

## Original Research Article

# Prevalence of musculoskeletal disorders among heavy earth moving machinery operators exposed to whole-body vibration in opencast mining

Bibhuti B. Mandal\*, Veena D. Manwar

Department of Occupational Hygiene, National Institute of Miners' Health, Nagpur, India

**Received:** 31 January 2017

**Revised:** 24 March 2017

**Accepted:** 30 March 2017

### \*Correspondence:

Dr. Bibhuti B. Mandal,

E-mail: [bbmandal@gmail.com](mailto:bbmandal@gmail.com)

**Copyright:** © the author(s), publisher and licensee Medip Academy. This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial License, which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

## ABSTRACT

**Background:** Low back pain (LBP) and degenerative changes in the spinal system are reportedly associated with exposure to low frequency (0.5- 80 Hz) whole-body vibration (WBV). The main objective of the study was to determine prevalence of musculoskeletal disorders among Heavy Earth Moving Machinery (HEMM) operators exposed to WBV in an opencast mine in western India.

**Methods:** Forty six operators from an opencast mine were recruited as exposed group in a questionnaire based cross-sectional study. Twenty eight employees engaged in sedentary office work were taken as control. All subjects were asked about location and severity of body pain in the past 7 days and 12 months. A four point pain scale was used. Significance of difference of demographic / anthropometric parameters was studied using t-test of independent samples. Association between the pain type and exposure was obtained using Chi-square test. Risk of each type of pain was determined in terms of odds ratio. Adjusted estimate of ORs were obtained through logistic regression modelling, wherein the model fitness was judged using Hosmer-Lemeshow test.

**Results:** The mean exposure duration was  $11.30 \pm 7.45$  years. LBP was the most predominant MSD which showed highly significant association with exposure ( $P < 0.001$ ). Overall, the risk analysis revealed a significant increase in the likelihood of MSD due to exposure. 39% of the exposed group required medical attention.

**Conclusions:** Based on subjective response of exposed group, it can be said that prevalence of musculoskeletal pain as manifestation of MSD due to exposure to WBV especially LBP is high among HEMM operators which affected their quality of life.

**Keywords:** Occupational hazards, Mine safety, Whole-body vibration, Environmental protection

## INTRODUCTION

Even though the mining industry is a century old, research related to whole-body vibration exposure in mines are fairly recent in India.<sup>1-3</sup> The Directorate General of Mines Safety (DGMS) in India (regulatory authority) issued the first Technical Circular in 1975 in respect of control of noise and vibration in mines.<sup>4</sup> There has been a proactive initiative from mining industry in

initiating vibration studies of mining equipment and prediction of health risk associated with operation of heavy earth moving machineries (HEMM) following the circulation of Recommendations of X<sup>th</sup> and XI<sup>th</sup> Conferences on Safety in Mines in 2008 and 2013 respectively.<sup>5,6</sup> National Institute of Miners' Health (India) has evaluated vibration characteristics of more than four hundred mining equipment in last five years on demand from mining industry. While these risk

assessment is based on ISO Standards which themselves are in the process of slow but continuous evolution in their applicability and approach, it will be appropriate to supplement such assessment with epidemiological studies. In fact, it is reasonable to suggest that epidemiological studies may be conducted prior to risk assessment of equipment by measuring vibration levels. Results of epidemiological studies enable us to focus more on those mine workers who already have developed musculoskeletal disorders (MSD). Thus it would be easier to identify the machines which caused these MSDs and further research may be undertaken on the duration and nature of exposure to vibration at work.

There is strong epidemiological evidence that occupational exposure to WBV (1-80 Hz) is associated with increased risk of low back pain, sciatic pain and degenerative changes in spinal system including lumbar inter-vertebral disc disorders.<sup>7,8</sup> In a critical review of musculoskeletal disorders and workplace factors, investigators of the National Institute of Occupational Safety and Health (NIOSH) observed that there is strong evidence of positive association between exposure to WBV and (low) back disorders.<sup>9</sup>

The major objective of this study was to find prevalence of musculoskeletal disorders among the operators exposed to whole body vibration in mines. Since prediction of health risk according to Health Guidance Caution Zone of ISO 2631-1:1997 is better applicable for WBV exposure in seated posture and current research does not provide enough guidelines to predict health risk due to vibration exposure in standing posture or persons travelling over a source platform it was decided to carry out a cross-sectional study only among the HEMM operators who are exposed to WBV in seated postures.<sup>10</sup>

