

The Hand-Arm Vibration Syndrome: An Historical Perspective

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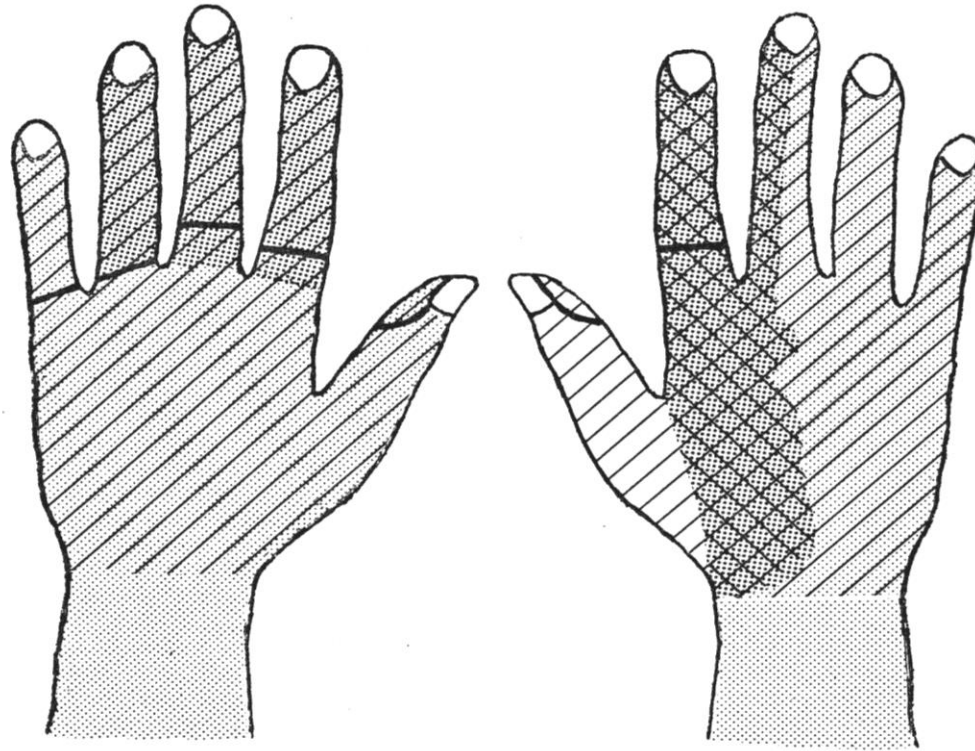
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Introduction

- In this lecture I shall summarize the development of knowledge of the Hand-Arm Vibration Syndrome
- It is a personal perspective, and is influenced mostly by developments in Europe, North America and Japan
- Our initial understanding was obtained from studies undertaken by two outstanding physicians - Dr. Alice Hamilton (USA), and Dr. William Taylor (UK) – although Dr. Loriga (Italy) first reported health hazards from using hand-held power tools in 1911

Symptoms After 7 Years' Operation of Air-Hammer Fingers

white from fingertip to thick lines [Hamilton et al., 1918]



CASE No 4 - AGE 28 YRS



MILD



MARKED

DECREASE IN SENSE OF TOUCH



MILD



MARKED

DECREASE IN SENSE OF PAIN



Professor Taylor's Main Contributions

- Documented (and photographed) progression of signs and symptoms occurring with continued operation of vibrating power tools and machines
- Introduced clinical grading of *Vibration-Induced White Finger* (VWF) by severity— the Taylor-Pelmear clinical stages of VWF (1974)
- Described other causes of white fingers to enable a differential diagnosis
- Encouraged the development of clinical tests [e.g., for blood flow, skin temperature; pain, tactile perception]

Classic Vibration White Finger (VWF) attack

Note clear line between unaffected and affected areas

[Photo credit W.Taylor]



Understanding of the Occupational Health Problem in the English Speaking World by mid 1970s

- Operators of some power tools (e.g., chain saws) experience what was believed at the time to be primarily vascular disturbances in the fingers
- The condition becomes progressively worse as the worker continues his/her occupation
- The repeated white finger attacks were believed to lead to peripheral nerve damage and reduced blood circulation within the fingers
- There is a common causative agent - exposure of the hands to vibration – the magnitude of which needs to be evaluated

Measurement of Tool Vibration c1975

Accelerometers at A and B record motion perpendicular to the plane of the photograph (i.e., in one direction)



