Hand-arm Vibration Syndrome (HAVS)
OEMAC Preconference 2013
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Conflict of Interest
No conflicts of interest to declare

Learning Objectives
- Classify the components of Hand-Arm Vibration Syndrome (HAVS) and the spectrum of health problems associated with the use of vibrating tools
- Evaluate the utility of the various diagnostic tests used to assess the components of HAVS
- Outline key elements in managing workers with HAVS and preventing HAVS in exposed workers
Topics

- Background information about HAVS program at St Michael’s Hospital
- Prevalence of hand-arm vibration (HAV) exposure and hand-arm vibration syndrome (HAVS)
- Clinical aspects of HAVS
  - Health effects and their measurement
- Management of workers with HAVS/HAV exposure
- HAVS research at St. Michael’s Hospital / University of Toronto
- Another area of current HAV research
  - Controversy about frequency weighting (Workshop at 12th International Conference on Hand-arm Vibration, Ottawa, June, 2011)

Occupational Health Clinic
St Michael’s Hospital, Toronto

- Started assessing HAVS patients in 1991
- Now assess about 200 workers per year for HAVS
- Largest centre for the clinical assessment of workers with HAVS in Canada

Occupational Disease Specialty Program (ODSP)

- Program funded by the Workplace Safety and Insurance Board (WSIB)
- Program established in 2002
- ODSP clinical assessments carried out in the Occupational Health Clinic, St. Michael’s Hospital
- Focus is on in-depth assessment of Occupational Disease
  - Diagnosis
  - Workplace accommodation / Return to work
ODSP Interdisciplinary Team

- **Clinical Activities Coordinator**: The administrative team lead for a patient’s flow through the clinic process. Books appointments, communicates with WSIB re bookings and reports.

- **Return-To-Work Coordinator**: Team lead on the workplace relevance including exposure assessment and link with diagnosis and considerations for workplace exposure “treatment” (e.g., ventilation assessment to reduce exposure).

- **Nurse/Nurse Practitioner**: The team lead on the workplace relevance including education, counseling and referrals for management of workplace exposure “treatment” (e.g., restrictions assessment to reduce exposure).

- **Clinical Occupational Hygienist**: The team lead on the workplace relevance including exposure assessment and link with diagnosis and considerations for workplace exposure “treatment” (e.g., ventilation assessment to reduce exposure).

- **Physician Specialist**: The clinical team lead for diagnosis and management, performs specialized testing such as:
  - Skin prick testing
  - Patch testing
  - Tests for HAVS
  - Audiometry

- **Clinical Support Technician**: Performs specialized clinical testing such as:
  - Skin prick testing
  - Patch testing
  - Audiometry

- **Patient Worker**: Team lead if patient requires return to work assistance. Communicates with patient, WSIB and workplace to facilitate return to work.

ODSP Disease Streams

- Hand-arm Vibration Syndrome (HAVS)
- Occupational Dermatitis
- Occupational Asthma / Allergy
- General Occupational Disease
  - Occupational toxicology

Centre for Research Expertise in Occupational Disease (CREOD)

- Collaborative research program involving St. Michael’s Hospital and the University of Toronto
- Established in 2004
- Goal is to improve understanding and prevention of occupational disease
- Three primary disease foci
  - Hand-arm Vibration Syndrome (HAVS)
  - Occupational Skin Disease
  - Occupational lung and airways disease
Hand-Arm Vibration Exposure

- **Common exposure**
  - Estimated that about 1.5 - 2 million workers in the U.S. are exposed to HAV (Bureau of Labor Statistics, U.S.)

- **Based on epidemiologic data it is estimated that about 50% of workers exposed to hand-arm vibration have or will develop HAVS**

<table>
<thead>
<tr>
<th>Industry</th>
<th>Tool Type</th>
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</thead>
<tbody>
<tr>
<td>Mining</td>
<td>Jack-leg drills</td>
</tr>
<tr>
<td></td>
<td>Stoper drills</td>
</tr>
<tr>
<td>Automotive</td>
<td>Impact wrenches</td>
</tr>
<tr>
<td></td>
<td>Riveting guns</td>
</tr>
<tr>
<td>Construction</td>
<td>Jackhammers</td>
</tr>
<tr>
<td>Agriculture &amp; Forestry</td>
<td>Chainsaws</td>
</tr>
<tr>
<td>Foundries</td>
<td>Chippers</td>
</tr>
<tr>
<td></td>
<td>Grinders</td>
</tr>
<tr>
<td>Metal working</td>
<td>Sanders</td>
</tr>
<tr>
<td></td>
<td>Buffers</td>
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</tbody>
</table>

HAVS is a Occupational Sentinel Health Event

- An Occupational Sentinel Health Event is a disease, disability or untimely death which is occupationally related and whose occurrence may:
  - (1) provide the impetus for epidemiologic or industrial hygiene studies, or
  - (2) serve as a warning signal that materials substitution, engineering control, personal protection or medical care may be required.