## METHODS

For this epidemiological study, a mechanized opencast metal mine in western India was selected. A questionnaire was specially designed and developed which could be easily explained to the workers. A ten-point pain scale which was readily available was not found suitable since subjective rating of subtle variations in feeling any pain was difficult to be rated by mine workers while testing the questionnaire prior to field use. Hence a simplified four-point pain scale was preferred. Employees engaged in office work which is sedentary in nature were taken as control for comparison. The questionnaire contained details about the following:

- Personal data comprising name, age, height, weight, smoking or drinking habits, past history of illness and injury etc.
- Employment data: Present designation and job, type of equipment operated, years employed in the job.
- Previous occupation: History of employment prior to the present job in other mines or organizations including type of work.

- Self-reported complaints of MSD: in low back, neck, shoulder, knee. Frequency and severity of pain symptoms: severity was divided in four categories with numerical assignments as shown in Table 1.
- History of medical treatment availed for symptoms of MSD including type of medication or otherwise.
- Variation in pain symptoms: before work, at work, after work.
- Subjective view about whether these symptoms are related to his work.

The musculoskeletal pain such as low back pain, knee pain, neck pain etc. are primary manifestation of musculoskeletal disorders, therefore in present study musculoskeletal pain has been considered as indication of musculoskeletal disorder.

The purpose of this investigation was informed to the mine management so that appropriate arrangements can be made for availability of the workers. It was ensured that routine work was not hampered in any way. Tea breaks or end of the shift departure periods were preferred for interviewing the workers (Figure 1). The shift in-charge was present during the interaction between the study team and the workers.

**Table 1: Simplified four point scale used for study of MSD symptoms.**

Scale Point	Nomenclature	Short Description
0	Nil	No Pain
1	Mild	Noticeable but one can get used to it
2	Moderate	Tolerable and not necessarily reportable
3	Severe	Not manageable and reportable for medical attention



**Figure 1: Three workers in the mine canteen being interviewed by the team members.**

## Study group

Forty six employees from a total of 90 HEMM operators from one mechanized opencast mine were considered and

selected as subjects exposed to whole body vibration during their daily work. They were randomly selected from a list of employees who had been regularly deployed for operating the Dumpers, Dozers, Loaders, Excavators and Shovels. Driving these machines in mine workings involve uneven terrain, changing slopes on haul road, needs careful speed control etc. all of which can influence level of exposures.<sup>3,11</sup> ISO 2631-1:1997 have been the most widely used tool for health risk prediction arising out of WBV exposure.<sup>12,13</sup> This standard cites several years as the period required to develop such health disorders (ISO, 1997). Since no dose-response relationship has been established till date between exposure to WBV and onset of MSD, a period of five years of occupational exposure to WBV was adopted as necessary inclusion criteria. Persons having history of past injuries resulting from accidents such as falls, etc were excluded from the study.

### ***Selection of controls***

Twenty eight employees from the same mine who were not exposed to whole body vibration at work were selected as controls. All of them were engaged in sedentary jobs at the mine office. In this case also, persons having history of past injuries resulting from accidents such as falls, etc were not included. Persons who were rehabilitated from mines for any reasons were not considered in the control group. The employees in both groups stayed in nearby mining colony and did not travel long distances regularly by vehicles before and after work.

### ***Ethical issues***

The purpose of the study and the risk/benefits of participation were explained to the study subjects in local language. Voluntary consent for participation was obtained while recruiting the study subjects.

### ***Questionnaire***

Information regarding occupational history, previous medical history, location of pain (back, shoulder, neck and knee) and degree of pain, medications, etc was collected through structured interview of exposed and control groups. All 46 operators and 28 subjects in control group were asked about pain (back, shoulder, neck and knee) in the past seven days and over past twelve months. The questionnaire for collecting the above information and to estimate severity of pain was pre-tested in the field before usage.

The investigation depended on self-reported MSD symptoms along with their location, frequency and severity. During the interview each employee was asked to pinpoint the body location(s) where pain was felt and information about pain in the Neck, Shoulders, Back and

Knees were recorded in separate datasheets and apart from these body locations all other issues related to the health were recorded separately for each individual.