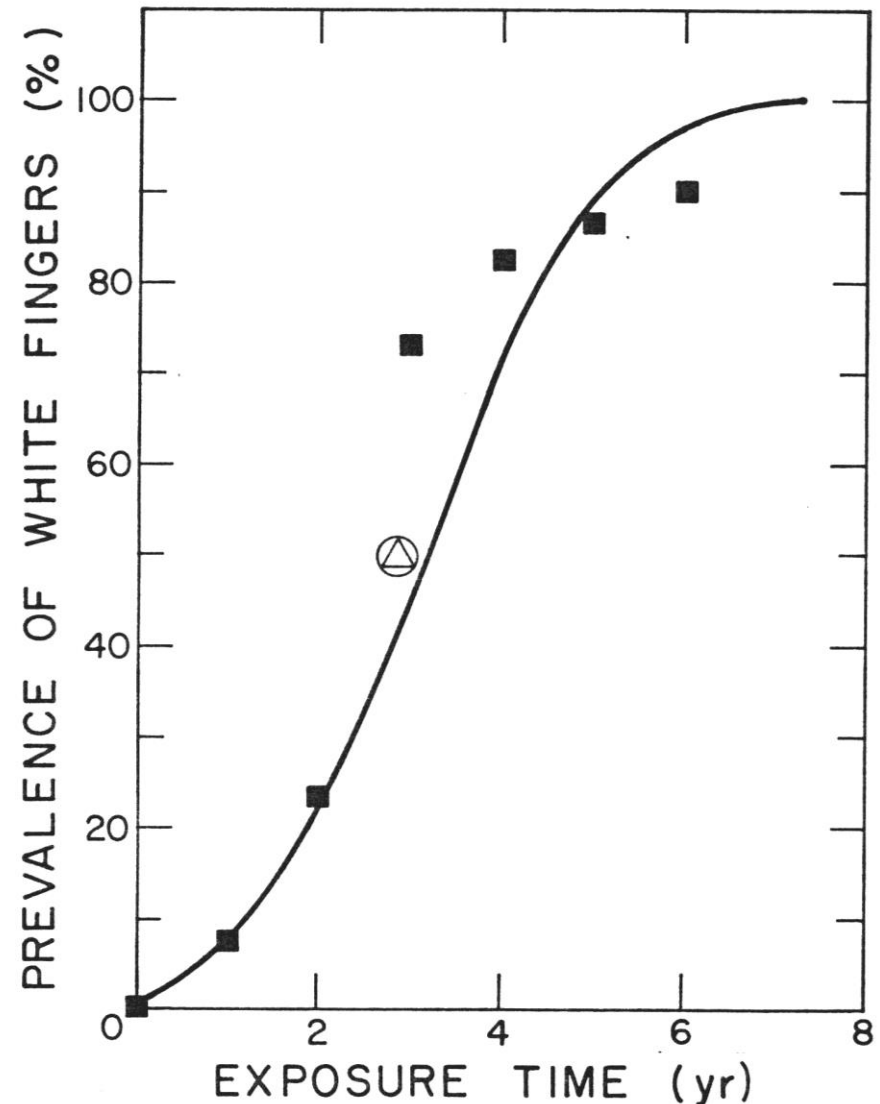
Consequences of Activities Described So Far by Late 1970s

- Epidemiological studies had been conducted of many occupations in which power tools and machines were used, and VWF commonly found
- The vibration of many power tools and machines had been measured
- International efforts had commenced to standardize the measurement and evaluation of hand-transmitted vibration in ISO/TC 108/ SC 4 (which led to the publication of ISO 5349 in 1986)

Work commenced to model the development of VWF in 1980

In the model shown, a cumulative normal distribution (line) is used to model the onset of VWF in a population group from workers' reports of the time to develop white fingers (squares). The triangle shows the mean time for the group.

