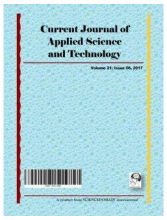

Current Journal of Applied Science and Technology

27(3): 1-7, 2018; Article no.CJAST.29796
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Effect of Chain Saw on Hand Arm and Whole Body Vibration in Selected Species of Timber

J. D. Amine[1], O. M. Injor[1*] and L. R. Shishi[1]

[1]Department of Mechanical Engineering, University of Agriculture, Makurdi, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author JDA designed the study and supervised the experiments. Authors OMI and LRS wrote the protocol, wrote the first draft of the manuscript and managed literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2018/29796
Editor(s):
(1) Manoj Gupta, Associate Professor, Department of Mechanical Engineering, NUS, 9 Engineering Drive 1, Singapore.
Reviewers:
(1) Seshendra Kumar, Gitam University, India.
(2) Mario Bernardo-Filho, Universidade do Estado do Rio de Janeiro, Brasil.
(3) Seung-Bok Choi, Inha University, Korea.
Complete Peer review History: http://www.sciencedomain.org/review-history/24568

Original Research Article

Received 29th September 2016
Accepted 14th December 2016
Published 10th May 2018

ABSTRACT

Experimental data collected over the years, for defining limits of vibration exposure to human beings, have resulted in a set of vibration criteria specified in ISO Standard 2631. In this article, instrumentation requirements for evaluation of the responses of humans to vibration according to these criteria are described, as well as some of the pitfalls to be avoided during these measures. The operators' exposure to hand-arm as well as whole body transmitted vibration at Terry-Man Saw mill was tested on different kinds of wood. Using a vibrometer levels obtained by measurements for related activities and their average durations during working day, the daily vibration exposure A(8) (expressed in terms of 8-hour energy-equivalent frequency-weighted) and vibration total value was calculated in accordance with ISO 5349-1. The A(8) values obtained were compared with the limit values set for the workers' exposure to hand-arm transmitted vibration at 2.5 m/s^2 (action value). The comparison clearly shows that the work at Terry-man saw mill can be classified as dangerous as a result of exposure to vibration.

Keywords: Hand-arm vibration; whole body vibration; vibration exposure; Terry-Man saw mill; daily vibration exposure A(8).

**Corresponding author: E-mail: injorman@yahoo.com;*

1. INTRODUCTION

Mechanical vibration arises from a wide variety of processes and operations performed in industry, construction, agriculture, and public utilities. Vibration exposure occurs when a person's body contacts directly or indirectly with the vibrating object. Vibration exposures are segmented into specific parts of the body such as hand, arm, leg; or whole body vibration, in which the vibration is transmitted throughout the whole body [1]. It is a known fact that exposure to vibration is dangerous because various health problems are caused by vibration which result to increased acute injury as a result of impacts [2].

The undesirable risks related to some types of activities determine investigations about new possibilities of activities that could bring benefits to the individual without risks or with minimal possibilities of injuries [3].

Prolonged exposure to hand-transmitted vibration (HTV) from powered tools is associated with an increased occurrence of disorders in the vascular, neurological and osteoarticular systems of the upper limbs [4]. The vascular component of the HTV syndrome is represented by a secondary form of Reynaud's phenomenon known as vibration induced white finger (VWF), and is recognized as an occupational disease in industrialized countries [4].

The neurological component is characterized by a peripheral, diffusely distributed neuropathy with predominant sensory impairment. An increased risk for upper limb muscle and tendon disorders, as well as nerve trunk entrapment syndromes, has also been reported in workers who use hand-held vibrating tools [5-,8]. Similarly, neurophysiological studies have suggested that sensory disturbances in the hands of vibration-exposed workers are likely due to vibration-induced impairment to various skin mechanoreceptors (Meissner's corpuscles, Pacinian corpuscles, Merkel cell neurite complexes, Ruffini endings) and their afferent nerve fibers [2,9].

Electron microscopic studies of human finger biopsy specimens suggest that hand transmitted vibration can provoke perineural fibrosis, demyelination, axonal degeneration and nerve fibre loss [10,11].

