Whole-body Vibration Exposure:
What you need to know to prevent vibration induced injuries

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Centre for Research in Occupational Safety and Health
Laurentian University
Presentation Overview

• Vibration basics
• Occupational exposed to vibration
  – Whole-body vibration
  – Foot-transmitted vibration
• Health risks
• Evaluation methods
• Prevention/reduction strategies
• Whole-body vibration (WBV)
• Hand-arm vibration (HAV)
• Foot-transmitted vibration (FTV)
4 factors are required to describe human response to vibration:

- **Magnitude**
  - ‘bounce height’ (m/s²)
- **Frequency**
  - # of ‘bounces’ per sec. (Hz)
- **Direction**
  - X, Y, Z axes
- **Duration**
  - length of exposure time
Vibration Basics

4 factors are required to describe human response to vibration:

- **Magnitude**
  - ‘bounce height’ (m/s²)

- **Frequency**
  - # of ‘bounces’ per sec. (Hz)

- **Direction**
  - X, Y, Z axes

- **Duration**
  - length of exposure time

Exposure at resonance is linked with increase injury risk

Image From: http://physics.stackexchange.com/questions/
Health Risks: Whole-body Vibration

- lower-back pain, spinal degeneration, neck problems
- muscle fatigue
- sleep problems, headaches, & nausea
- hearing loss
- gastro-intestinal tract problems

(Scutter et al., 1997; Seidel, 1993; Seidel, 2005; Thalheimer, 1996; Mansfield, 2005)
Health Risks: Foot-Transmitted Vibration

- Pain and numbness in the toes and feet
- Increased sensitivity to cold
- Blanching of toes
- Joint pain

Vibration-Induced White-Foot

(Thompson et al., 2010)
Hand-Arm Vibration Syndrome

• Vascular component of HAVS
  – Blanching of the fingers
  – Trophic changes to the skin
Evaluation Methods
# Predicting Health Risks

<table>
<thead>
<tr>
<th>Vibration Type</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole-Body Vibration</td>
<td>ISO 2631-1</td>
</tr>
<tr>
<td></td>
<td>ISO 2631-5</td>
</tr>
<tr>
<td></td>
<td>EU Directive 2002/44/EC</td>
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<tr>
<td>Hand-Arm Vibration</td>
<td>ISO 5349-1</td>
</tr>
<tr>
<td></td>
<td>EU Directive 2002/44/EC</td>
</tr>
<tr>
<td>Foot Transmitted Vibration</td>
<td>???</td>
</tr>
</tbody>
</table>
Measuring WBV

WBV is measured in accordance with ISO 2631-1

Tri-axial accelerometer mounted in rubber seat pad

Seat pad positioned on vehicle seat

Data-logger used to record the vibration data collected in the field
WBV v1.0, ByteWorks

http://ergonomics.uq.edu.au/WBV/WBVpod/Index.html
ISO 2631-1

Tri-axial acceleration values measured at the seat

Apply frequency weightings
\(x\text{-axis} = W_d; \ y\text{-axis} = W_d; \ z\text{-axis} = W_d\).

Apply scaling factors for health analysis
\(x\text{-axis} = 1.4; \ y\text{-axis} = 1.4; \ z\text{-axis} = 1\)

Calculate r.m.s.

Record instantaneous peak frequency-weighted acceleration

Calculate Crest Factor Value for the period of interest \((CF_x, CF_y, CF_z)\)

Determine if \(CF_x, CF_y\) or \(CF_z\) is greater than 9

NO

Compare the axis with the highest frequency weighted r.m.s. value to the health guidance caution zone

YES

Compare the axis with the highest VDV to the equivalent health guidance caution zone limits
To predict health risk for DAILY exposure 8hr equivalent values are calculated.
# Health Risk Determination

