Human Body Vibration: Evaluation, Effects and Prevention

Nadendla Udaya Sankar[1], Monisha Gowri Srinivasan[1], Tharani Kumaran[1], Gowri Priya Shoba[1], Singam Jayanthu[2], Ravi Kant Avvari[1], Mirza Khalid Baig[1], Thirugnanam Arunachalam[1*]

[1] Department of Biotechnology and Medical Engineering, National Institute of Technology Rourkela, Odisha, India.

[2] Department of Mining Engineering, National Institute of Technology Rourkela, Odisha, India.

*Corresponding author email: thirugnanam.a@nitrkl.ac.in

Abstract

Vibration is a common aspect in a human environment that deals with the field of ergonomics. The exposure to vibration in various work environments such as mining industries, aviation, and transportation on the human body is termed human body vibration (HBV) which is classified into whole body vibration (WBV) and hand-held vibration (HHV) based on the transmission of vibration into the body. These vibrations on the human body have short-term effects causing tingling and numbness. As the exposure gets prolonged, it leads to drastic effects on the physiological systems of the human body. Hence to avoid these effects, workers should be monitored regularly to evaluate their exposure to vibration. The evaluation of vibration depends upon various parameters such as weighted root-mean-square (rms) acceleration (a_w), and vibrational dose value (VDV). In a working environment, the action limits of a_w (for 8 h) are 0.5m/s^2 and 2.5m/s^2 for WBV and HHV respectively. As the values are predefined, organisations can take various steps such as continuous monitoring of vibration exposure in workers using wireless transmission of data calculated from sensors placed on the workers, rotating the shift of workers if the limit exceeds, educating on proper ergonomics and positioning of hand-held tools during work. This paper describes an overview of various standards and techniques used to measure and validate human body vibrations along with suggestive remedial measures.

Keywords: Whole body vibration, hand-held vibration, acceleration, vibrational dose value, ergonomics

HUMAN BODY VIBRATION: EVALUATION, EFFECTS AND PREVENTION

Humanizing Work and work Environment
Conference 2022
Presented by

Dr. A. Thirugnanam

Department of Biotechnology and Medical Engineering
National Institute of Technology, Rourkela
November 2022

CONTENTS

- Human Body Vibration
- Whole body vibration
- Evaluation of whole body vibration
- Effects of whole body vibration
- Hand arm vibration
- Evaluation of Hand arm vibration
- Effects of hand arm vibration
- Preventions of Human body vibration
- Development of evaluation unit

HUMAN BODY VIBRATION

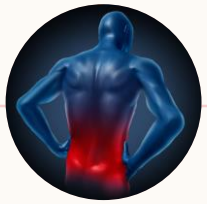
- Whole body Vibration (WBV).
- Transmitted through body in sitting or standing position.

- Hand arm vibration (HAV).
- Transmitted by hand power tools in mining and construction to the person's hand or arm

WHOLE BODY VIBRATION

EVALUATION

- ISO: 2631
- Location of sensors
- Crest factor
- Weighted root mean square acceleration
- Vibrational Dose Value