[Brammer, 1982]



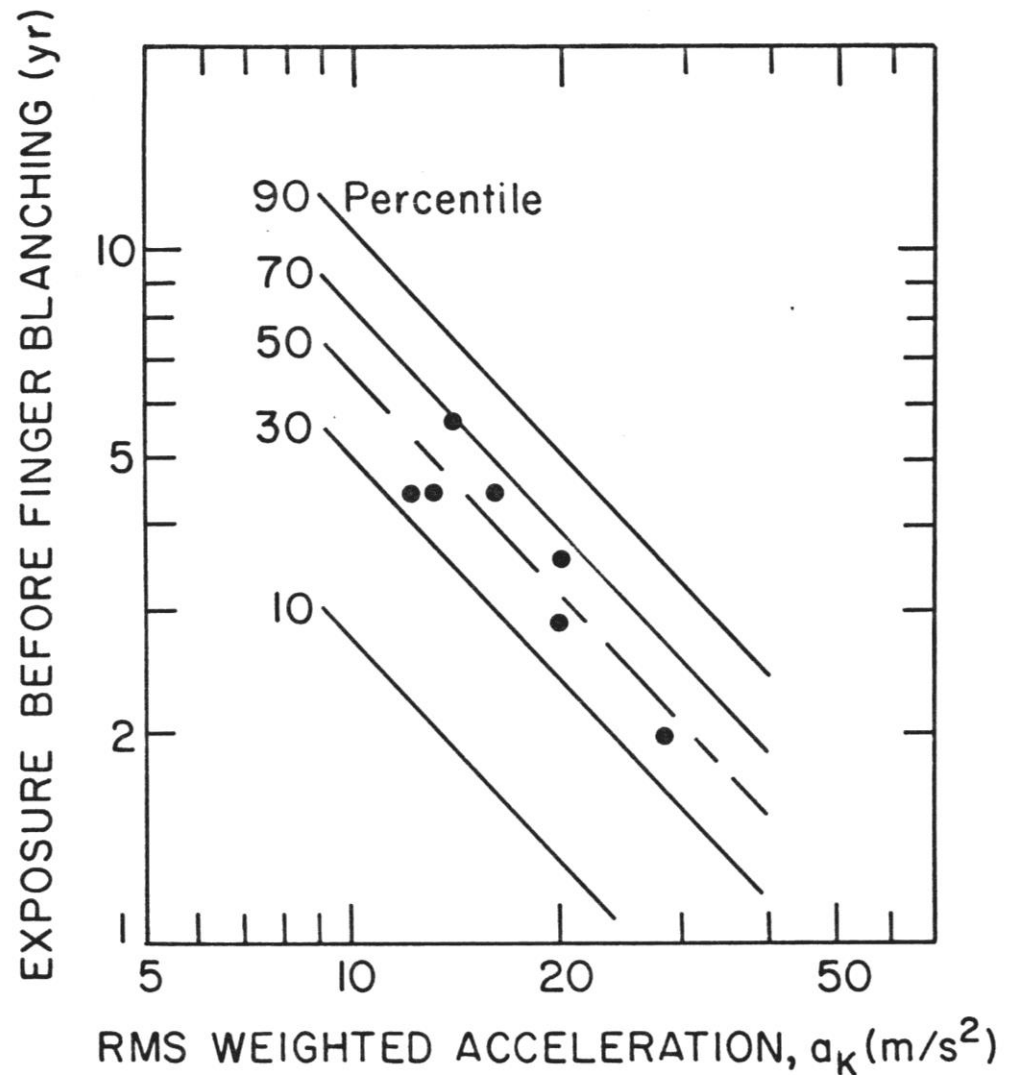
Exposure-Response Model for Onset of VWF, 1982

- Time for first white fingertip to occur (latency) in members of a population group, who operate throughout the day a single power tool or machine, is modeled by a normal distribution
- Standard deviation increases linearly with increasing mean latency in different population groups (17 groups)
- In order to relate symptoms to exposure, the hazard posed by vibration acceleration at different frequencies needs to be established
- Frequency weighting under study by ISO for a standard selected for this purpose

Exposure-response relationship for VWF

The predicted years of exposure before onset of VWF in members of a population group exposed daily to a given frequency-weighted acceleration a_K is shown for percentiles of those ultimately affected.

