Understanding and Lowering the Risk of Hand-Arm Vibration Syndrome (HAVS)

Danny A. Riley, PhD
Professor of
Cell Biology, Neurobiology & Anatomy and
Physical Medicine & Rehabilitation
Medical College of Wisconsin
Milwaukee, Wisconsin

2014 Indiana Safety & Health Conference & Expo
February 19, 2014
dariley@mcw.edu

Neuromuscular cell biologist examining how tissues respond to the environmental stresses of gravity and vibration

NIOSH
R01 OH003493

NASA
Translate research to practice
# Understanding and Lowering the Risk of Hand-Arm Vibration Syndrome

## Overview
- Hand-Arm Vibration Syndrome (HAVS)
- Power tool vibration
- Risk assessment measurements
- Vibration injury reduction
- Worker responsibilities
- Employer responsibilities
- Information sources

## Workers exposed to hand-transmitted vibration in the USA

<table>
<thead>
<tr>
<th>Industry</th>
<th>Type of tools</th>
<th># of workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>Handtools</td>
<td>500,000</td>
</tr>
<tr>
<td>Truck, auto manufacturing</td>
<td>Handtools</td>
<td>250,000</td>
</tr>
<tr>
<td>Farming</td>
<td>Gasoline chain saws</td>
<td>200,000</td>
</tr>
<tr>
<td>Mining</td>
<td>Pneumatic drills</td>
<td>100,000</td>
</tr>
<tr>
<td>Steel</td>
<td>Furnace cleaning with powered tools</td>
<td>54,000</td>
</tr>
<tr>
<td>Furniture manufacturing</td>
<td>Handtools</td>
<td>34,000</td>
</tr>
<tr>
<td>Lumber and wood</td>
<td>Gasoline chain saw</td>
<td>30,000</td>
</tr>
<tr>
<td>Metal working</td>
<td>Handtools</td>
<td>14,000</td>
</tr>
</tbody>
</table>

National Occupational Research Agenda (NORA) Sectors: Agriculture, Forestry & Fishing; Construction; Manufacturing; Mining; Oil & Gas Extraction

1.25 million workers at risk estimated from Bureau Labor Statistics
Hand-Arm Vibration Syndrome is a vasospastic, neurodegenerative and musculoskeletal disease

Hand-arm vibration syndrome
Stockholm Workshop staging scale

Stage Sensorineural Symptoms

0SN Exposed to vibration, but no symptoms
1SN Intermittent numbness with/without tingling
2SN Intermittent or persistent numbness, reduced sensory perception
3SN Intermittent or persistent numbness, reduced tactile discrimination and/or manipulative dexterity

Stage Vascular Symptoms (vibration white finger)

01 Blanching of fingertips, with/without tingling and numbness
02 Blanching beyond tips usually in winter, interference in non-work activities
03 Extensive blanching in summer/winter, interference in work activities
04 Extensive blanching, change in occupation

Level 3 disease is irreversible
Magnitude and duration of vibration from powered hand tools determine the rate and severity of injury.

Repeated injury eventually exceeds the capacity or destroys the ability of the tissues to repair.

**Why does HAVS take years to develop and become permanent?**

Indiana rock cutters in 1918 acquired HAVS after switching to percussive hammers and drills.

- Magnitude and duration of vibration from powered hand tools determine the rate and severity of injury.
- Repeated injury eventually exceeds the capacity or destroys the ability of the tissues to repair.

**Fundamental frequencies of powered hand tools**

<table>
<thead>
<tr>
<th>Power tool</th>
<th>Dominant frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riveting hammer</td>
<td>30 Hz</td>
</tr>
<tr>
<td>Heavy duty sander</td>
<td>45 Hz</td>
</tr>
<tr>
<td>Impact wrench</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Light duty sander</td>
<td>80 Hz</td>
</tr>
<tr>
<td>Palm orbital sander</td>
<td>90 Hz</td>
</tr>
<tr>
<td>Vertical polisher</td>
<td>100 Hz</td>
</tr>
<tr>
<td>Chainsaw</td>
<td>200 Hz</td>
</tr>
</tbody>
</table>

Hand-Arm Vibration Syndrome causation is linked primarily to 30-250 Hz sinusoidal vibration.

Disease onset 3 to 5 years for tool use 4 hr/day.

Impact percussive tools have low Hz and very high Hz shock wave energy.
Impulse vibration from impact percussive tools has been studied less but may present a high HAVS risk

Dandanell and Engström, 1986

Increasing the total amount of daily use of impact tools shortens the time to onset of HAVS

use    onset
1 min/d – 10 yr
15 min/d – 2.5 yr
240 min/d – 2.5 mo

Rat tail vibration model simulating bucking bar vibration exposure

shock waves
sinusoidal

33 Hz impact cycle

RRH04P-12
Atlas Copco Tools
20 psi
Is the European Standard ISO 5349 frequency-weighted reduction of acceleration magnitude underestimating injury risk?