EFFECTS

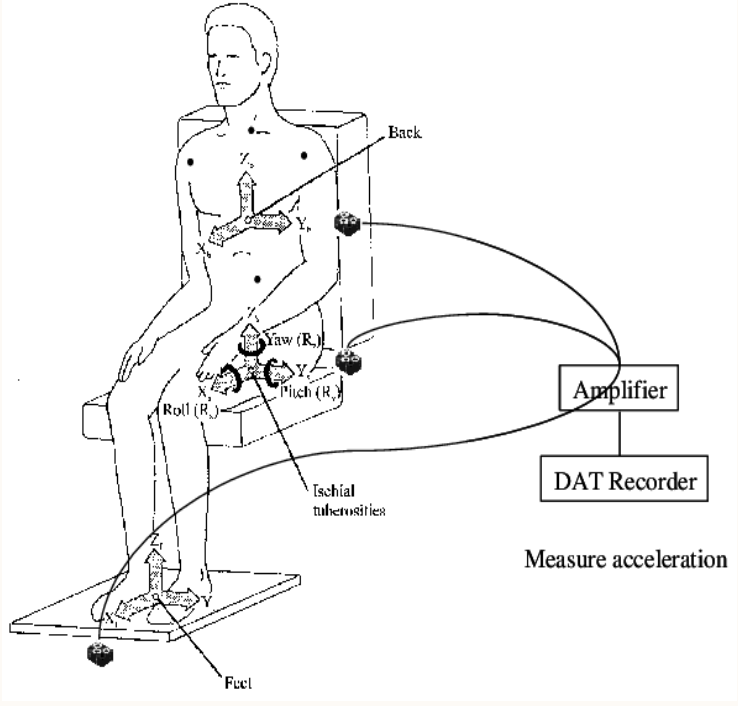
- Musculoskeletal Disorders
- Physiological system
- Motion Sickness
- Heart Rate Variability
- Loss of Balance

PREVENTION

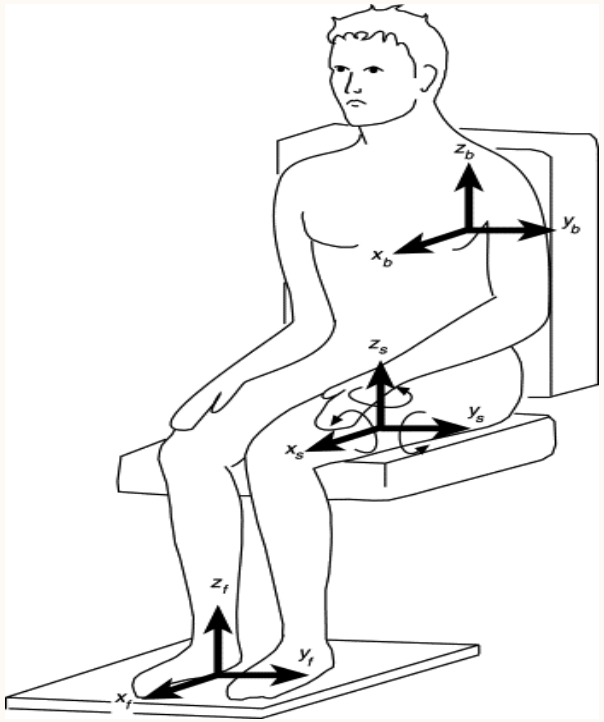
- Continuous Monitoring and rotation of subjects exposed to vibration
- To damp the incoming vibrations
- Regular medical checkups and proper healthcare.

EVALUATION OF WHOLE BODY VIBRATION

- Location of accelerometers
  - a) below ischial tuberosities.
  - b) seat- back area.
  - c)feet.
- Basi-centric axis is followed to place the accelerometers



placement of vibrational transducers
Image



basi-centric axis in seated position

METHODS

CREST FACTOR

- Modulus of the ratio of the maximum instantaneous peak value of the frequency weighted acceleration signal to its rms value

- CF < 9 RMS method
- CF > 9 RMS &VDV method

FREQUENCY WEIGHTED ROOT MEAN SQUARE ACCELERATION

$$a_w = \{\frac{1}{T}\int_0^t a_w^2(t).dt\}^{\frac{1}{2}}\ m/s^2$$

VIBRATIONAL DOSE VALUE

$$vdv = \{\int_0^T [a_w(t)]^4.dt\}^{\frac{1}{4}}\ m/s^{1.75}$$

- $a_w(t)$, is the weighted acceleration as a function of time, in meter per second square.
- T, is the time duration of the measurement in seconds