Clinical and epidemiologic surveys have revealed an increase in sensorineural disorders with the increase of daily vibration exposure, duration of exposure, or lifetime cumulative vibration dose. The currently available epidemiologic data, however, are insufficient to outline the form of a possible exposure-response relationship for vibration-induced neuropathy. A few clinical and epidemiologic studies have reported that exposure to hand-transmitted vibration can aggravate the risk of noise-induced hearing loss and provoke disturbances of the central nervous system [4,12]. The independent contribution of vibration exposure and physical work load (forceful gripping, heavy manual labor, wrist flexion and extension), as well as their interaction, in the etiopathogenesis of carpal tunnel syndrome (CTS) have not yet been established in epidemiologic studies of workers who handle vibratory tools. It has been suggested that ergonomic risk factors are likely to play the dominant role in the development of CTS. As a result, to date it is hard to draw a specific relation between CTS and exposure to HTV. Early radiological investigations had revealed a high prevalence of bone vacuoles and cysts in the hands and wrists of vibration-exposed workers, but more recent studies have shown no significant increase with respect to control groups made up of manual workers. An increased risk for wrist osteoarthrosis and elbow arthrosis and osteophytosis has been reported in coal miners, road construction workers and metal-working operators exposed to shocks and low frequency vibration (<50 Hz) of high magnitude from percussive tools (pick, riveting chisel hammers, and vibrating compressors). An excess prevalence of Kienbock's disease (lunate malacia) and pseudoarthrosis of the scaphoid bone in the wrist has also been reported by a few investigators [1].

On the contrary, there is little evidence for an increased prevalence of degenerative bone and joint disorders in the upper limbs of workers exposed to mid- or high-frequency vibration arising from chain saws or grinding machines. It is thought that, in addition to vibration, joint overload due to heavy physical effort, awkward postures, and other biomechanical factors can account for the higher occurrence of skeletal injuries found in the upper limbs of users of percussive tools. A constitutional susceptibility might also play a role in the etiopathogenesis of premature wrist and elbow osteoarthritis [13].

Epidemiologic studies have pointed out that the prevalence of VWF is very wide, from 0-5% in workers using vibratory tools in geographical areas with a warm climate to 80-100% in the past among workers exposed to high vibration magnitudes in northern Countries [12,14,15]. Studies have reported that VWF may improve, persist or worsen in workers with current or previous exposure to hand-transmitted vibration. It has been suggested that cessation or reduction of vibration exposure may be associated with some reversibility of VWF, but the rate of remission of vasospastic symptoms over time is not well-known [16].

Other factors believed to be related to the injurious effects of vibration, are the duration of exposure (daily, yearly, and lifetime cumulative exposures), the pattern of exposure (continuous, intermittent, rest periods), the type of tools, processes or vehicles which produce vibration, the environmental conditions (ambient temperature, airflow, humidity, noise), the dynamic response of the human body (mechanical impedance, vibration transmissibility, absorbed energy), and the individual characteristics (method of tool handling or style of vehicle driving, body posture, health status, training skill, use of personal protective equipment, and individual susceptibility to injury) [17].

For the health effects of hand-transmitted vibration on the upper limbs, the evaluation of vibration exposure is based on the vibration total value , a quantity defined as the square root of the sum of the squares (r.m.s.) of the frequency weighted acceleration values determined on the three orthogonal axes x, y, z [8].

$$ahv = \sqrt{{a_{hwx}}^2 + {a_{hwy}}^2 + {a_{hwz}}^2} \tag{1}$$

The vibration total has been proposed for evaluation of health effects on the whole body vibration if no dominant axis of vibration exists [18]. For a seated or standing worker, the vibration total value () for the frequency-weighted accelerations () of whole-body [8,19] vibration is;

$$av = \sqrt{k_x {a_{wx}}^2 + k_y {a_{wy}}^2 + k_z {a_{wz}}^2} \tag{2}$$

Where,

k =1.4 for x- and y-axes, and
k =1 for z-axis.

Since it is believed that the health effects of whole-body vibration are influenced by shocks or vibration peaks, the international standard [20] suggests the use of the fourth power vibration dose method instead of the second power of the acceleration time history (i.e. r m s) as the basis for averaging expressed in m/s$^{1.75}$.

Exposure to whole body vibration is a known risk that results to the development of low back pain [20,21]. The assessment of exposure to whole-body vibration is based on the calculation of daily exposure A(8) expressed as continuous equivalent acceleration over an eight hour period, [19] calculated as the highest (r m s) value, in accordance with the international standard [20].

$$A(8) = \frac{1}{T_0 (a_{hvi} \times T_i)} \tag{3}$$

Where

T_i is the total daily duration of exposure to the vibration of the *i th* activity,

T_0 is reference duration of 28, 800 s (8 hours),

n is the number of individual vibration exposures and

a_{hvi} is the vibration total value for the *i th* activity

The EU Directive [22] specifies “daily exposure action values” and “daily exposure limit values” for both hand-transmitted vibration and whole-body vibration, above which administrative, technical and medical measures have to be implemented by employers with the aim to protect workers against the risks arising from vibration exposure.