## ISO 2631-1

<table>
<thead>
<tr>
<th>Assessment of Adverse Health Effects</th>
<th>Terminology used to describe the Predicted Health Risks</th>
<th>ISO 2631-1 (A(8) and VDV&lt;sub&gt;total&lt;/sub&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;For exposures below the zone (HGCZ), health effects have not been clearly documented and/or objectively observed&quot;</td>
<td>LOW</td>
<td>A(8) &lt; 0.45</td>
</tr>
<tr>
<td>&quot;..in the zone (HGCZ), caution with respect to potential health risks is indicated&quot;</td>
<td>MODERATE</td>
<td>0.45 - 0.90</td>
</tr>
<tr>
<td>&quot;..above the zone (HGCZ) health risks are likely&quot;</td>
<td>HIGH</td>
<td>&gt; 0.9</td>
</tr>
</tbody>
</table>
## “Guidelines” WBV Exposure

<table>
<thead>
<tr>
<th>“Probable” Health Risk</th>
<th>ISO 2631-1</th>
<th>EU Directive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\mathbf{A(8)}$ (m/s$^2$)</td>
<td>$\mathbf{VDV}_{\text{total}}$ (m/s$^{1.75}$)</td>
</tr>
<tr>
<td>low</td>
<td>&lt; 0.45</td>
<td>&lt; 8.5</td>
</tr>
<tr>
<td>moderate</td>
<td>0.45 - 0.90</td>
<td>8.5 - 17</td>
</tr>
<tr>
<td>high</td>
<td>&gt; 0.9</td>
<td>&gt; 17</td>
</tr>
</tbody>
</table>
Example: WBV Field Study: Load-Haul-Dump Vehicle

- Health risk predictions based on ISO 2631-1 HGCZ comparison

4 of 11 (large) LHD operators were exposed the WBV levels above the HGCZ.

7 of 10 (small) LHD operators were exposed the WBV levels above the HGCZ.
## WBV Exposure
### Mining Equipment Operation

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Application</th>
<th>Vibration Exposure</th>
<th>Vibration Exposure</th>
<th>Study Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$A(8)$ m/s²</td>
<td>$YDV_{0.2}$ m/s¹.⁷⁵</td>
<td></td>
</tr>
<tr>
<td>Haul Truck (16 ton)</td>
<td>underground nickel mine</td>
<td>1.20</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Haul Truck (30 ton)</td>
<td>open pit mine</td>
<td>0.69</td>
<td>14.5</td>
<td>moderate</td>
</tr>
<tr>
<td>Haul Truck (36 ton)</td>
<td>open pit mine</td>
<td>0.78</td>
<td>16.4</td>
<td>moderate</td>
</tr>
<tr>
<td>Haul Truck 50 ton</td>
<td>aggregate stone quarry</td>
<td>0.99</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Haul Truck 70 ton</td>
<td>aggregate stone quarry</td>
<td>0.58</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Haul Truck 100 ton</td>
<td>open pit mine</td>
<td>0.74</td>
<td>12.4</td>
<td>moderate</td>
</tr>
<tr>
<td>Haul Truck 150 ton</td>
<td>open pit mine</td>
<td>0.61</td>
<td>10.8</td>
<td>moderate</td>
</tr>
<tr>
<td>Haul Truck 240 ton</td>
<td>overburden mining</td>
<td>0.71</td>
<td>---</td>
<td></td>
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<tr>
<td>Haul Truck 320 ton</td>
<td>overburden mining</td>
<td>0.67</td>
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<tr>
<td>Bulldozer</td>
<td>underground nickel mine</td>
<td>1.64</td>
<td>11.8</td>
<td>moderate</td>
</tr>
<tr>
<td>Bulldozer</td>
<td>surface coal mine</td>
<td>0.59</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Grader</td>
<td>underground nickel mine</td>
<td>0.79</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Front end Loader</td>
<td>South African Mine</td>
<td>2.0</td>
<td>---</td>
<td></td>
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<tr>
<td>Dumper</td>
<td>coal mine</td>
<td>1.10</td>
<td>13.84</td>
<td>moderate</td>
</tr>
<tr>
<td>LHD (3.5 yard)</td>
<td>underground gold mine</td>
<td>1.12</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>LHD (3.5 yard)</td>
<td>underground gold mine</td>
<td>2.25</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>LHD (1.5-4 yards)</td>
<td>underground gold mine</td>
<td>1.7</td>
<td>34.0</td>
<td>high</td>
</tr>
<tr>
<td>LHD (3-6 yards)</td>
<td>underground gold mines</td>
<td>0.97</td>
<td>22.96</td>
<td>high</td>
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<tr>
<td>LHD (5 yard)</td>
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<tr>
<td>LHD (6 yard)</td>
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<td>---</td>
<td></td>
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<tr>
<td>LHD (7 yard)</td>
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<td>---</td>
<td></td>
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<tr>
<td>LHD (8 yard)</td>
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<td>---</td>
<td></td>
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<td>LHD (6-11 yards)</td>
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<td>19.94</td>
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<td>Articulated haul Truck</td>
<td>South African Mine</td>
<td>3.4</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Hydraulic Face Shovel</td>
<td>South African Mine</td>
<td>4.4</td>
<td>---</td>
<td></td>
</tr>
</tbody>
</table>