Types of painkillers/oointments used by the subjects were verified through their medical prescriptions. The epidemiological studies were completed within a period of ten days in February 2012.

### ***Statistical analysis***

The data on demographic and behavioural characteristics of subjects from both experimental and control group were obtained through a structured questionnaire. Summary statistics like mean and standard deviations were obtained for continuous variables, while percentages were obtained for behavioural variables defined on nominal scale as per study groups. The statistical significance of difference in the mean age and BMI in two groups was evaluated using t-test of independent samples. The data on different types of musculoskeletal pains and their intensity was obtained for each subject from both the groups. The statistical significance of association between the pain type and exposure was obtained using Chi-square test. A  $2 \times 2$  contingency table was obtained, with rows indicating presence or absence of particular pain and columns indicating groups and the test was applied. Further, the risk of each type of pain due to exposure was determined in terms of odds ratio (OR). Crude estimate of OR was obtained from the contingency table. An adjusted estimate of ORs was obtained through logistic regression modeling. Covariates like age, BMI, exercise, smoking, tobacco and alcohol consumption were adjusted and the impact of exposure on the likelihood of particular type of pain was evaluated. The fitness of the regression model was assessed using Hosmer-Lemeshow test. The analysis was performed using SPSS ver. 11.0 (SPSS Inc.) and the statistical significance was tested at 5% level.

## **RESULTS**

A total of 74 subjects, 46 from exposed and 28 from control group were included in the study. Information on demographic and behavioural parameters as described in the methods section was obtained on each subject and has been summarized in Table 2.

Table 2 shows that the mean age in the exposed group ( $44.22 \pm 6.70$  years) was significantly higher than the control group ( $40.14 \pm 7.57$  years) with P-value of 0.023. Also, the mean BMI of exposed group ( $25.70 \pm 3.78$  kg/m<sup>2</sup>) was significantly higher than that of control group ( $23.67 \pm 3.78$  kg/m<sup>2</sup>) with a P-value of 0.0286. The behavioural habits of subjects in two groups did not differ significantly as suggested by z-test of proportions. The mean exposure duration in the experimental group was  $11.30 \pm 7.45$  years.

**Table 2: Descriptive statistics for demographic and behavioural parameters according to study groups.**

Parameters	Exposed (n=46)	Control (n=28)
Age (years) [Mean $\pm$ SD (Median)]*	44.22 $\pm$ 6.70 (44.50)	40.14 $\pm$ 7.57 (41.50)
BMI (kg/m <sup>2</sup> ) [Mean $\pm$ SD (Median)]*	25.70 $\pm$ 3.78 (25.62)	23.67 $\pm$ 3.78 (23.51)
Exercise (Yes) [No. (%)]	22 (48)	16 (57)
Smoking (Yes) [No. (%)]	15 (33)	5 (18)
Tobacco (Yes) [No. (%)]	17 (37)	11 (39)
Alcohol (Yes) [No. (%)]	22 (48)	10 (36)
Exposure (years) [Mean $\pm$ SD (Median)]	11.30 $\pm$ 7.45 (8.00)	NIL

\*P &lt;0.05 as per t-test of independent samples.

**Table 3: Distribution of subjects according to type of pain and study groups.**

Type of pain	Extent	Exposed (n=46) (%)	Control (n=28) (%)	P-value*
Low back pain				
	Nil	8 (17)	22 (78)	< 0.001
	Mild	9 (20)	5 (18)	
	Moderate	26 (56)	1 (4)	
	Severe	3 (7)	0	
Neck pain				
	Nil	32 (70)	26 (93)	0.018
	Mild	4 (9)	1 (4)	
	Moderate	8 (17)	1 (3)	
	Severe	2 (4)	0	
Shoulder pain				
	Nil	33 (72)	28 (100)	0.001
	Mild	5 (11)	0	
	Moderate	8 (17)	0	
	Severe	0	0	
Knee pain				
	Nil	32 (70)	27 (96)	0.005
	Mild	3 (6)	0	
	Moderate	11 (24)	1 (4)	
	Severe	0	0	

\*Using Chi-square test.