This research is to carried out in order to define the vibration exposure level at work on chain saw operators where the workers are exposed to vibration levels that are above the limit of 2.5 m/s^2 and 5 m/s^2 set as lower and upper limit values respectively in the EU Directive [22] on the minimum health and safety requirements regarding the exposure of workers to the risk arising from physical agents.

2. MATERIALS AND METHODS

The materials used in this research includes the following; Stihl chain saw MS 170 with 2.6 kW motor, weighing 4.8 kg, specific power 0.54 kW/kg, chain pitch 0.325" and guide length 37 cm, equipped with anti-vibration system (elasto-start, quick-Stop brake and Decompression valve), Vibration meter (0011-VB-821HA), Stop watch, and 10 different wood species, namely;

Gmalina above, Daniella oliveri, Viteleria paradoxa, Parka biglobosa, Isobertima doka, Atzelia africana, Pterocapus osun, Vitex doniana, Ceiba pentandra and Syzygium guineense.

Measurements of vibration were done in accordance with international standard for hand arm vibration and for whole body vibration using vibration meter [20,23]. The vibration meter incorporates a tri-axial accelerometer, in accordance with the requirements of ISO [24]. The triaxial accelerometer was set up to log frequency-weighted average vibration magnitudes at 2-s interval over the complete measurement period. The accelerometers were calibrated prior to use using a PCB Piezotronics Hand-held shaker.

Initially, hand-arm transmitted vibration values for idle movement were taken for front and rear handles in x, y, and z directions respectively. The axes of the accelerometer were aligned such that the Z axis measured vertical acceleration, the Y axis measured transverse acceleration and the X axis measured backward and forward accelerations [2]. However, the transducer (accelerometer) from the vibration meter was placed firmly to the vibrating surface area or handle with a clip where the operator carefully holds the vibrating tool, however signals from the tri-axial accelerometer were passed to the vibration meter where the values measured in x, y and z direction of both the racing and cross-cutting operations were digitally recorded. Frequency-weighted vibration magnitude (meters per square second) was calculated as the root sum of squares of vibration in the three orthogonal axes (x, y, and z) at the handle.

While for whole body vibration, the operator sat on the accelerometer while cutting the different species of the wood and the frequency-weighted vibration magnitude (meters per square second) was calculated using the root mean-square vibration magnitude acceleration of the highest of three orthogonal axes (x, y, or z) of both the racing and cross-cutting operations [25]. The time taken for both the hand-arm and the whole body vibration cutting operation was recorded in seconds for each direction (x, y, z) using a stop watch. All measurements were carried out on the working ground and real working conditions were simulated [26].

Using vibration levels obtained by measurements for related activities and their average durations during working day, the daily vibration exposure *A(8)* expressed in terms of 8-hour energy-equivalent frequency-weighted, and vibration total value , at a surface in contact with the hand was calculated in accordance with ISO 5349-1 [23]. The *A(8)* values such obtained were compared with the limit values set for the workers' exposure to hand-arm transmitted vibration at 2.5 m/s^2 (action value), i.e. 5 m/s^2 (upper limit value).

3. RESULTS AND DISCUSSION

The daily vibration exposure *A(8)* and the vibration total value , were plotted against the different species of wood using racing and cross cutting operations for hand-arm and whole body vibrations as shown in Figs. 1 and 2.

Hand-arm vibration on the rear handle for racing operation showed that Pterocapus osun was highest with vibration total value of 50 m/s^2 and daily vibration exposure *A(8)* of 35 m/s^2 while cross cutting operation showed that Pterocapus osun was highest with vibration total value of 47 m/s^2 and daily vibration exposure of 11.75 m/s^2 as shown in Fig. 1.

Also, hand-arm vibration on the front handle for racing operation as indicated in Fig. 1 showed that Pterocapus osun was highest with vibration total value of 42 m/s^2 and daily exposure *A(8)* of 27 m/s^2 while cross cutting operation showed that Pterocapus osun was highest with vibration total value of 39 m/s^2 and daily exposure of 12 m/s^2. This high vibration generation is attributed to the high impact imposed on the wood by the operator [25] because of the nature of the wood [19,27].