RISK ZONES OF WHOLE BODY VIBRATION

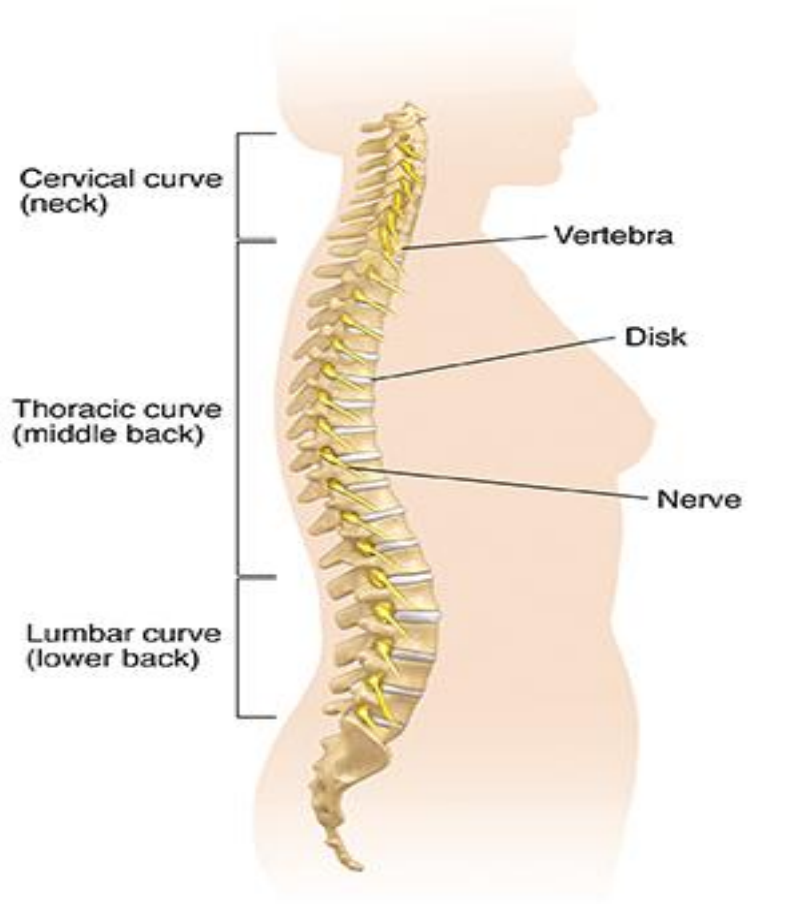
- $a_{rms} < 0.45\ m/s^2$ -- No risk zone
- $0.45\ m/s^2 < a_{rms} < 0.9\ m/s^2$ – Buffer zone
- $a_{rms} > 0.9\ m/s^2$ -- High risk zone

When Crest Factor > 9 :-

- $VDV > 9\ m/s^{1.75}$ – High risk zone

EFFECTS OF WHOLE BODY VIBRATION

- Short term effects such as headache, loss of balance. Long term effects such as musculoskeletal disorders(MSD) are caused due to WBV.
- Low back pain is the most prominent musculoskeletal disorder.
- Musculoskeletal disorders also can be observed in hip, neck, shoulders and ankle.
- Effects on Physiological systems.



EFFECTS OF WHOLE BODY VIBRATION

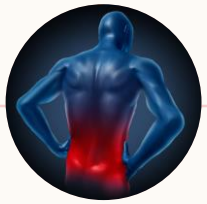
- Motion sickness occurs when frequency of vibration if less than 0.5 hz.
- One of the symptoms of motion sickness is a general feeling of nausea while riding in a car, train, or any other kind of transportation
- Motion sickness dose value (MSDV) is used to validate motion sickness which is measured in $m/s^{1.5}$.

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

HAND ARM VIBRATION

EVALUATION

- ISO: 5439
- Location of sensors
- Weighted root mean square acceleration is the sum of squares of rms acceleration the three directions in the coordinate system.



