

OSC | 10
Ohio Safety Congress & Expo

Occupational whole-body vibration
253
Helmut Paschold, Ph.D., CIH, CSP

Wednesday, March 31, 2010, 10:30 to 11:30 a.m.

Ohio | Bureau of Workers' Compensation

OVERVIEW

- Introduction
- Whole Body Vibration (WBV)
 - Basics, Sources, Measurement, Standards, and Adverse Health Effects
- A "hidden culprit"?
- Remedies for WBV
- Summary/Questions

Ohio | Bureau of Workers' Compensation

INTRODUCTION

- Whole Body Vibration is the result of external vibrations causing motion of part or all of the body
- These vibrations may result in adverse health effects

Ohio | Bureau of Workers' Compensation

VIBRATION BASICS

Vibration –

- A wave motion, oscillating about a fixed point
- Capable of transferring energy from object to another

Ohio | Bureau of Workers' Compensation

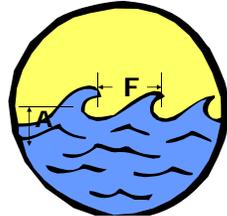
VIBRATION BASICS

- Vibration is typically represented by the **sine** wave, characterized by frequency and amplitude
- Acceleration is given in meters per second squared ($m-s^{-2}$), or sometimes in "g's" ($9.8 m-s^{-2}$)

Ohio | Bureau of Workers' Compensation

VIBRATION BASICS

Frequency: distance from wave to wave
Amplitude: distance from wave trough to crest



The diagram shows a circular cross-section of a wave. The wave is represented by a blue sine wave oscillating between a yellow crest and a blue trough. A horizontal line with arrows at both ends is drawn across the wave, labeled 'F' for frequency, indicating the distance between two consecutive crests. Another horizontal line with arrows at both ends is drawn from the trough to the crest, labeled 'A' for amplitude.

VIBRATION BASICS

- Frequency is generally expressed in **Hertz** (Hz) such as in household electric current – 110 volts, 60 Hz
- In reality, our vibration wave exposures are complicated by numerous simultaneous waves

VIBRATION BASICS

WBV is expressed in terms of the **root-mean-square** (r.m.s.), a mathematical method analogous to the statistical standard deviation function

VIBRATION BASICS

Natural frequency

- The inherent frequency of a spring-mass system
- When an external natural frequency is applied to a system, a synergistic effect known as **resonance** occurs.

VIBRATION TRANSMISSION and SOURCES

Vibration from the environment is transmitted to the human when

- Standing,
- Sitting, or
- Reclining

VIBRATION TRANSMISSION and SOURCES



VIBRATION TRANSMISSION and SOURCES



VIBRATION TRANSMISSION and SOURCES



VIBRATION TRANSMISSION and SOURCES



VIBRATION TRANSMISSION and SOURCES



VIBRATION TRANSMISSION and SOURCES



VIBRATION TRANSMISSION and SOURCES



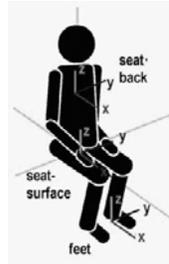
VIBRATION MEASUREMENT

- Integrated instrument
- Accelerometer
- Amplifier
- Frequency weighting filter
- Signal analyzer

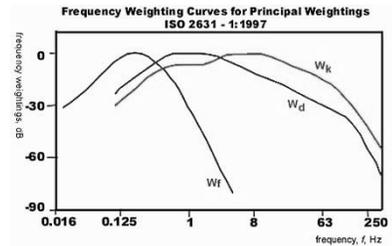


VIBRATION MEASUREMENT

Coordinate systems

**VIBRATION MEASUREMENT**

Frequency weighting

**VIBRATION AND THE HUMAN BODY**

- The key concern is the natural frequencies of human body parts
- WBV is of greatest concern with frequencies between 1 and 20 Hz.
- Frequencies less than 1 Hz are associated with motion sickness

VIBRATION AND THE HUMAN BODY

Body - Whole, Part or Organ	Resonant Frequency (Hz)
Whole body – standing	12.3 +/- 0.1
Whole body – seated vertically	4 to 6
Whole body, prone	3 to 4
Whole trunk (vertical)	4 to 8
Lumbar disks	4.5 to 5.5

VIBRATION AND THE HUMAN BODY

Body - Whole, Part or Organ	Resonant Frequency (Hz)
Head relative to body	20 to 30
Eyes	20
Shoulder girdle	5
Stomach	4 to 5
Cardiovascular system	below 20

VIBRATION AND THE HUMAN BODY

Problem:

- When exposed to frequencies below 20 Hz, many body organs will resonate

VIBRATION STANDARDS

- British Standards Institution (BSI)
 - BS 6841 (1987)
- International Organization of Standardization (ISO)
 - ISO 2631-1 (1997)

VIBRATION STANDARDS

In the United States.....

- ANSI S3.18
 - Guide for the Evaluation of Human Exposure to Whole-Body Vibration
- American Conference of Governmental Industrial Hygienists (ACGIH)
 - Published thresholds for WBV exposure

VIBRATION STANDARDS

What about OSHA????