Frequency weighting is based on human hand feeling vibration

![Graph showing filter response for different frequencies](image)

Vibration exposure risk

What you can’t feel can hurt you

What you can hear can hurt you

20 Hz – 20,000 Hz
Calculation of Hand-Arm Vibration daily exposure to weighted acceleration $A(8)$
ISO 5349-1:2001

Sum of vibration magnitudes in 3 orthogonal axes ($a_{hv}$) triaxial accelerometer

$$a_{hv} = \sqrt{a_{Ix}^2 + a_{Iy}^2 + a_{Iz}^2}$$

Daily exposure to vibration normalized to 8 hr day $A(8)$
$T = \text{total hr tool use}, \ T_o = 8 \text{ hr}$

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

Are the European Union legal definitions of 8 hr day vibration exposure magnitude limits correct?

Exposure action value of 2.5 m/s$^2$ weighted $A(8)$
If exceeded, employer must take corrective action to lower exposure

Exposure limit value of 5.0 m/s$^2$ $A(8)$
If exceeded, stop activity immediately
Frequency weighting dismisses high frequency vibration energy and underestimates injury risk

The frequency weighted acceleration of 7.13 m/s² is safe* for <59 min/day

*Staying below the EAV still leaves a 10% risk of getting HAVS in 12 years

Unweighted acceleration 98.6 m/s² requires stopping use in 1 min

Incidence of HAVS for riveting hammer

1 min/d – 10 yr
15 min/d – 2.5 yr
240 min/d – 2.5 mo

Is frequency weighting that reduces acceleration magnitude for frequencies above 16 Hz generating a false sense of security for vibration injury risk?

Yes, the weighted acceleration value underestimates risk

Has the implementation of vibration regulations reduced vibration injury?

Yes, but could do better with improved risk calculator

Currently, 3 schemes that include the high frequency energy components are being evaluated
Has implementation of vibration regulations reduced vibration injury in Great Britain?
Reduced number new cases seeking Industrial Injuries Disablement Benefits for Hand Arm Vibration syndrome

- positive impacts in education and engineering
- greater recognition of hazardous vibration in the workplace
- more health monitoring
- increased availability of low vibration tools

Brereton, 2011

Regulations for hand arm vibration exposure in US

Occupational Safety and Health Administration (OHSA) None exist

National Institute for Occupational Safety & Health (NIOSH) No standards
1989 review literature 89-106, but no setting of exposure limits
recommend exposure and health monitoring
recommend against ISO 5349 frequency weighting; use unweighted acceleration

American National Standards Institute Recommend ISO 5349
ANSI S2.70-2006 Threshold Limit Value (TLV)
recommend Daily Exposure Action Value 2.5 m/s²
Daily Exposure Limit Value (8-hr equivalent exposure) 5.0 m/s²

American Conference of Governmental Industrial Hygienist (ACGIH)
Recommend Threshold Limit Values (TLV) 2008
4 m/s² limit to 4 to <8 hr/d
6 m/s² limit to 2 to <4 hr/d
8 m/s² limit to 1 to <2 hr/d
12 m/s² limit to <1 hr/d
Each exceeds ALV but less than ELV
Raise awareness of hazards

- Low awareness of vibration disease “part of job”
- Cultural “wimps” wear PPE
- Low vibration tools more expensive (long run no)
- Years to develop disease (sinusoidal yes, but not impact)
- Always exceptions (60 yr Indiana disease-free stone driller)
- No OSHA standards
- Surveillance (early intervention prevents chronic disease)

Antivibration gloves and medical monitoring reduce risk

- Effective Intervention With Ergonomics, Antivibration Gloves, and Medical Surveillance to Minimize Hand–Arm Vibration Hazards in the Workplace


  \[
  \begin{align*}
  &\text{Transmissibility } T_z \text{ M Hz } \leq 1.0; \ T_z \text{ H Hz } \leq 0.6 \\
  &\text{Medium Hz (16-400 Hz)} \quad \text{High Hz (100-1600 Hz)}
  \end{align*}
  \]

  Anti-vibration certified ISO 10819 (1996) revised so that the glove fingers no longer have to be identical to palm construction ISO 10819/CD 2010

  M-spectrum 31.5-200Hz, H-range 200-1250Hz
Antivibration gloves block high Hz, may increase low Hz

Griffin, 1998

ISO 10819 certified

Certified anti-vibration gloves

Glove vibration absorbing strategies
polymer pad
air bladder
air cells

Manufacturers listing ISO 10819 certified gloves
Chase Ergonomics Decade® (Gfom)
ErgoAir (air bladder)
Ergodyne (Nu²O₂)
Impacto (air cells)
Valeo (air bladder)
To glove or not to glove?
The decision is not straightforward

Efficacy and durability field testing is needed for specific tools and tasks

Current EU position: Gloves can be used to keep hands warm, but should not be relied upon to provide protection from vibration below 500 Hz