EFFECTS

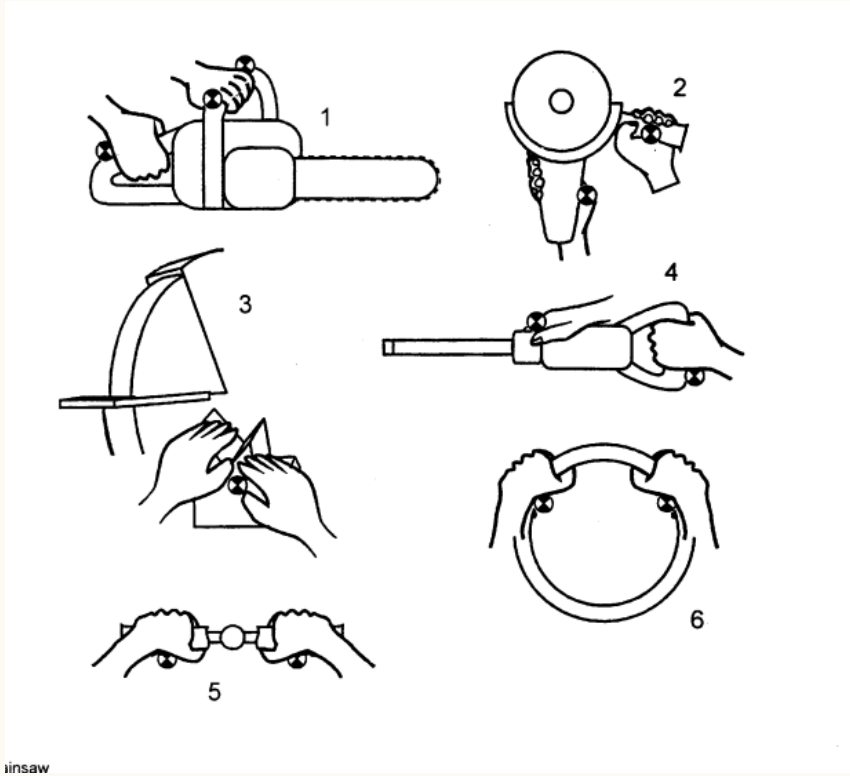
- Hand arm vibrational syndrome(HAVS)
- Numbness of fingers
- Carpel tunnel syndrome

PREVENTION

- Proper holding postures of power tools
- Duration of operating the tool
- Design of hand tool handles.

EVALUATION OF HAND ARM VIBRATION

- Location of accelerometers is based upon the holding the vibrating surface or tool.
- Basi-centric coordinate system is followed to place the accelerometers.
- The mounting of transducers also depends upon the type of power tool used.



Pictorial representation placement of transduces depending on type of hand power tool.
1. Chainsaw
2. Angle grinder
3. Pedestal grinding
4. Chipping hammer
5. Hand-guided machine
6. Steering wheel

Image source: ISO 5439-2

METHOD

- $a_{hw} = \left\{\frac{1}{T}\int_0^t a_w^2(t).dt\right\}^{\frac{1}{2}}$ is the rms acceleration for single axis.

- Let a_{hwx}, a_{hwy}, a_{hwz} be the frequency weighted rms value in the three directions x, y, z respectively

$$a_{hv} = \sqrt[2]{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2}$$

- Daily exposure value, A(8) for different durations is calculated as

$$A(8) = a_{hv}\sqrt{\frac{T}{T_0}}$$

Where, T is the daily exposure time and T_0 is reference duration 8 hours (28,800 s).

- If the exposure is such that it has different vibration magnitudes, A(8) is calculates as,

$$A(8) = \sqrt[2]{\frac{1}{T_0}\sum_{i=1}^{i=n} a_{hvi}T_i}$$

- **$a_w(t)$, is the weighted acceleration as a function of time, in meter per second square.**
- **T, is the time duration of the measurement in seconds**

RISK ZONES OF HAND ARM VIBRATION

- $a_{rms} < 2.5\ m/s^2$ -- No risk zone
- $2.5\ m/s^2 < a_{rms} < 5.0\ m/s^2$ – Buffer zone
- $a_{rms} > 5\ m/s^2$ -- High risk zone