History of HAVS

- Loriga (1911) – first described association between vibration and Raynaud’s phenomenon in Italian miners

- Hamilton (1918) – described high prevalence of Raynaud’s phenomenon in limestone quarry workers in Indiana

- Recognition of vascular effects
  - Vibration White Finger(VWF), Traumatic Vasospastic Disease (TVG)

- Later recognition of non-vascular effects of HAV
  - Neuropsychological
  - Musculoskeletal

- Attempts to classify and measure HAVS
  - Stockholm classification (1986)
HAVS Clinical Perspective
- Vascular
- Sensorineural
- Musculoskeletal

Vascular Effects
Raynaud’s Phenomenon in Hands
- Strong evidence of a causal association between exposure to HAV and Raynaud’s Phenomenon (RP)
- Risk related to the duration and intensity of HAV exposure
- Latency can be quite short (< 2 yr) with high exposure

Vascular Component of HAVS
The Stockholm workshop scale for the classification of cold-induced Raynaud’s Phenomenon in the HAVS

<table>
<thead>
<tr>
<th>Stage</th>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No attacks</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Mild</td>
<td>Occasional attacks affecting only the tips of one or more fingers</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>Occasional attacks affecting distal and middle (rarely also proximal) phalanges of one or more fingers</td>
</tr>
<tr>
<td>3</td>
<td>Severe</td>
<td>Frequent attacks affecting all phalanges of most fingers</td>
</tr>
<tr>
<td>4</td>
<td>Very Severe</td>
<td>As in stage 3, with trophic skin changes in the fingertips</td>
</tr>
</tbody>
</table>

Objective Tests for VWF

- Cold induced vasospasm
  - Digital Plethysmography
    - Baseline
    - Post cold water immersion
- Recovery of finger temperature after cold water immersion
  - Thermometry
  - Thermography (IR camera)
Problems in Evaluation of Vascular Tests

- Test protocols not well standardized
  - Temperature of water
  - Duration of immersion
  - Time of measurement post immersion
  - Cut-off point for a positive test

- Each testing facility needs to document its test protocols, normal values, test performance (sensitivity / specificity)

Development of Vascular Test at SMH
Based on IR Thermography and ISO Guideline for testing
(12°C for 5 minutes)

Vascular Abnormalities in Feet

  - Literature review suggests that vasospastic symptoms in feet are associated with upper extremity HAVS
  - Appears to need HAVS in the hands before vasospastic effects occur in the foot
    - Local and central stimulation of the sympathetic nervous system
    - Systemic release of vasoconstrictors (endothelin-1)
Vascular Abnormalities in Feet


- The risk of a severe reduction in plethysmography amplitude (post cold immersion vs baseline) in the feet is increased about 4 - 5 fold in workers with severe changes in the hands.

<table>
<thead>
<tr>
<th>Foot</th>
<th>Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>4.11 (1.60-10.6)</td>
</tr>
<tr>
<td>Left</td>
<td>4.97 (1.82-13.53)</td>
</tr>
</tbody>
</table>

Other Vascular Problems in Workers Using Vibrating Tools

- Ulnar artery thrombosis
- Digital artery thrombosis

Case #1

DIGIT PLETHYSMOGRAPHY
Arterial Thrombosis in Workers using Vibrating Tools


Three cases described of workers using vibrating tools who developed thrombi in the ulnar and/or digital arteries in the hands

- Hypothemar hammer syndrome (HHS)
  - Clear history of using the hypothenar eminence for hammering
  - Ulnar artery thrombosis without history suggestive of HHS
  - Digital artery thrombosis

Frequency of Ulnar Artery Thrombosis in Workers Exposed to HAV


Reported the results of arteriography on 330 workers (293 with HAVS) exposed to HAV who were assessed at a Workers’ Compensation Hospital in Japan

- Exposure mean 19.4 yr, SD 7.3, range 5-30
- 24 (7.2%) had ulnar artery thrombosis (Hypothemar Hammer Syndrome)