References:
- Eger et al., 2006
- Smets et al., 2010
- Mayton et al., 2008
- Kumar, 2004
- Mandal and Srivastava, 2010
- Van Niekerk et al., 2000
- Village et al., 1989
- Eger et al., 2011
- Eger et al., 2006
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<tr>
<td></td>
<td></td>
<td>$A(8)/m^2$</td>
<td>$V_{D_{34000}}$ $m/s^{1.75}$</td>
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<tr>
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<td>Health Risk¹</td>
<td>Health Risk²</td>
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<td>1.7</td>
<td>22.96</td>
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<td>high</td>
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<td>underground mine</td>
<td>0.82</td>
<td>19.94</td>
<td>Eger et al., 2013</td>
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<td>underground mine</td>
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<td>22.5</td>
<td>Eger et al., 2011</td>
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<td></td>
<td>South African Mine</td>
<td>4.4</td>
<td>high</td>
<td>Van Niekerk et al., 2000</td>
</tr>
</tbody>
</table>
• No specific standard
  – ISO 2631-1
  – ISO 5349-1
**Foot-transmitted Vibration**

- In a recent field study by Leduc et al., 2010, FTV characteristics were reported:

<table>
<thead>
<tr>
<th>Machine</th>
<th>$a_{wz}$ (m/s$^2$)</th>
<th>DFz (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locomotive-1</td>
<td>0.43</td>
<td>6.3</td>
</tr>
<tr>
<td>Locomotive-2</td>
<td>0.36</td>
<td>3.15</td>
</tr>
<tr>
<td>Jumbo-1 Boom</td>
<td>0.44</td>
<td>31.5</td>
</tr>
<tr>
<td>Wooden Raise</td>
<td>1.13</td>
<td>40</td>
</tr>
<tr>
<td>Metal Raise</td>
<td>1.08</td>
<td>40</td>
</tr>
</tbody>
</table>

*Dominant Frequency btw 3.15 – 6.3 Hz*

*Dominant Frequency btw 31-5-40 Hz*

According to ISO 2631-1 Raise workers were above the 8hr HCGZ
Foot-Transmitted Vibration

Raise Platform Workers

• 100 % hand problems
• 75 % had foot problems
• Raise workers were exposed to the greatest magnitude of FTV
• Dominant exposure frequency was 40 Hz

2 of 3 raise workers were diagnosed by their doctor to have VWFt and HAVS
Mining and FTV

• 6/27 miners displayed Raynaud’s phenomenon in their feet after having stood on platforms with attached drills (Hedlund, 1989)

• Case study report – a miner (bolter) with vibration induced white foot without corresponding HAV syndrome (Thompson et al., 2010)
## FTV Exposure