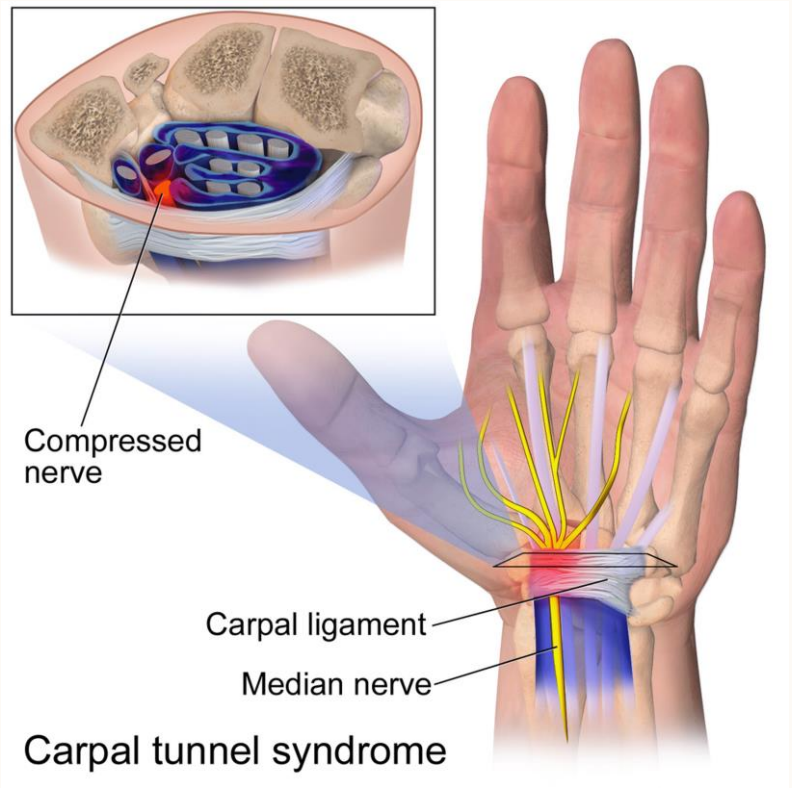
EVALUATION OF HAND ARM VIBRATION

- Hand arm vibration syndrome (HAVS).
- Vascular and Non-vascular
- Vibration induced white finger (VWF), which is the secondary type of Reynaud's disease
- Blood vessels dilate when blood begins to flow
- Necrosis- fingertips are damaged and the tissue dies.

Vibration Induced white finger

EVALUATION OF HAND ARM VIBRATION

- Non- vascular diseases deal with neurological disorders, musculoskeletal disorders in fingers and hand
- damage to peripheral nerves reduces the sensory perception.
- Carpel tunnel syndrome.



carpel ligament and median nerve.

USES OF VIBRATION EXPOSED TO BODY

- The WBV is utilized as a workout module in sports
- Provides quick, energy-efficient warm-up impact
- Enhances flexibility.
- Effective training strategy for increasing jump height and muscular strength.
- Enhance postural control

USES OF VIBRATION EXPOSED TO BODY

- Minimizes the negative ageing effects on joints, and connective tissues.
- Increases the levels of somatotrophin hormones in the human body.
- Improves the gait pattern of the patients.
- increases bone development and decreases osteoclast activity.

PREVENTIONS

- Vibration can’t be excluded from work environment.
- Vibration can be minimized.
- In transportation such as cars, trucks, seats can be designed for damping the vibration.
- Continuous monitoring and rotational shifts of workers.
- The proper postures of sitting in transportation.
- Workshops on holding power tools for workers can improve the knowledge of effects and prevention.

DEVICE AND DEVELOPMENT FOR MONITORING VIBRATIONAL EXPOSURE

- Vibrational exposure evaluation setup is being developed.

- Development :

  → vibrational transducer unit – completed

  →Developing of evaluation unit for the data – initial stage.

THANK YOU

Dr. A. Thirugnanam