**Table 4: Odds for different types of pain upon exposure to vibrations.**

Type of pain	Unadjusted OR (95% CI)		Adjusted OR (95% CI)*	
	Exposure		Exposure	
	No (Reference)	Yes	No (Reference)	Yes
Low back pain	1.00	16.22 (5.25 - 58.37)	1.00	24.65 (5.48 - 110.75)
Neck pain	1.00	5.27 (1.29 - 39.10)	1.00	12.14 (1.65 - 89.42)
Shoulder pain	-	-	-	-
Knee pain	1.00	10.26 (1.85 - 260.72)	1.00	9.10 (0.88 - 94.27)

\*Adjusted for age, BMI, exercise, smoking, tobacco and alcohol.

Complaints of different types of musculoskeletal pains as felt by subjects from exposed and control group according to severity have been given in Table 3.

Table 3 shows low back pain (LBP) as the most dominant musculoskeletal disorder among operators and was higher (83%) than that observed in the control group (21.42%).

There were 20% cases with mild LB pain, while 56% had moderate pain and 7% had severe pain. Nearly 42% of these operators complained of pain radiating towards legs. The statistical significance of association between the presence or absence of LBP with exposure was evaluated using Chi-square test. The subjects across pain severity were pooled together constituting one group



(Present) and those without any pain belonged to other (Absent) group. Low back pain showed highly significant association with exposure ( $P < 0.001$ ).

There were 14 (30%) operators having neck pain (NP), out of which 8 had moderate pain, 4 with mild and 2 with severe pain. The association between neck pain and exposure was significant with P-value of 0.018. Also, there were 14 (30%) cases of knee pain (KP), out of which 11 had moderate pain, while 3 had mild pain. The association of neck pain was also found significant with exposure with P-value of 0.005. Out of 46 operators, 13 (28%) complained about shoulder pain (SP), with 8 having moderate and 5 with mild pain. The association between knee pain and exposure was also statistically significant with P-value of 0.001. In summary, the proportion of subjects with musculoskeletal pain in the exposed group was significantly higher than that of unexposed group.

The risk of each type of pain due to exposure was also assessed in terms of odds ratio as shown in Table 4. Crude (unadjusted) estimates of odds ratio were obtained for each type of pain based on  $2 \times 2$  contingency tables. It is evident that the unadjusted OR corresponding to LBP was 16.22 (95% CI: 5.25 – 58.37) times higher in exposed group compared to unexposed group. This was followed by knee pain with unadjusted OR of 10.26 (95% CI: 1.85 - 260.72), and neck pain with unadjusted OR of 5.27 (95% CI: 1.29 - 39.10). OR for shoulder pain could not be determined as no subject from control group presented with this pain. Since age, BMI, exercise and different behavioural habits are the confounders of such discomforts, the effect of exposure on each type of pain was adjusted in presence of these covariates using logistic regression model, and the adjusted risk of each type of pain due to exposure was evaluated as shown in Table 4.

It is evident that the adjusted odds for LBP and NP increased by 51.9% and 130.3% respectively as compared to crude estimates indicating negative effect of

confounders on discomforts. On the contrary, for KP, the adjusted odds reduced after controlling for confounders indicating magnified association of exposure and outcome in the absence of confounders. In other words, for KP, the confounding effect was positive, with a decrease of 11.3%. All the adjusted estimates were statistically significant with  $P < 0.001$ .

To understand which confounding factors influenced various discomforts, a two-step modelling approach was adopted based on the type of confounders. For LBP, in the first step, age and BMI were considered in the model resulting into OR of 22.82 (95% CI: 5.93 – 87.74) for exposure. In the second step, behavioural factors i.e. smoking, tobacco, alcohol and exercise were added to the model resulting into OR of 24.65 (95% CI: 5.48 - 110.75). Thus, inclusion of behavioural factors in the model increased the odds by only 8.01%, implying that age and BMI were the major negative confounders for LBP. For NP, age and BMI resulted into OR of 7.97 (95% CI: 1.51 – 42.03); and the inclusion of behavioural factors increased the OR to 12.14 (95% CI: 1.65 – 89.42). The increase in OR was 52.3% suggesting that the behavioural factors also influenced the outcome. For KP, age and BMI resulted into OR of 9.13 (95% CI: 1.08 – 77.37) which reduced marginally to 9.10 (95% CI: 0.88 - 94.27) by 0.3%. In other words, behavioural factors had negligible confounding effect on knee pain.

Overall, the risk analysis revealed a significant increase in the likelihood of musculoskeletal pain due to exposure to vibration at workplace.