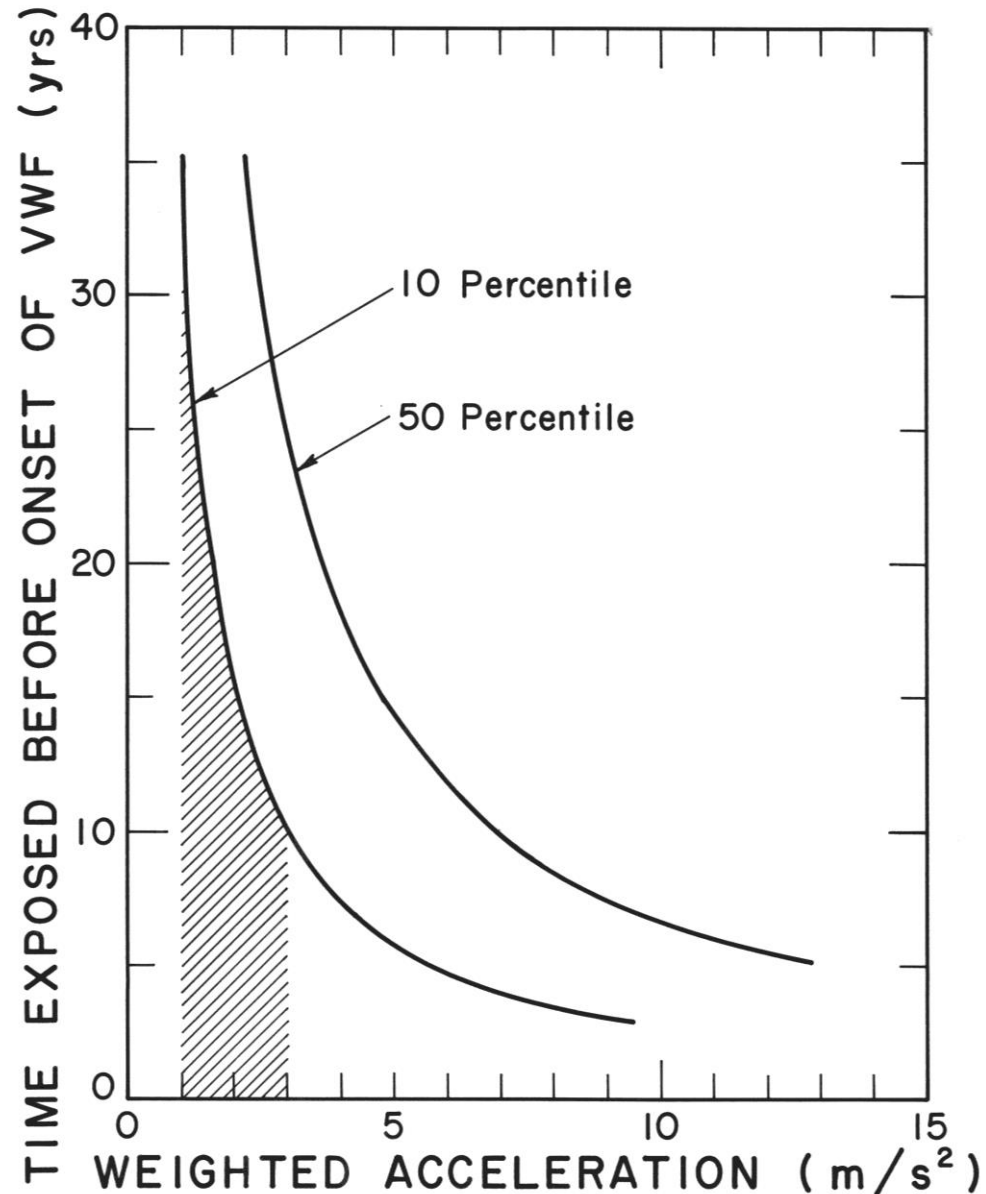
Dashed line mean response from 7 studies.



Use of model to predict
vibration threshold for
the occurrence of VWF

Prediction of the time
exposed to vibration to delay
the onset of VWF in
members of a population
group for a “working
lifetime” (shaded)

[Brammer, 1982]



ISO 5349 - Guidelines for the Measurement and Assessment of Hand-Transmitted Vibration, 1986 (1)

- Specified methods for measuring vibration on a vibrating surface in contact with the hand, where energy enters the body
- Specified a frequency-weighting filter for combining vibrations at different frequencies
- Specified exposures be assessed in terms of 4-h energy-equivalent daily exposure
- Specified how to calculate the daily exposure from use of several vibrating tools or machines during a workday (energy addition)

