International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Effect of Whole-Body Vibration on Vehicle Operators: A Review

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Abstract: ***Operators of on road and off-road vehicles have been associated with discomfort and a number of musculoskeletal disorders (low back pain as well as long term health degradation) due to regular and long-term sitting during operation. These problems become more severe when exposed to whole-body vibration (WBV) that encountered on the seats of industrial and agricultural vehicles, platforms of moving and heavy machinery. With the increase in the duration of exposure of a operator to whole-body vibration, the risk of musculoskeletal disorders have also been increased. The most commonly reported musculoskeletal disorder from exposure to whole body vibration is low back pain. Studies have also shown degeneration of the lumbar spine with long-term exposure to whole-body vibration. If the exposure of human body to the vibrations exceeds a certain limit, that may be hazardous to the health of driver. The measurements of whole body vibration are commonly expressed in terms of the frequency weighted acceleration (measured on the vibrating surface which is in contact with the body), the frequency and the exposure time as per ISO 2631-1 standard. In the present paper, research work carried out by various researchers in the field of effect of WBV on vehicle operators has been reviewed and presented.***

Keywords: Whole-body Vibration, Health Effects, Musculoskeletal disorders, Resonance Frequency, Vehicle Operators.

1. 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 (www.hse.gov.uk) [21]. Material handling equipments such as forklift and trucks play a major role in Medium and large manufacturing companies for the smooth handling and flow of inventories from warehouses to production facilities. Along with that operation of tractors and other equipments are used as agriculture vehicles. Drivers of these vehicles are subjected to extreme vibrations due to the vibrations generated from its engine, improper structural design of the vehicle and the bad road/surface conditions. The response to a vibration exposure is primarily dependent on the characteristics of vibration and duration of exposure. Many studies on effects of whole-body vibration have been carried out in the past. These studies have found that most of the effects can be divided into three categories a) Interference with comfort b) Interference with activities c) Interference with health (Griffin 1990) [9]. 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 operators of heavy machinery and tractors (Bovenzi M. et al. 1992, Waters T. 2008, Koley et al. 2010) [3-20-11]. The risks are greatest when the vibration magnitudes are high and combined with awkward posture, which may cause excessive risk of injury and disorder (Kittusamy et al. 2003) [10]. Exposure to whole-body vibration from tractors has been associated with low back pain and degeneration of intervertebral disc (Seidel H. 1993, Varghese M. 2001) [17-19]. It is therefore important to assess the effect of vibration on the human body. As per ISO 2641-1:1997 standard, the effect of vibration on the human body has been generally studied in three postures namely standing, sitting and recumbent.

The scope of using ISO 2631-1 1997 standard is to define methods for quantifying whole body vibration in relation to (a) Human health and comfort, (b) The probability of vibration perception, (c) The incidence of motion sickness. Various methods for the measurement of whole-body vibrations as defined in ISO 2631-1 standard, determines the degree to which vibration exposure may be acceptable. Vibration should be measured on the surface between the body and seat interface by placing the accelerometer on the seat pad. Various national and International standards have been drafted to measure the risk assessment of whole-body vibration.

Vibrations influence the human body in many different ways as certain frequencies have negative effects upon different parts of the body. The response to a vibration exposure is particularly dependent on the frequency, amplitude, and duration of exposure (Griffin, 1990) [9]. Vibration leads to both voluntary and involuntary contractions of muscles, and can cause local muscle fatigue, particularly when the vibration is at the resonant-frequency level. Motor performance capabilities would be reduced due to reflex contraction. Health effects due to whole-body vibration corresponding to Resonance frequencies are given in table 1.

Table 1: Health effect due to whole-body vibration (Rasmussen, 1982)

Health effects due to whole-body	*Frequencies (Hz)*
General feeling of discomfort	4-9
Head symptoms	13-20
Lower Jaw symptoms	6-8
Influence on speech	13-20
Lump in throat	12-16
Chest Pains	5-7
Abdominal pains	4-10
Urge to urinate	10-18
Increased muscle tone	13-20
Influence on breathing movements	4-8
Muscle contractions	4-9

2. Literature Review

Various researchers have been attracted and carried out the research in the field of effects of whole-body vibrations to the human body. Comprehensive review of literature reported by various researchers has been carried out and presented.