Whole body vibration for racing operation showed that Pterocapus osun was highest with vibration total value of 18 m/s^2 and daily exposure of 17 m/s^2 while cross cutting operation showed that Pterocapus osun was also highest with vibration total value of 21 m/s^2 and daily vibration exposure of 12 m/s^2 as shown in Fig. 2. Higher whole body vibration recorded is an indication that the measurements were collected during real work conditions [25].

For both racing and cross cutting operations carried out, Ceiba pentandra specie of the wood showed a low daily vibration exposure and a low vibration total value. This could be attributed to the close grain structure of the wood. However, Pterocapus osun specie showed a high daily vibration exposure and a high vibration total value because of its uniform grain structure [27].

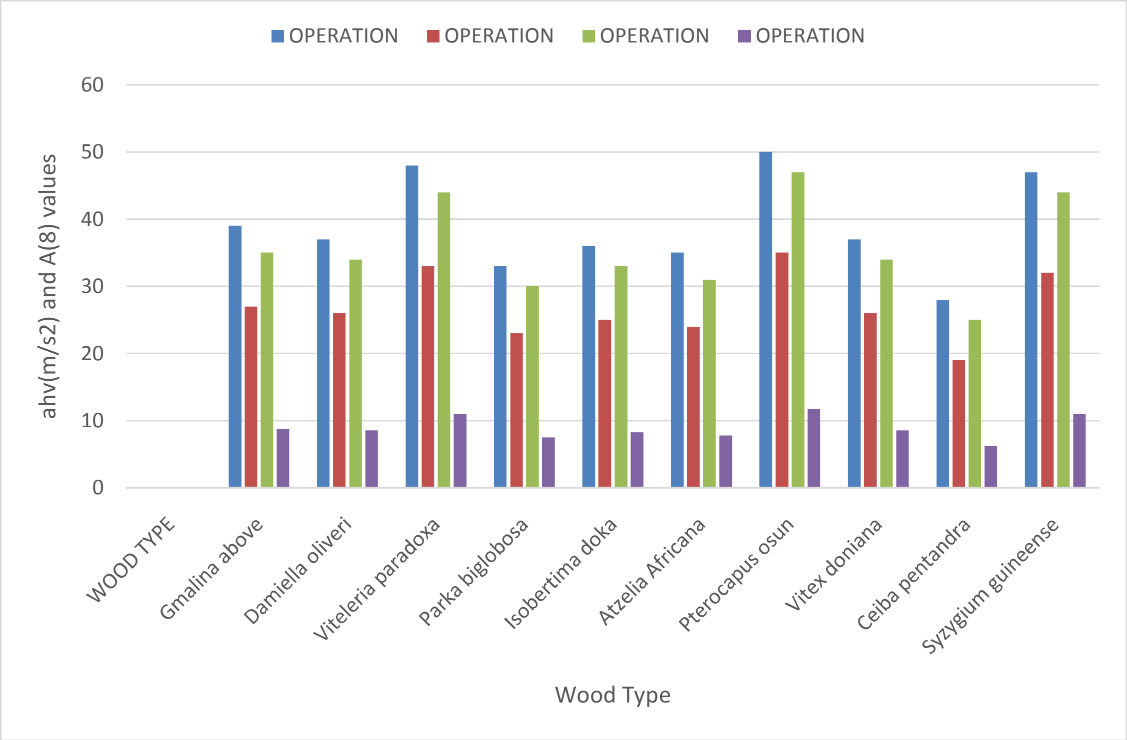

Fig. 1. Daily vibration exposure *A(8)* and the vibration total value for racing and cross cutting operation on hand-arm vibration using rear and front handle