ADVERSE EFFECTS OF WBV

- WBV at the resonant frequency of the whole body or its parts causes numerous voluntary or involuntary muscle contractions
- This, in turn, can cause fatigue or reduced motor performance ability

ADVERSE EFFECTS OF WBV

Back injuries:

- Belgium, Germany, Netherlands, and France recognize WBV exposure combined with lower back pain as an occupational disease qualifying workers for compensation

ADVERSE EFFECTS OF WBV

Back injuries:

- Heavy construction equipment operators have Lower Back Injuries (LBI) without lifting or trauma (Kittusamy)
- Forklift operators have greater LBI rates than non-drivers (Hoy)

ADVERSE EFFECTS OF WBV

Back injuries:

- Medical exams did not prove a correlation between WBV and LBI in a study of 20 earth moving equipment operators (Drerup)
- Epidemiological studies provide clear links between WBV and LBI (Bovenzi)

ADVERSE EFFECTS OF WBV

- Digestive system diseases are associated with exposures to WBV at 4 to 5 Hz (SafetyLine Institute)
- Respiration interference occurs at 1 to 4 Hz (Grandjean)
- Potential inner ear damage at 10 Hz (Bochnia)

ADVERSE EFFECTS OF WBV

- Blurred vision can occur from exposure to 10 to 30 Hz.
- A 50% reduction in visual acuity is reported for 50 Hz at 2 m-s² (Grandjean)
- Or, general complaints such as discomfort, distraction or interference with cognitive activities (Ljungberg)

ADVERSE EFFECTS OF WBV

Motion sickness:

- Sea-sickness - vertical very low frequency with high amplitude
- Motion sickness in vehicles – low frequency, horizontal high amplitude from starting, stopping and turning.

**ADVERSE EFFECTS OF WBV**

Good effects from WBV?

- Body building for athletes
- Muscle strengthening for persons with paralysis

**THE "HIDDEN CULPRIT"**

"How could he hurt his back? All he does is sit in his truck all day."



THE "HIDDEN CULPRIT"

"How could he hurt his back? All he does is sit in his truck all day."

A client's division utilizing heavy equipment reported 28 operator LBI claims in a three-year period totaling \$500,000 in direct worker compensation costs. No lifting, no trauma. WBV?

NIOSH study – mining dozer operators, 50% of injuries and 55% of costs due to "jolted/jarred" from 1988-1997

THE "HIDDEN CULPRIT"

"How could he hurt his back? He's a forklift driver and doesn't lift a thing by hand!"



THE "HIDDEN CULPRIT"

"How could he hurt his back? He's a forklift driver and doesn't lift a thing by hand!"

Driving the forklift transmits 5 Hz WBV to an operator, seated with poor posture. WBV?

THE "HIDDEN CULPRIT"

"How could he hurt his back getting off of the earthmoving equipment? He didn't fall; and, we have the best handhold and footstep systems available."



THE "HIDDEN CULPRIT"

"How could he hurt his back getting off of the earthmoving equipment? He didn't fall; and we have the best handhold and footstep systems available."

A WBV weakened back receives an LBI-causing-jolt when he jumps a short distance to the ground. WBV?

THE "HIDDEN CULPRIT"

"Why didn't the driver see the obstacle in the middle of the road? It was daytime and the windshield was clean!"



THE "HIDDEN CULPRIT"

"Why didn't the driver see the obstacle in the middle of the road? It was daytime and the windshield was clean!"

Visual acuity may have been reduced by WBV.

THE "HIDDEN CULPRIT"

"How can this employee claim hearing loss due to on-the-job exposure when we have proof that the time-weighted averages are 82 dBA or less? "

**THE "HIDDEN CULPRIT"**

"How can this employee claim hearing loss due to on-the-job exposure when we have proof that the time-weighted averages are 82 dBA or less? "

By exposure to 10 Hz WBV at high amplitude? If it hurts guinea pigs, could it harm humans? WBV.

THE "HIDDEN CULPRIT"

"We sampled and analyzed the air for every chemical known to mankind, found nothing of concern, and improved ventilation. Why do the employees continue to complain of *bad air*?"

THE "HIDDEN CULPRIT"

"We sampled and analyzed the air for every chemical known to mankind, found nothing of concern, and improved ventilation. Why do the employees continue to complain of *bad air*?"

Respiratory interference can occur between 1 and 4 Hz. Possibly caused by nearby vehicle traffic, machinery or air handling equipment. WBV?

REMEDIES FOR WBV

- Engineering to eliminate the sources of WBV
- Remove employees from vibration prone locations
- Replace old equipment with new equipment that vibrates less
- Ship by train instead of truck

REMEDIES FOR WBV

- Reduce vehicle speeds on rough terrain
- Install devices to dampen vibration on vibrating equipment
- Maintain equipment in optimal operating condition
- Eliminate unnecessary job steps

REMEDIES FOR WBV

- Install vibration dampeners on the wheels, cabs and seats of vehicles
- Improve mirror and control location to eliminate body turning by seated equipment operators
- Job rotation
- Employee training and rules

SUMMARY

- WBV can cause occupational injuries and illnesses solely or with other work and environmental factors
- Control is best achieved by the elimination or isolation of vibration

Whole Body Vibration