Deshmukh, (2009) [5] predicted the health risks associated with whole-body vibration of forklift driver and compared the exposure limits with ISO 2631-1 and ISO 2631-5. Vibration exposure was measured at operator/seat interface according to the procedures established in ISO 2631-1 Outcomes were compared in accordance to frequency weighted root mean square, vibration dose value and equivalent compressive strength. Study found drivers were exposed to high risk of exposure and moderate risk of exposure during whole-body vibration. Smets et al., (2010) [18] studied the level of whole-body vibration associated with the operation on eight surface haulage trucks. Vibration was measured and assessed at the seat/operator interface using ISO 2631-1 standard during 1 h of normal operation. Highest acceleration readings were observed in the z-axis (vertical). Further observations showed that estimated equivalent daily exposure values ranges from 0.44–0.82 ms^2 using the frequency-weighted R.M.S method and 8.7–16.4 $ms^{1.75}$ by using the vibration dose value method. Eger et al. (2008) [7], measured health related issues of whole-body vibration on 7 LHD vehicles, used in underground mining environments, in accordance with ISO 2631-1and -5. Based on the R-Factor their study predicted moderate to high health risks in accordance to ISO 2631-1 while the ISO 2631-5 predicted low health risks across all vehicles. Bongers P.M. et al. (1988) [1] investigated the health effects associated with whole-body vibration among the crane operators who were exposed to vibration for more than 5 years. Their study identified that the drivers of the forklifts have been shown to suffer from back disorders and degeneration of the inter-vertebral disc. Increasing age had the strongest association with vibration risk and hence the risk ratio for disability also increased due to inter-vertebral disc disorders. Boshuizen, et al. (1992) [2] concluded that predominantly, operators of mobile equipment, transport vehicles, heavy industrial vehicles, tractors, locomotives, buses and helicopters are exposed to unsafe levels of whole-body vibration. Waters et al (2005) [20] identified that the drivers of the forklifts have been shown to suffer musculoskeletal disorders due to various occupational risk factors. These factors include static sedentary position while driving (hands and feet held steady on handles and pedals) repeated exposure to short and long term awkward trunk posture (hand and feet held steady on handles and pedals); repeated exposure to short and long term awkward posture (twisting and bending of trunk) particularly during reverse operation; and exposure to whole-body vibration while driving. Milosavljevic et al. (2010) [12] have determined the relation between personal, physical, and workplace characteristics with the exposure to whole-body vibration of 130 quad bike drivers through structured Vibration Health Surveillance Questionnaire. The responses of WBVs and mechanical shocks were analyzed in accordance with the International Standardization for Organization (ISO 2631-1 and ISO 2631-5) standards and showed in the form of vibration dose value (VDV) and mechanical shock exposures. The study considered Personal (age and BMI), physical (shock absorbers and velocity), and workplace characteristics (driving duration and dairy farming). It suggests that a mix of engineered workplace and behavioral interventions is required to reduce this level of exposure to vibration and shock. Ozkaya et al. (1996) [14], carried out research to compare the intensity of vibration between simple and more complex seats. They found that less vibration has been transmitted with the use of some simple sitting design as compared with the complex designs. Scutter et al. (1999) [16] reported that simple modification can be made to a tractor seat in addition to an air polymer–based gel seat cushion, which not only reduces cost but also increases comfort to the farmers. Using modified air cushion seat, less low back pain and neck pain have been experienced by the farmers while driving the tractor and after driving the tractor. The vibration transfer and discomfort that comes from riding on the tractor is significantly reduced because of the gel seat cushion's ability to dampen cyclic chair vibrations and relieve bony prominence pressure points. Musa Marul et al., (2012) [13] tried three different cushion materials (wool, sponge and cotton) on driver seat of agriculture tractor to study the effects of vibration. Responses were compared in accordance with ISO 2631 standard. It was found that cotton and sponge is better for vibration isolation than cushion less driving seat. Further the study concluded that wool cushion provided the best isolation in comparison of cotton and sponge. Futatsuka M (1998) [8] compared health risks associated due to whole-body vibration of agriculture machines operator's farmers with non operator's farmers through questionnaire. Researchers concluded that, no specific injury or other effects, i.e. low back injuries were found among the group of operators as compared with those of non-operator farmers. Seidel (1993) [17] indicated that Long-term whole-body vibration exposure can probably contribute to the pathogenesis of disorders of female reproductive organs (menstrual disturbances, anomalies of position) and disturbances of pregnancy (abortions, stillbirths). Whole-body vibration has a minor synergistic effect on the development of noise-induced hearing loss and degenerative changes of the spine are more prevalent among whole body vibration exposed workers. Koley et al. (2010) [11] investigated 169 male tractor drivers and found the severity of low back pain through Oswestry pain questionnaire. The result indicated that a gradual increase of pain, as the exposure to whole body vibration and age increased. Cvetanovic et al. (2013) [4] have studied the level of whole-body vibration and found that tractor drivers are exposed to vibration to negative influences that leads the health related problems. Drakopoulos D. (2006) [6] reported that operator remain seated for extended periods of time during operation. The extended sitting of the operator, changes the weight bearing surfaces, which restricts spinal movement and flattens the normal curves. Because of which, the pelvis immobilizes. The design of the seats must be changed, so that weight spreads evenly to avoid pressure points and the muscular and skeletal interactions of the spine to avoid stresses. A modern seat must permit the worker to perform tasks from the suitable position, so its relationship to the rest of the workplace is important. The size, design, and materials are the important factors that affect the comfort of the user.

3. Conclusion

After going through the research reported by various researchers in the field of whole-body vibration and its effect on human being, It has been concluded that musculoskeletal injuries of the hip, buttock, neck, high and low back pain are associated with the operators of on-road and off-road vehicles (or other related equipment). These musculoskeletal disorders are developed in human body due to exposure to whole-body vibration and awkward postures during operations.

4. Future Scope

As limited research has been carried out in this field, more in-sight is needed to characterize the exposure of whole-body vibration to operators to these ergonomic hazards systematically. In terms of future scope, focus would be given to reduce the exposure of whole-body vibration emission level on operators of on road and off road vehicles; adequate measures and good working postures need to be developed. Seat design would be one of the other areas of interest to be considered to reduce the health related issues and to improve the comfort level of operators.

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