### Mining Equipment Operation

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Application*</th>
<th>Vibration Exposure</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$A(8) : m/s^2$</td>
<td>Dominant Frequency</td>
</tr>
<tr>
<td><strong>Cavo Loader</strong></td>
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<td>2.29</td>
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<tr>
<td><strong>Muck Machine</strong></td>
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<td>1.02</td>
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<td>Crusher</td>
<td>underground nickel mine</td>
<td>0.22</td>
<td>10.1</td>
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<tr>
<td>Rotary Crusher</td>
<td>South African mine</td>
<td>0.42</td>
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<td>South African mine</td>
<td>0.24</td>
<td>not reported</td>
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<td>underground gold mine</td>
<td>0.76</td>
<td>not reported</td>
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<td>underground gold mine</td>
<td>0.4</td>
<td>4.65</td>
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<tr>
<td>Locomotive</td>
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<td>0.4</td>
<td>4.2</td>
</tr>
<tr>
<td>Bolting Platform</td>
<td>underground nickel mine</td>
<td>0.45</td>
<td>not reported</td>
</tr>
<tr>
<td>Bolter</td>
<td>underground gold mine</td>
<td>0.11</td>
<td>5</td>
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<tr>
<td>Bolter</td>
<td>underground gold mine</td>
<td>0.29</td>
<td>5.7</td>
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<tr>
<td>Scissor Lift</td>
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<td>0.72</td>
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<tr>
<td>Jumbo Drill</td>
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<td>31.5</td>
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<td>Raise Platform</td>
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<td>0.84</td>
<td>40</td>
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<tr>
<td><strong>Raise Platform</strong></td>
<td>underground gold mine</td>
<td><strong>1.0</strong></td>
<td>40</td>
</tr>
</tbody>
</table>

*all measures were taken at the floor when the worker was standing*
Toe Waveforms at Room Temperature
Right Foot
Left Foot

Finger Waveforms at Room Temperature
Right Hand
Left Hand

Finger Waveforms Post-cold Stress
Right Hand
Left Hand

Toe Waveforms Post-cold Stress
Right Foot
Left Foot
Interventions and Prevention Strategies
Hierarchy of Controls

- Elimination
- Substitution
- Engineering
- Administration
- Personal Protective Equipment
Factors Influencing WBV Exposure

- Risk potential (ISO 2631-1)
- Exposure duration
- Vibration characteristics
- Road condition
- Maintenance
- Vehicle load
- Shift length
- Tire pressure
- Driving style
- Seat design
- Suspension
- Vehicle load
Driving Task
Forward
Backward
Mucking

Driving Speed
G1
G2
G3
AS

Haulage
Loaded
Unloaded

Terrain
Rough
Maintained

Ride Control
On
Off

Frequency-Weighted RMS Vibration
(floor/seat interface)
(operator/seat interface)

ISO 2631-1 HGCZ
A(8)
VDV_{total}

EU Directive
A(8)
VDV_{total}
Ride Control

WBV exposure was lower with Ride Control engaged

5.7 m³
Bucket LHD

ISO 2631-1
Health Guidance Caution Zone for 8-hour equivalent A(8) value

- ◆ RC OFF; MT; G1-AS
- ▲ RC OFF; MT; G1-3
- ■ RC ON; MT; G1-AS
- ● RC ON; MT; G1-3
- □ RC ON; Main; G1-3
- △ RC ON; MT: G1-AS: No seat amp.
Decrease Speed

Decreased WBV exposure with reduced speed - avoid 4\textsuperscript{th} gear
Maintain Roadways

Decreased WBV exposure with maintained roadways

5.7 m³
Bucket LHD
Seat “performance” matters

Decreased WBV exposure with a seat SUITED to the equipment
Exposure was still within ISO HGCZ BUT below EU 2002/44/EC action value
Field Test

Evaluation of a NEW “Ergonomic” Seat

BLUE = seat   RED=floor
S.E.A.T. (seat effective amplitude transmissibility)

\[ \text{SEAT}(\%) = \frac{\text{vibration}_{\text{seat}}}{\text{vibration}_{\text{floor}}} \times 100\% \]

A rigid seat = ratio of 1.0
A value greater than 1 = amplification
A value less than 1 = attenuation

Vibration measured at the seat
Vibration measured at the floor
FIELD TESTING:

Evidence was found to indicate seats in LHD vehicles were AMPLIFYING the vibration

LAB testing CONFIRMED the seat amplified the vibration (in the DF range)
Seating Innovations

• New seating was intended to
  – Improve seating posture
    • Allow greater adjustability
  – Improve seating comfort
    • Avoid end-stops due to vibration impacts
  – Attenuate vibration
    • Decrease WBV exposure

NEW does not always mean BETTER
Seat Selection is Important

- Paddan and Griffin (2002) evaluated the vibration isolation efficiency for 100 seats found in 14 different types of vehicles and found **94% of the vehicles evaluated would have improved vibration attenuation if a seat from one of the other vehicles tested in the study was used over the current seat.**
30 of the most common field vibration profiles were used to evaluate the seats.