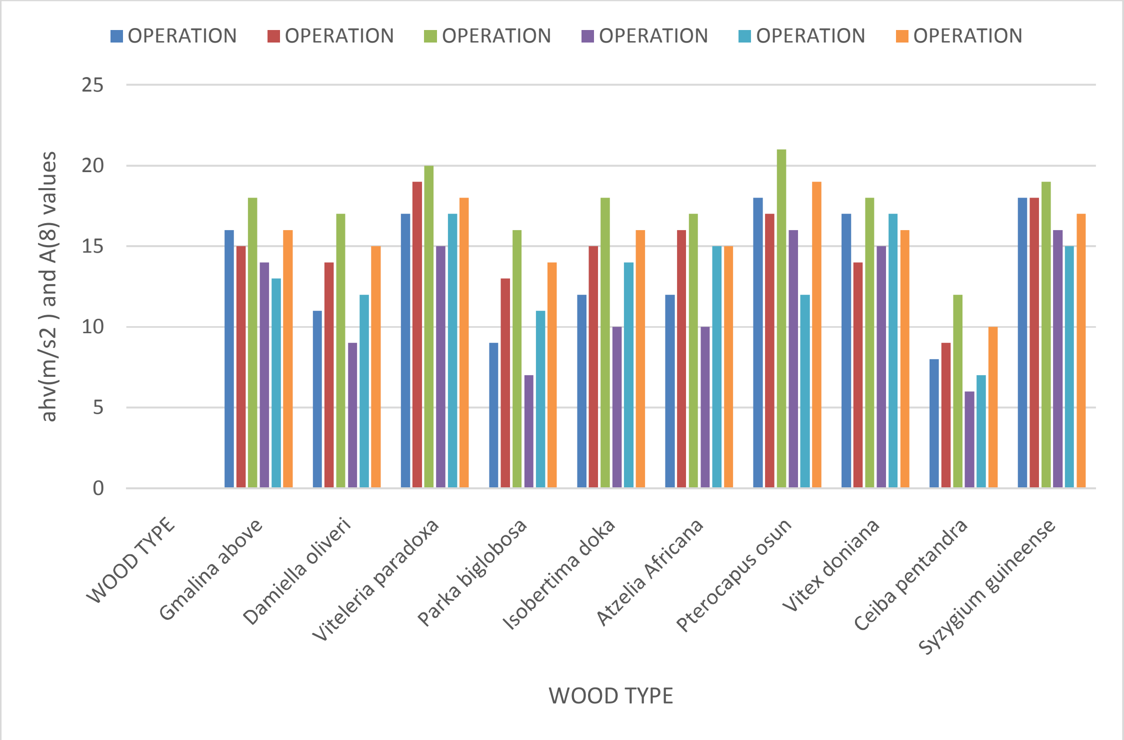

Fig. 2. Daily whole body vibration exposure *A(8)* and the vibration total value for racing (x,y,z) and cross cutting (x,y,z) operation

4. CONCLUSION

Occupational exposure to hand-arm and whole body vibration by chain saw operations on different species of wood was evaluated and the following conclusions were drawn;

1. Pterocapus osun specie exhibits higher daily vibration exposure and higher vibration total value for both racing and cross cutting operations.
2. Higher impact imposed by the operator on Pterocapus osun specie generated the high vibration.
3. Ceiba pentandra specie exhibits relatively lower daily vibration exposure and lower vibration total value for both racing and cross cutting operations.
4. Higher whole body vibration recorded shows that the measurements were collected under real working conditions [25].
5. The higher vibration value exposures exceeds the limit values specified by the EU Directive [22] however administrative, technical and medical measures have to be implemented by employers with the aim to protect workers against the risks arising from these vibration exposures.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Costa PR, Sá-Caputo DS, Arnóbio A, Pacheco R, Kutter C, Costa R, Giehl PM, Paiva DN, Marin PJ, Salmon JR, Tillman M, Bernardo-Filho M. Whole-body vibration and benefit for people with osteoarthritis: A systematic review. International Journal of Medicine and Medical Sciences. 2014; 6(9):201-210.
2. Mehmet SM, Gültekin AA, Barış B. Experimental investigations of accelerations and vibrations on vehicles and boats. Istanbul Technical University, Faculty of Naval Architecture and Ocean Engineering; 2015.
3. Golbidi S. Laher I. Exercise and the aging endothelium. Journal of Diabetes Research. 2013;12.
4. Griffin MJ. Minimum health and safety requirements for workers exposed to hand-transmitted vibration and whole-body vibration in the European Union: A review. Occupational and Environmental Medicine. 2004;61:387–97.
5. Bernard P. Musculoskeletal disorders (MSDs) and work-place factors. A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity and low back. Cincinnati, OH: NIOSH; 1997.
6. Hagberg M, Silverstein B, Wells R, Smith M, Hendrick H, Cararyon P, Perusse MC. Identification, measurement and evaluation of risk. In Kuorinka, Forcier (eds): Work-Related Musculoskeletal Disorders—A Manual for Prevention. Taylor & Francis, London.1995;139–212.
7. Min-Soo P, Takabumi F, Tae-gu K, Setsuo M. Health risk evaluation of whole-body vibration by ISO 2631-5 and ISO 2631-1 for operators of agricultural tractors and recreational vehicles. Industrial Health, 2013;51:364–370.
8. Jan S, Wojciech T, Jacek K. Vibration energy absorption in the whole-body system of a tractor operator. Annals of Agricultural and Environmental Medicine. 2014;21(2):399–402.
9. National institute of arthritis and musculoskeletal and skin diseases. Osteoarthritis.
   (Accessed June 23, 2013)
   Available:http://www.niams.nih.gov/Health_Info/osteoarthritis/default.asp
10. Cann A, Salmoni A, Vi P, Eger T. An exploratory study of whole body vibration exposure and dose while operating heavy equipment in the construction industry. Applied Occupational and Environmental Hygiene. 2003;18:999–1005.
11. Loeser RF. Molecular mechanisms of cartilage destruction: Mechanics; inflammatory mediators and aging collide. Arthritis and Rheumatism. 2006;54:1357-1369.
12. Griffin M. Handbook of human vibration, Academic Press, London; 1991.
13. French HP, Cussack T, Brennan A, Caffrey A, Conroy R, Cuddy V, FitzGerald OM, Gilsenan C, Kane D, O'Connell PG, White B, McCarthy GM. Exercise and manual physiotherapy arthritis research trial (EMPART) for osteoarthritis of the hip: A multicenter randomized controlled trial. Archives of Physical Medicine and Rehabilitation. 2013;94:302-314.
14. Bovenzi M, Hulshof CTJ. An updated review of epide-miologic studies on the