All the operators who suffered from LBP ( $n=38$ ) were of the opinion that their pain symptoms were related to their profession (Table 5). It was also felt that there is a general lack of awareness about vibration related health disorders among the operators. A general lack of awareness and education has been similarly highlighted by Rajsekhar et al.

**Table 5: Response of workers related to different types of pains.**

Type of pain						
Questions	Low back pain (n=38)		Neck pain (n=14)		Knee pain (n=14)	
	Yes	No	Yes	No	Yes	No
Q1	30 (79%)	8 (21%)	12 (86%)	2 (14%)	10 (71%)	4 (29%)
Q2	17 (45%)	21 (55%)	6 (43%)	8 (57%)	5 (36%)	9 (64%)
Q3	38 (100%)	0	13 (93%)	1 (7%)	12 (86%)	2 (14%)
Q4	23 (60%)	15 (40%)	8 (57%)	6 (43%)	7 (50%)	7 (50%)

**Q1:** Whether the pain is over after taking rest?

**Q2:** Do you still have some back pain when working on next day?

**Q3:** Do you think your back pain is related to HEMM?

**Q4:** Does it get worse while on work on HEMM?

Thirty eight percent operators suffering from LBP were of the opinion that it had caused interference in discharge of their duties. 39% of the exposed group consulted doctors and were prescribed painkillers, ointments or injections. Doctors who examined these affected operators suggested exercise or physiotherapy in addition to medication for improvement of health (53.33%). On

the basis of their subjective response related to the effect of MSD, it can be said that there is significant degradation of quality of life.

## DISCUSSION

Mining of coal and minerals is considered as a major economic activity in India. Even though only about a million people are reported to be employed in Indian mines, the actual figure is believed to be much higher considering the huge part of it which falls under the unorganised sector. Silicosis or coal workers' pneumoconiosis (CWP) is well known diseases in mining occupation since they lead to severe disabilities or death of workers. On the contrary noise induced hearing loss (NIHL) and vibration related MSDs are less known facts in Indian mines. These are not life threatening disorders but such occupational illness severely degrades quality of life, increases leave or absence from duties.

In the present study, low back pain (LBP) was the most dominant musculoskeletal disorder among operators (83%). In a larger study among Indian population screened by the Indian Council of Medical Research (ICMR) in 2012, data analysis of musculoskeletal symptoms had revealed that pain was the predominant symptoms of MSD. Spine/back pain was observed to vary between 31.53% and 36.9% across three different regions.<sup>15</sup> The incidences of LBP in the population exposed to vibration in mines are therefore much higher than the general population.

Apart from the varied effects of the confounding factors on the incidences of MSD as shown in the Results section, the vehicle operators are also exposed to hand-arm vibration (steering vibration) resulting into a different cause of concern of health and safety. On the other hand, the misery of low back pain is exacerbated as a result of poor vehicle seating, awkward postures and manual cargo handling.<sup>16-18</sup> There was no doubt, although that there was an alarming degradation in quality of life among the population studied. Summarily, the situation warrants us enforcement of regular monitoring of vibration and comparison with statutory guidelines to determine the levels of compliance. Chronic symptoms related to WBV generally take some time to develop hence preventive measures can be suitably decided and put into action as required for specific mining situations where such risks exist.

## CONCLUSION

The HEMM operators working in mines are exposed to whole body vibration during their work. Earlier studies conducted in other countries suggest that exposure to whole body vibration is associated with occurrence of musculoskeletal disorder specially low back disorders. The present study conducted in an Indian metal mine among 46 HEMM operators who are potentially exposed to WBV at work and 28 controls show that prevalence of

musculoskeletal pain as indicator of musculoskeletal disorder was significantly higher among HEMM operators. This was true for all type of musculoskeletal pain, low back pain being the most prevalent. The confounding factors such as age, BMI and behavioural factors had little influence on occurrence of musculoskeletal pain. Majority of the subject in exposed group were of the opinion that their symptoms were related to their work and were severe enough to interfere with discharge of their duties and caused degradation of quality of life. It can be reasonably concluded that prevalence of musculoskeletal pain as manifestation of musculoskeletal disorder especially low back pain is high among HEMM operators in mines which significantly affects quality of life. Large scale studies in developing countries like India will elucidate the magnitude and extent of the disorder in mines.