(Dickey et al., 2013)
Seat Evaluations

Access new, ½ worn, fully worn out

KAB 525 new, ½ worn, fully worn out

KAB 301 new, CAT new, ISRI worn out
Figure 4. S.E.A.T. factors for five seats in four BMI groups based on an average of thirty most common vibration profiles. Error bars represent one standard deviation.
What does this mean?

Based on the vibration profiles (created from UG mining equipment operation) the CAT seat generally performed better.

(Dickey et al., 2013)
Increased low-back injury risk when WBV exposure is combined with non-neutral working postures

Port workers – cranes & lift trucks (Bovenzi et al., 2002)
Farm workers – tractors (Wikstrom, 1993; Bovenzi & Betta, 1994)
Construction – excavators, pavers etc. (Kittusamy and Buchholz, 2004)
Locomotive operators (Johanning et al., 2002)
LHD operators (Eger et al., 2009)
WBV Interventions

- Remove the worker from vibration source
- Purchase equipment with lower vibration emissions
- Maintain equipment (and roadways)
- Reduce driving speed
- Install suspension and seating suited to the conditions
- Maintain a neutral driving posture
Interventions
HAV and FTV
Procedures to Reduce Vibration Exposure of Tools

• Purchase lower vibration tools
  – Purchasing policy for company

• Tool maintenance
  – Set up maintenance and replacement program for vibrating tools
    – Keep cutting tools sharp
    – Replace worn parts
    – Replacing anti-vibration mounts & suspended handles before they deteriorate (cracking, swelling, hardening)
    – Checking/replacing defective vibration dampers, bearings, gears
Better Equipment
Drill with an “anti-vibration” intervention

Below 0.45 m/s² – Health effects are unlikely
0.45-0.9 m/s² – Health Guidance Caution Zone: Health effects are possible
Above 0.9 m/s² – Health effects are likely
Better Equipment
Jumbo with a isolation platform

Health Guidance Caution Zone

- Metal Raise "Anti-Vibration" Drill
- Primary
- Secondary

Equipment Type

A(8) Value (m/s²)

0 0.2 0.4 0.6 0.8 1 1.2

Jumbo Drill
Bolter
Administrative Controls

• Minimizing exposure time
  – Job rotation/Scheduling

• If working in cold ambient conditions, provide opportunity for re-warming
  – Warm building/shelter for breaks
  – Portable hand warmers
Personal Protective Equipment

Anti-vibration gloves

• ISO/ANSI certified
  – Full fingered
  – Meet the vibration dampening requirements (ISO)
    • 31.5-200 Hz: Transmission < 1.0
    • >200 -1000Hz: Transmission < 0.6
## Vibration Induced Injury

<table>
<thead>
<tr>
<th>Whole-Body Vibration (WBV)</th>
<th>Hand-Arm Vibration Syndrome (HAVs)</th>
<th>Vibration Induced White Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>• spine disorders</td>
<td>• osteoarticular, neurological and vascular disorders including vibration induced white finger and vibration induced white feet</td>
<td></td>
</tr>
<tr>
<td>• neck disorders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• gastrointestinal disorders</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
OHS Legislation

No occupational health and safety regulations specifically related to vibration in Ontario

— General Duty Clause

• 25.(2)(h) every reasonable precaution.. “take every precaution reasonable in the circumstances for the protection of a worker.”