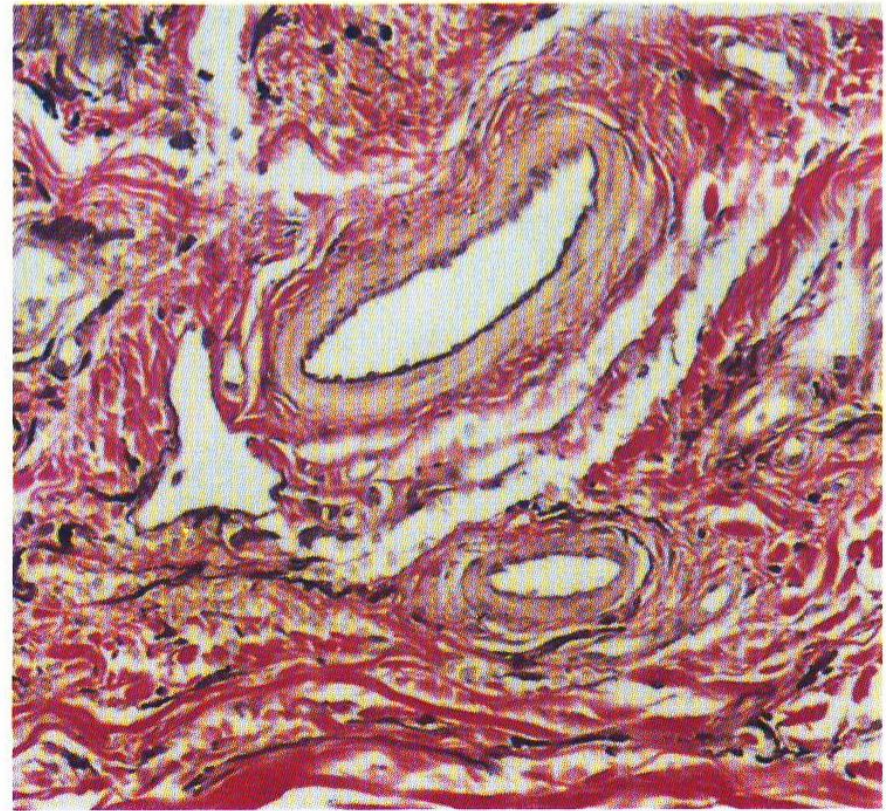
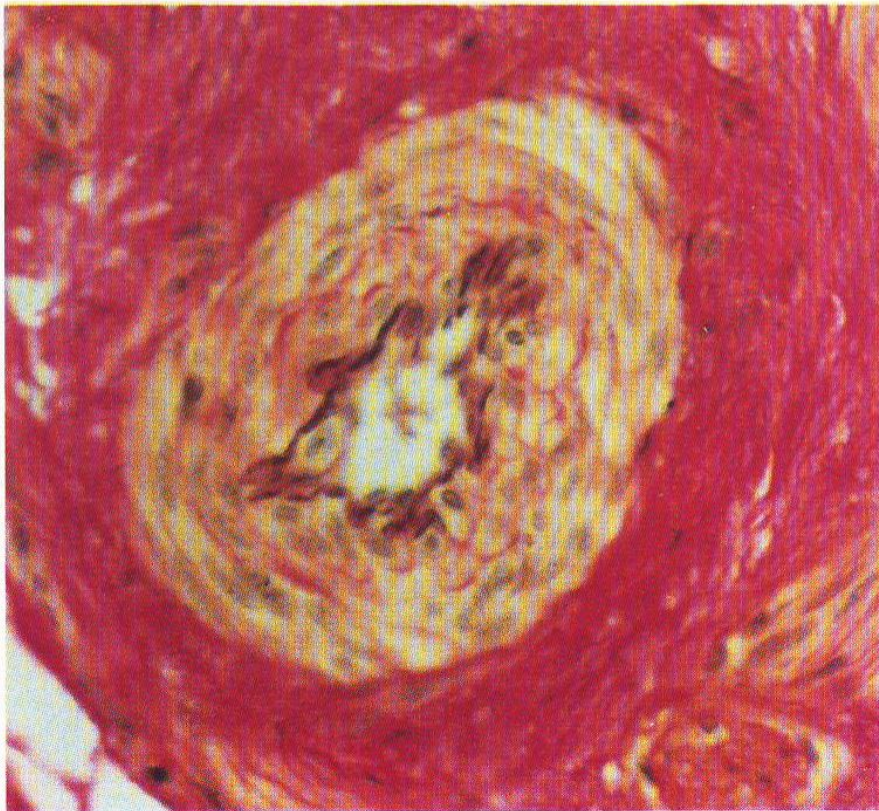
ISO 5349 - Guidelines for the Measurement and Assessment of Hand-Transmitted Vibration, 1986 (2)