- Possibly in most affected workers the condition develops slowly with time for development of collateral vessels
  - Acute presentation may be atypical
Neurological Abnormalities

Two types of neurological problems found in workers being assessed for HAVS:

• Digital Sensory Neuropathy
  – Sensorineural component of HAVS

• Compressive neuropathies proximal to the hand
  – Median neuropathy
  – Ulnar neuropathy

The Stockholm Workshop Scale for the Classification of Sensorineural Effects of HAVS*

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 SN</td>
<td>Exposed to vibration but no symptoms</td>
</tr>
<tr>
<td>1 SN</td>
<td>Intermittent numbness, with or without tingling</td>
</tr>
<tr>
<td>2 SN</td>
<td>Intermittent or persistent numbness, reduced sensory perception</td>
</tr>
<tr>
<td>3 SN</td>
<td>Intermittent or persistent numbness, reduced tactile discrimination, and/or manipulative dexterity</td>
</tr>
</tbody>
</table>


Compression Neuropathies
Carpal Tunnel Syndrome and Vibration

NIOSH (1997)
- Evidence (but not strong evidence) for association between vibration + CTS
  - Inadequate control of ergonomic factors
- Strong evidence for association between ergonomic risk factors (force + repetition) + CTS

- Reasonable evidence that regular and prolonged use of hand-held vibratory tools increases the risk of CTS >2-fold
- Substantial evidence for similar or even higher risks from prolonged and highly repetitious flexion and extension of the wrist, especially when allied with a forceful grip

Measurement of Neurological Abnormalities

- Nerve conduction tests
  - Good test for large myelinated fibres proximal to the hand
    - Median neuropathy at wrist
    - Ulnar neuropathy

- Current perception threshold (quantitative sensory test)
  - More sensitive test to measure abnormalities in the fingers
    - 2000 Hz - Alpha (large myelinated) fibres
    - 250 Hz - Alpha (small myelinated) fibres
    - 5 Hz - C (unmyelinated) fibres

Musculoskeletal Component

- The musculoskeletal component is not as well understood as the HAVS vascular and neurological components
Musculoskeletal Problems in Workers Using Vibrating Tools

Main outcomes investigated:

- Dupuytren’s contracture
- Upper extremity muscle/joint pain
- Decreased Grip Strength
- Osteoarthritis – wrist, elbow, shoulder
- Osteoporosis of hand/wrist bones
- Bone cysts

Association of Musculoskeletal Outcomes with HAV

  - Review of 212 articles published between 1980-2000 dealing with musculoskeletal problems and hand-arm vibration

- Strong evidence that working with vibrating tools is associated with musculoskeletal disorders
  - Broad range of MSK disorders affecting bones, joints, muscles

- Evidence that vibration per se is a risk factor for musculoskeletal disorders is still inconclusive
  - Possible confounding by ergonomic factors

Grip Strength and HAV

- Farkkila et al (1978) first reported decreased grip strength associated with HAV exposure

- Other studies have shown similar results (Farkkila et al, 1986, McGeoch & Gilmour, 2000)

  - Effects due to direct muscle injury & secondary to motor nerve injury
Dupuytren’s Contracture and HAV

- Meta-Analysis of work relatedness of Dupuytren’s contracture

<table>
<thead>
<tr>
<th>Exposure</th>
<th># HQ Papers</th>
<th>Meta-OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual work</td>
<td>5</td>
<td>2.01 (1.51 – 2.66)</td>
</tr>
<tr>
<td>Vibration</td>
<td>4</td>
<td>2.14 (1.59 – 2.88)</td>
</tr>
</tbody>
</table>

Health Outcomes Associated with the Use of Vibrating Tools

- Vascular
  - Raynaud’s phenomenon
    - Hands **
    - Feet
    - Thrombi in hands
- Neurological
  - Digital neuropathy (fingers) **
  - Proximal neuropathies (wrist) – CTS, Ulnar neuropathy
- Musculoskeletal
  - Dupuytren’s contracture
  - Upper extremity muscle / joint pain
  - Decreased grip strength *
  - Osteoarthritis – wrist, elbow, shoulder
  - Osteoporosis of hand / wrist bones
  - Bone cysts

Assessment protocol at SMH

- Occupational and Medical History
- Physical exam
- Clinical chemistry (to r/o other conditions)
- Special tests
  - Vascular
    - Doppler
  - Thermometry, Plethysmography
  - Neurologic
    - Nerve conduction test
    - Current perception threshold
  - Musculoskeletal
    - Grip strength
    - Purdue pegboard
Management of Workers with HAVS