relationship between exposure to whole-body vibration and low back pain. Journal of Sound and Vibration. 1998;215:595–611.

15. Olsen N. Physiological and diagnostic aspects of vibration-induced white finger. International Archives of Occupational and Environmental Health; 2001.
16. Hagberg M. Clinical assessment of musculoskeletal disorders in workers exposed to hand-arm vibration. International Archives of Occupational and Environmental Health; 2001.
17. Nur SAR, Ahmad YBH, Seri RK, Mohd NAM, Siti AA. On lower-back pain and its consequence to productivity. Journal of Industrial and Intelligent Information. 2014; 2(2):83-87.
18. Peter WJ, Jack D, Luz MR, Claudia A, Andrés CRE, Ivon ERB, Lavi A, Hugo P, Lope HB. Assessment of continuous and impulsive whole body vibration exposures in heavy equipment mining vehicles. Proceedings 19th Triennial Congress of the IEA, Melbourne; 2015.
19. Alfaro DG, Coltrinari G, Lippiello D, Pinzari M. Risk assessment of the whole-body vibration exposure for drivers of armored vehicles: A case study. International Journal of Safety and Security Engineering. 2016;6(1):53–62.
20. International Organization for Standardization, ISO 2631-1 Mechanical vibration and shock. Evaluation of human exposure to whole-body vibration - Part 1: General requirements. Geneva, Switzerland; 1997.
21. Burström L, Nilsson T, Wahlström J. Whole-body vibration and the risk of low back pain and sciatica: A systematic review and meta-analysis. International Archives of Occupational and Environmental Health. 2014;88(4):403-18.
22. European Parliament and the Council of the European Union Directive 2002/44/EC of the European Parliament and of the Council on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration). Official Journal of European Communities. 2002;177:13-19.
23. International Organization for Standardization, ISO 2631-2. Mechanical vibration measurement and evaluation of human exposure to hand-transmitted vibration – Part 2. Practical guidance for measurement at workplace; 2001.
24. International Organization for Standardization, ISO 5349-1. Mechanical vibration-measurement and assessment of human exposure to hand transmitted vibration-Part 1: General guidance; 2001.
25. Marie AC, Eric VL, Margaret M, Gurmail P, Ken M. Evaluation of hand-arm and whole-body vibrations in construction and property management. Annals of Occupational Hygiene. 2010;54(8):904–914.
26. Aye SA, Heyns PS. The evaluation of whole-body vibration in a South African opencast mine. The Journal of the Southern African Institute of Mining and Metallurgy. 2011;111:751-757.
27. Sinha KP, Goel DB. Foundry Technology. Nem Chand Publishers, Delhi; 2011.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/24568