If vibration energy in frequencies >500 Hz are causing injury, then gloves reducing the high frequency component should be beneficial

<table>
<thead>
<tr>
<th>Positive effects</th>
<th>Negative effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>reduce HAVS risk</td>
<td>reduced ability to grip (30-45%)</td>
</tr>
<tr>
<td>(1 study with monitoring)</td>
<td>hand fatigue</td>
</tr>
<tr>
<td>keep hands warm</td>
<td>compression of blood flow</td>
</tr>
<tr>
<td>keep hands dry</td>
<td>reduced dexterity</td>
</tr>
<tr>
<td>reduce high Hz impact vibration</td>
<td>awkward postures</td>
</tr>
<tr>
<td></td>
<td>carpal tunnel syndrome</td>
</tr>
<tr>
<td></td>
<td>reduced sensory perception</td>
</tr>
<tr>
<td></td>
<td>amplify low Hz vibration</td>
</tr>
</tbody>
</table>

The decision is not straightforward
To glove or not to glove?

• Request low vibration engineered tools
• Check manufacturer’s declared acceleration value
• Field testing and measurement recommended
• Success stories reengineered low vibration tools
  Chainsaw
  Rock drill

Anti-vibration engineered tools
Chainsaw lacking antivibration mounts

1968
Model 090
3.5 ft bar

Prevalence of vibration white finger was 40% (1972)
Chainsaws manufactured with antivibration mounts 5% (1990)

Shock isolation of chainsaw handle from motor dramatically reduced vibration-induced disease

Homelite 1958 frame mounted engine
Raket 1982 anti-vibration mounted engine

Vibration sampled 2 Hz-10 kHz range

Starck et al 1983; Starck 1984
Shock isolation of chainsaw handle from motor dramatically reduced vibration-induced disease

Homelite 1958 frame mounted engine
Raket 1982 anti-vibration mounted engine

Vibration sampled 2 Hz-10 kHz range

ISO 5349 weighted accelerations decreased from 9.1 m/s² to 2.2 m/s²
HAVS latency increased from 5 to 25 years and prevalence fell from 40% to 5%

Starck et al 1983; Stark 1984

Conventional rock drill jarring, bucking and noisy
“Have to muscle it and feel it working”
Antivibration engineered

Swedish Institute of Production Engineering Research, Goteborg, Sweden

Antivibration rock drill not required to be manhandled
Ergonomic and antivibration handle
Databases of vibration specifications for powered hand tools

CDC power Tools Database
http://wwwn.cdc.gov/niosh-sound-vibration/

Umeå University, Faculty Medicine, Depart Public Health Clinical Medicine, Occupational Environmental Medicine
http://www.vibration.db.umu.se/HavSok.aspx?lang=en

What should the worker know and do?

Understand when at risk for HAVS
- When work regularly with sinusoidal hand powered tools more than a few hours each day or 15 minutes a day with impact tools

Recognize symptoms of vibration injury
- Tingling and numbness in the fingers
- Cold exposure triggers finger blanching (vibration white finger)
- Weakness in the hands

Try to lower risk
- Use low vibration and well maintained tools, short duration use, avoid over-gripping, warm tool handles, keep hands dry and warm, avoid nicotine, consider wearing antivibration gloves

Proactive awareness
- Recognize early signs of HAVS, report symptoms to health officer and employee representative
Guidelines for safe use of vibrating power tools

• Avoid bare hand contact to guide chisels, sockets, bucking bars and metal work pieces (you cannot feel the full energy of high Hz shock waves)

• Avoid increasing vibration-induced blood vessel constriction by using nicotine and exposing hands to cold temperature; keep hands dry and gloved to reduce loss of heat

• Grasp tool as lightly as feasible to reduce energy transfer

• Take 10 min breaks? (this is not documented; if works, positive effect may be from reduced daily exposure to vibration)

• Rotate off work tasks using vibrating tools to minimize daily exposure and not exceed daily exposure limits

• Use low vibration tools and maintain tools to minimize vibration

What should the employer know and do?

Know what jobs are vibration hazardous
accelerations of sinusoidal and impact tools used
duration of vibration exposure

Provide training, protective gear, low vibration tools
good work practices, gloves, tool maintenance

Understand hand-arm vibration syndrome
early signs and symptoms and health effects

Establish health surveillance and monitoring
identify workers at risk
catch early (reversible) disease
prevent disease progression and disability
assess efficacy of vibration reduction measures
**Contacts in Vibration Injury**

Danny A. Riley, PhD  
Medical College of Wisconsin, Milwaukee, WI  
dariley@mcw.edu

Ren G. Dong, PhD  NIOSH/HELD/ECTB  Morgantown, WV USA  
rkd6@cdc.gov

Michael J. Griffin, PhD  University of South  Hampton, UK  mjg@isvr.soton.ac.uk

Massimo Bovenzi, MD  Trieste, Italy  
 bovenzi@units.it