- Avoid cold and dress warmly in cold to maintain core temperature
- Smoking cessation
- Medication for Raynaud’s Phenomenon
  - calcium channel blocking agents
- Reduce or eliminate vibration exposure
  - Anti-vibration gloves
  - Anti-vibration tools
  - Modified work - decreased duration/intensity of exposure
  - Job change
- Treat co-morbid upper extremity conditions
  - Carpal tunnel syndrome, lateral epicondylitis, rotator cuff tendonitis

Main HAVS Research Activities at SMH

- Vascular tests for HAVS
  - Thermometry, digital plethysmography
  - Thermography
- Neurological tests
  - Nerve conduction, Current perception threshold
- Systemic effects associated with HAVS
  - Vasoconstriction in the Feet
  - Hearing loss
- Disability and Quality of Life in Workers with HAVS
- Compensation experience with HAVS in Canada
- Education of HAVS patients and co-workers
  - Evaluate impact of educational materials

Disability and Quality of Life in Workers with HAVS

Disability of the Arm, Shoulder and Hand (DASH)


Work related disability (DASH Work Module)


Quality of Life (SF12-Physical, SF-12 Mental)
**DASH Scores**

Distribution of DASH scores in study group (N=139)
- Mean: 42.22
- Median: 41.67
- S.D.: 20.94
- Range: 2.50-87.50

Population normal value:
- Mean 10.1 (95% CI: 9.403-10.797)

Difference Statistically significant (P< 0.001)

**DASH Work Module**

Distribution of DASH Work Module Scores in study group
- Mean: 54.68
- Median: 56.25
- S.D.: 26.23
- Range: 0-100

Population Normal Value
- Mean 8.81 (95% CI: 7.912 – 9.708)

Difference Statistically Significant (P<0.001)

**SF12 – Physical Scores**

Distribution of SF12–Physical Scores in study group
- Mean: 36.28
- Median: 35.08
- S.D.: 8.78
- Range: 18.08 – 57.34

Population Normal Value
- Mean: 50
- S.D.: 10

Difference Statistically Significant (p=0.001)
SF12 – Mental Scores

Distribution of SF12 - Mental Scores in study group:
- Mean: 43.86
- Median: 43.34
- S.D.: 11.76
- Range: 15.20-63.28

Population Normal Value:
- Mean: 50
- S.D.: 10

Difference Statistically Significant (p<0.001)

Reporting / Recognition of HAVS in Canada

- No legislative requirements for health surveillance for HAVS in Canada
- Compensation board data are main source of information on the occurrence of HAVS in Canada

Compensation Board Experience in Canada
Accepted Claims for HAVS (2003-2008)


<table>
<thead>
<tr>
<th>Province/Territory</th>
<th># Accepted Claims</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Columbia</td>
<td>39</td>
</tr>
<tr>
<td>Alberta</td>
<td>8</td>
</tr>
<tr>
<td>Saskatchewan</td>
<td>5</td>
</tr>
<tr>
<td>Manitoba</td>
<td>9</td>
</tr>
<tr>
<td>Ontario</td>
<td>940</td>
</tr>
<tr>
<td>Quebec</td>
<td>187</td>
</tr>
<tr>
<td>New Brunswick</td>
<td>1</td>
</tr>
<tr>
<td>NS, PEI, Nfld</td>
<td>0</td>
</tr>
<tr>
<td>NWT/Nunavut</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>1190</td>
</tr>
</tbody>
</table>

Average of 198 accepted claims/yr in Canada with 79% of these occurring in Ontario.
Under-recognition / Under-reporting of HAVS in Canada

• < 200 accepted HAVS claims per yr in Canada

• Estimated number of prevalent cases of HAVS in Canada
  – 75,000 – 144,000
    • 75,000 – based on U.S. data (Bernard et al, 1998) extrapolated to Canada
    • 144,000 – based on U.K. data (Palmer et al, 2000) extrapolated to Canada


Legislation/Standards Incorporating HAV Exposure Limits

• Canada
  – ACGIH TLV
    • Referenced in regulation by two Canadian provinces:
      – British Columbia
      – New Brunswick

• European Union
  – European Union Directive 2002/44/EC
    • Exposure Limit Value (ELV) - 5 m/sec^2 (A(8))
    • Daily Exposure Action Value (EAV) - 2.5 m/sec^2 (A(8))
    • when EAV is exceeded, employer required to institute a program to reduce hand-arm vibration, train workers, do medical surveillance