(OHSA)
Vibration Workshop December 2\textsuperscript{nd}

The Centre for Research in Occupational Safety and Health \textit{in partnership with} The Centre for Research Expertise in Occupational Disease \textit{and} The Centre of Research Expertise for the Prevention of Musculoskeletal Disorders \textit{present an}

OCCUPATIONAL VIBRATION WORKSHOP

Participants will explore hands-on activities and leave with an understanding of how to measure, evaluate, and interpret vibration exposure data. Controls and best practices will also be presented.

DECEMBER 2, 2014
8:00 a.m. to 3:30 p.m.
Registration and continental breakfast at 7:30 a.m.
Workshop begins at 8:15 a.m.
West Residence, W-132
Laurentian University

WORKSHOP PRESENTERS INCLUDE:

Dr. Ron House
- Leads research in the area of hand-arm vibration syndrome with the Centre for Research Expertise in Occupational Disease
- Associate Professor, Northern Ontario School of Medicine (NOSM)

Dr. Tammy Eger
- Leads research in the area of whole-body and foot-transmitted vibration for Laurentian University
- Director of the Centre for Research in Occupational Safety and Health, Sudbury

Dr. Jim Dickey
- Leading research in whole-body vibration exposure and evaluation of seats for mobile equipment
- Director of the Joint Biomechanics Laboratory at Western University

Workshop admission is free but requires pre-registration. Confirm your attendance by November 21st to crosh@laurentian.ca.
Guide to good practice on

Hand-Arm Vibration

Non-binding guide to good practice with a view to implementation of Directive 2002/44/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibrations).

Guide to good practice on

Whole-Body Vibration

Non-binding guide to good practice with a view to implementation of Directive 2002/44/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibrations).
Vibration at Work

Worried about risks from exposure to vibration?

Did you know, vibration can cause long-term painful damage to your hands and fingers - and that shocks and jolts from driving certain types of vehicles can cause severe back pain?

Other Information on Vibration

http://www.hse.gov.uk/vibration/index.htm

Hand-arm vibration

Advice on reducing the risks of pain in the hands and arms caused by using hand-held tools.

Whole body vibration

Advice on reducing the risks of back and muscle pain caused by shocks/vibrations when driving certain types of vehicle.
Acknowledgements

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- Dr. Ron House, St. Michael’s Hospital
- Dr. Michele Oliver, University of Guelph
- Dr. Aaron Thompson, St. Micheal’s Hospital

Industry Partners
- Workplace Safety North
- Ontario Mining Industry
- Mining Equipment Manufacturers

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- Canada Foundation for Innovation
- Ontario Innovation Trust
- Centre of Research Expertise for the Prevention of Musculoskeletal Disorders
- NSERC CRSNG
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Standards


References

The purpose of this part of ISO 2631 is to define a method of quantifying whole-body vibration containing multiple shocks in relation to human health. Examples of conditions that result in vibration containing multiple shocks include, but are not limited to, machinery travelling over rough surfaces, small boats in rough sea, aircraft in buffeting, presses and mechanical hammers.

Adverse effects on the lumbar spine are the dominating health risks of long-term exposure to vibration containing multiple shocks. Therefore, this part of ISO 2631 is basically concerned with the lumbar spine response. Annex A provides guidance on assessment of adverse health effects.

The assessment method described in this part of ISO 2631 is based on the predicted response of the bony vertebral endplate (hard tissue) in an individual who is in good physical condition with no evidence of spinal pathology and who is maintaining an upright unsupported posture. However, the assessment method and related models described in this part of ISO 2631 have not been epidemiologically validated.
# ISO 2631-1 & ISO 2631-5

## Predicted Health Risk Variables

<table>
<thead>
<tr>
<th>“Health Risk”</th>
<th>ISO 2631-1</th>
<th>ISO 2631-5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A(8) (\text{m/s}^2)</td>
<td>(\text{VDV}_{\text{total}}) (\text{m/s}^{1.75})</td>
</tr>
<tr>
<td>low</td>
<td>&lt; 0.45</td>
<td>&lt; 8.5</td>
</tr>
<tr>
<td>moderate</td>
<td>0.45 - 0.90</td>
<td>8.5 - 17</td>
</tr>
<tr>
<td>high</td>
<td>&gt; 0.9</td>
<td>&gt; 17</td>
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