*Funding: This research article is the outcome of work done under Science and Technology Project "Development of a protocol for evaluation of vibration hazard potential for mining equipment" funded by the Ministry of Mines, Govt. of India*

*Conflict of interest: None declared*

*Ethical approval: Not required*

## REFERENCES

1. Mandal BB, Srivastava AK. Musculoskeletal disorders among the dumper operators exposed to whole body vibration in Indian mines. *Int J Min Reclaim Env*. 2010;24(3):233-43.
2. Mandal BB, Sarkar K, Manwar V. A study of vibration exposure and work practices of Loader and Dozer operators in opencast mines. *Int J Occup Saf and Health*. 2012;2(2):3-7.
3. Mandal, BB, Mansfield NJ. Contribution of individual components of a job cycle on overall severity of whole-body vibration exposure - a study in Indian mines. *Int J Occup Saf Ergon*. 2016;22(1):142-51.
4. Kaku LC. Directorate General of Mines Safety [DGMS] circulars. Dhanbad (India): Lovely Prakashan press; 2013. Technical Circular No. 18 (1975), Protection of workers against Noise and Vibration in the working environment. Ministry of Labour (India); 1975: 601.
5. Recommendations of the 10th Conference on Safety in Mines; 2007 Nov 26-27; New Delhi, (India). Available from: <https://elibrarywcl.files.wordpress.com> Accessed on 3 February 2017.
6. Recommendations of the 11th Conference on Safety in Mines; 2013 July 4-5 New Delhi,(India). Available from: <http://www.dgms.net/Recommendation%20of%2011th%20safety%20conference,9.7.13.pdf> Accessed on 7 February 2017.
7. Bovenzi M, Hulshof CJ. An updated review of epidemiologic studies on the relationship between exposure to whole-body vibration and low back pain

- (1986–1997). *Int Arch Occup Environ Health*. 1999;72:351–65.
8. Lings S, Leboeuf-Yde C. Whole-body vibration and low back pain: A systematic, critical review of the epidemiological literature 1992–1999. *Int Arch Occup Environ Health*. 2000;73:290–7.
9. National Institute of Occupational Safety and Health (US). *Musculoskeletal Disorders and Workplace Factors*. Edited by: Bruce P. Bernard (MD, MPH): Department of Health and Human Services (US); 1997. (Public Health Service Centers for Disease Control and Prevention; no. 97-141.)
10. International Organization for Standardization (ISO). *Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration - Part 1: General requirements*. (Standard No. ISO 2631-1:1997). Geneva: ISO; 1997.
11. Eger T, Contratto M, Dickey JP. Influence of driving speed, terrain, seat performance and ride control on predicted health risk based on ISO 2631–1 and EU Directive 2002/44/EC. *J Low Freq Noise V A*. 2011;30:291–312.
12. Cann A, Salmoni A, Eger T. Predictors of whole body vibration exposure in transport truck operators. *Ergonomics*. 2004;47:1432–53.
13. Eger T, Kociole AM, Dickey JP. Comparing Health Risks to Load-Haul-Dump Vehicle Operators Exposed to Whole-Body Vibration Using EU Directive 2002/44EC, ISO 2631-1 and ISO 2631-5. *Minerals*. 2013;3:16-35.
14. Rajsekhar S, Sharma P. Morbidity among mine workers: a cross sectional study in Chitradurga, Karnataka, India. *Int J Community Med Public Health*. 2017;4(2):378-84.
15. Sharma R, editor. *Epidemiology of musculoskeletal conditions in India*. New Delhi, India: Indian Council of Medical Research (ICMR);2012.
16. Abrams R. Sound and vibration in pregnancy, in *Seminars in Perinatology*, Part 11, W.B. Saunders, Philadelphia;1990: 273-334.
17. Peters A, Abrams R, Gearhardt K, Wasserman D. Acceleration of the fetal head induced by vibration of the maternal abdominal wall in sheep. *Am J Obstet.Gynecol*. 1996;174:552-6.
18. Seidel H. On the relationship between whole-body vibration exposure and spinal health risk. *Industrial Health*. 2005;43:361-77.

**Cite this article as:** Mandal BB, Manwar VD. Prevalence of musculoskeletal disorders among heavy earth moving machinery operators exposed to whole-body vibration in opencast mining. *Int J Community Med Public Health* 2017;4:1566-72.