• United States
  – American National Standards Institute (ANSI)
    • Developed a standard (ANSI S2.70 - 2006) based on the EU Directive
    • No OSHA regulation

Educational Research

• Construction Sector
• Aimed at HAVS patients and co-workers
• Developed educational materials about HAV / HAVS for patients
  – Double sided laminated educational document (3 copies)
  – Patients were asked to distribute the document to workplace supervisors, H&S representatives, co-workers
• Baseline questionnaire and follow-up questionnaire to assess changes in work practices after returning to work

House R, Holness L, Thompson A. MOHLTC Innovation Fund grant
Educational Intervention

AV Glove Use Before and After Educational Intervention (N=50)

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAVS Patients</td>
<td>4.3%</td>
<td>53.2%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Co-workers*</td>
<td>12.8%</td>
<td>36.2%</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

* As reported by HAVS Patients
Other Workplace Impacts of Educational Materials
Reported at 2 Months Follow-up (N=50)

<table>
<thead>
<tr>
<th>Question</th>
<th>% Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has your employer purchased new lower vibration tools?</td>
<td>20.4%</td>
</tr>
<tr>
<td>Has your employer provided more education about HAVS?</td>
<td>14.6%</td>
</tr>
<tr>
<td>Has your employer changed work processes to reduce HAV exposure?</td>
<td>16.0%</td>
</tr>
<tr>
<td>Has your employer reduced your time of exposure to HAV</td>
<td>16.3%</td>
</tr>
<tr>
<td>Did the educational materials result in any changes in workplace practices?</td>
<td>63.3%</td>
</tr>
</tbody>
</table>

Summary of Findings / Conclusions

• Our educational intervention showed modest benefits for HAVS patients and co-workers

• Much larger educational effort directed at employers is needed
  – Ministry of Labour
  – Health and Safety Associations
  – Companies
  – Unions

Frequency Weighting Workshop
12th International Conference on Hand-Arm Vibration
Ottawa, June, 2011

Aim of the workshop:

• The suitability of the ISO frequency weighting for assessing the risk of persons developing vibration-induced white finger will be discussed and alternative frequency weightings from different perspectives will be considered by invited speakers

  • Series of papers related to the Workshop content were published in the Industrial Health journal (2013, vol. 50)
Characteristics of Vibration and its Measurement

- Vector Quantity
  - Directionality
    - Measured with an accelerometer in three orthogonal axes
  - Magnitude
    - Acceleration (m/sec^2)

- Frequency
  - Frequency Spectrum
  - Frequency Weighting

International Standards Organization (ISO)
Frequency Weighting for Hand-Arm Vibration Exposure

Hand-arm system absorption / transmission of vibration

- < 100 Hz: transmitted up hand-arm system to neck (associated with musculoskeletal effects)
- >100 Hz: largely absorbed by fingers/hands (associated with vascular, neurological effects)
- Current ISO weighting gives less emphasis to the frequencies associated with the vascular and neurological effects
HAV Frequency Weighting Schemes

Workshop Format

- Presentation of existing evidence (invited speakers)
  - Animal Evidence (rat tail model)
  - Vibration Perception, Comfort, Physiological Response Evidence
  - Biodynamic Response Evidence
  - Epidemiological Evidence

- Discussion of Evidence

- Recommendations

Discussion of Evidence

- General agreement that the current ISO weighting scheme is problematic
  - Not sufficient weight given to higher frequencies

- There is no clear alternative at present
  - More research is needed

- Areas requiring more attention
  - Impact vibration (impact wrenches)
  - High frequency tools (e.g. dental tools operating at 6000-8000 Hz)

- Problem of how a change in frequency weighing would affect existing legislation in the E.U.
  - Based on ISO weighting
Conclusions of Workshop

- Resolution 1: While recognizing that there are limitations with the current frequency weighting, this workshop does not believe that there is sufficient evidence to propose an alternative to the current ISO frequency weighting.

- Resolution 2: Possible alternate frequency weightings should be considered for specific purposes and described in technical reports.

Prevention of HAVS in Workers Using Vibrating Tools

- Anti-vibration, ergonomically designed power tools
- Keep tools properly maintained
- Grip tool with minimum grip force consistent with safe operation of the tool
- Anti-vibration full finger gloves (ISO certified)
- Regular work breaks when vibration exposed (10 min every hour)
- Avoid cold exposure if possible
  - Thermal protective clothing when cold-exposed

Adapted from ANSI 2.70 standard