 2007. A cross-sectional study of back belt use and lowback pain amongst forklift drivers. International Journal of Industrial Ergonomics, 37: 505–513.
[16]. Kjell S. and Miltek, KS.. 1999. Project OSHA SME/2002/4668/DK. Ongoing standardization work of interest to the project. http://www.agrivib.com/pdf/RelevantStandards.pdf, accessed on 12-12-2009.
[17]. Kroemer K., Kroemer H.K., Elbert K.K., 2003. Ergonomics how to design for ease and efficiency. Second edition. NY: Prentice Hall.
[18]. Lings S. and Leboeuf, Y.C., 2000. Whole-body vibration and low back pain: a systematic, critical review of the epidemiological literature 1992–1999. Int Arch Occup Environ Health, 73: 290–297. doi: 10.1007/s004200000118.
[19]. Lis A.M., Black K.M., Korn H., Nordin M., 2007. Association between sitting and occupational LBP. Eur Spine J, 16: 283–298.
[20]. Matilla M., 1996. Computer-aided ergonomics and safety – A challenge for integrated ergonomics. International Journal of Industrial Ergonomics, 17: 309-314.
[21]. NRCIM (National Research Council, Institute of Medicine). 2001. Musculoskeletal disorders and the workplace: low back and upper extremities. Washington, D.C.: National AcademyPress.
[22]. Noorloos, D., Tersteeg, L., Tiemessen, I.J.H, Hulshof, C.T.J. and Frings-Dresen,
[23]. M.H.W.2008.Doesbodymassindexincreasetheriskoflowbackpainina population exposed to whole body vibration? Applied Ergonomics,39:779–785.
Palmer,K.T.Griffin,M.J.Bendall,H.2000.PrevalenceandpatternofoccupationalexposuretowholebodyvibrationinGreatBritain:findings fromanationalsurvey. Occupational Environmental Medicine, 57: 229–236.
[24]. Santos, B.R., Lariviere, C., Delisle, A., Plamondon, A., Boileau, P-E. andImbeau D. 2008. A laboratory study to quantify the biomechanical responses to whole-body vibration: The influence on balance, reflex response, muscular activity and fatigue. International Journal of Industrial Ergonomics, 38: 626–639.
[25]. van der Windt, D.A., Thomas, E., Pope, D.P., de Winter, A.F., Macfarlane, G.J., Bouter,
[26]. L.M. and Silman, A.J. 2000. Occupational risk factors for shoulder pain: a systematic review. Occup. Environ. Med., 57: 433–442.
[27]. Van Tulder, M.W, Koes, B.W. and Bouter, L.M. 1995. A cost-of-illness study of back pain in The Netherlands. Pain, 62: 233–240.
[28]. Waddell, G. and Burton, A.K. 2001. Occupational health guidelines for the management of low back pain at work; Evidence review. Occupational Medicine, 51: 124- 135. doi: 10.1093/occmed/51.2.124.
[29]. Wang, M.J.J., Chung, H.C. and Wu, H.C. 2003. The evaluation of manual FOUP handling in 300 mm wafer fab. IEEE Transactions on Semiconductor Manufacturing, 16: 551–554.
[30]. Weestgard, R.H. and Winkel, J. 1997. Ergonomic intervention research for improve musculoskeletal health: a critical review. International Journal of Industrial Ergonomics, 20: 463–500.
[31]. Wilder, D.G. and Pope, M.H. 1996. Epidemiological and aetiological aspects of lowback pain in vibration environments—an update. Clinical Biomechanics, 11: 61– 73.
[32]. Ziari, H. and Khabiri, M.M. 2006. Analysis characteristics and provide a prediction model of public bus accident in Tehran. Journal of Applied Science, 6(2): 247- 250.