- Guidelines for evaluating hand-transmitted vibration exposure adapt the model described by Brammer, which uses the ISO frequency weighting
- Guidelines assume daily exposures in the model are for a 4-h duration of exposure per day
- Guidelines assume different daily exposure durations, and combinations of part-daily exposures (e.g., to different tools or machines), can be expressed as a 4-h exposure by the energy conversion methods in the Standard

Pathological Changes in VWF Demonstrated, 1986

Cross sections of small finger artery showing increased middle muscular layer (brown) in VWF (left, x200), compared with healthy control (right x100 magnification)

[Photo credit: T. Takeuchi et al., 1986]



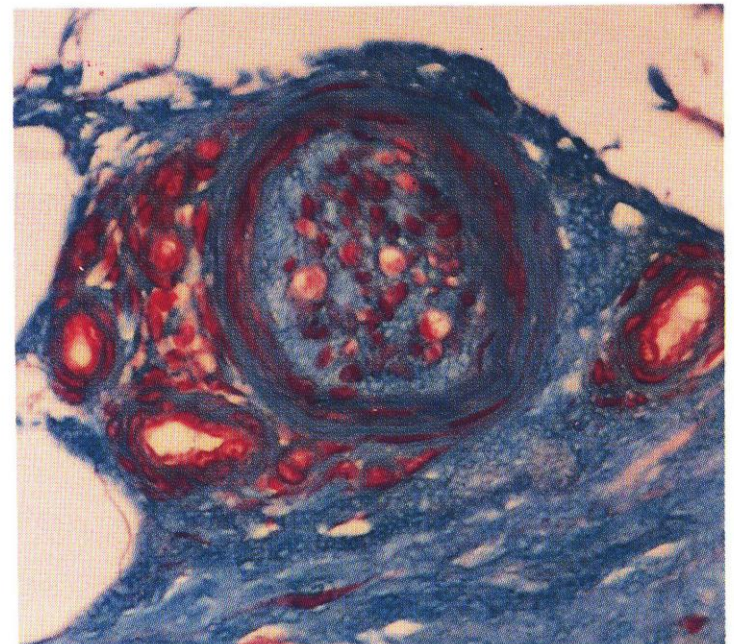
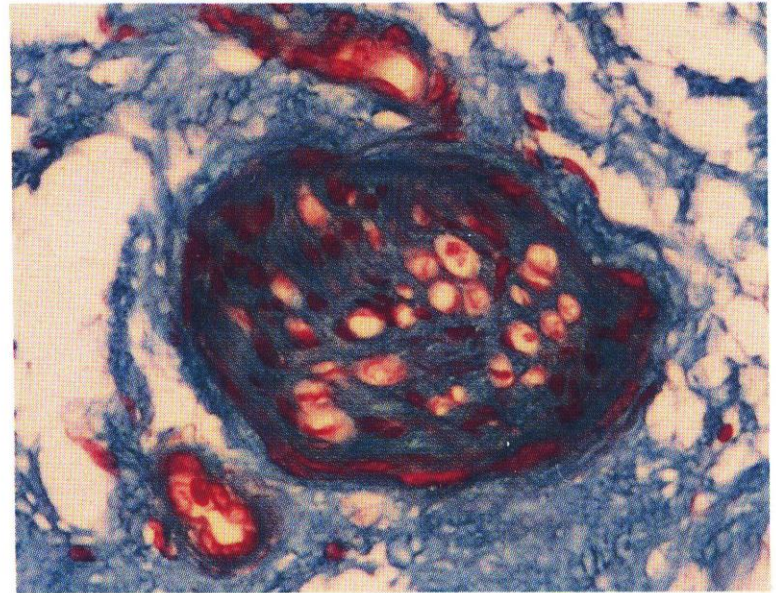
Stockholm Workshop on Symptomatology and Diagnostic Methods, 1987

- Recognition that the many signs and symptoms associated with manual work involving exposure to vibration (white fingers, finger numbness, and muscular and skeletal disorders) may develop separately, and independently
- Encouraged use of term *Hand-Arm Vibration Syndrome* (HAVS) for signs and symptoms caused by vibration
- Developed the *Stockholm Workshop Stages* for the clinical evaluation of the vascular signs and neurological symptoms of HAVS

Pathological Changes in Nerves Demonstrated, 1986

Cross sections of finger nerve (x100)
showing loss of nerve fibers: Upper
(mild case) ~25 axons remaining;
Lower (severe case) ~3 axons,
remaining.

[Photo credit: T. Takeuchi et al., 1986]



What Other Disorders Are Associated with Manual Work Involving Exposure to Vibration?

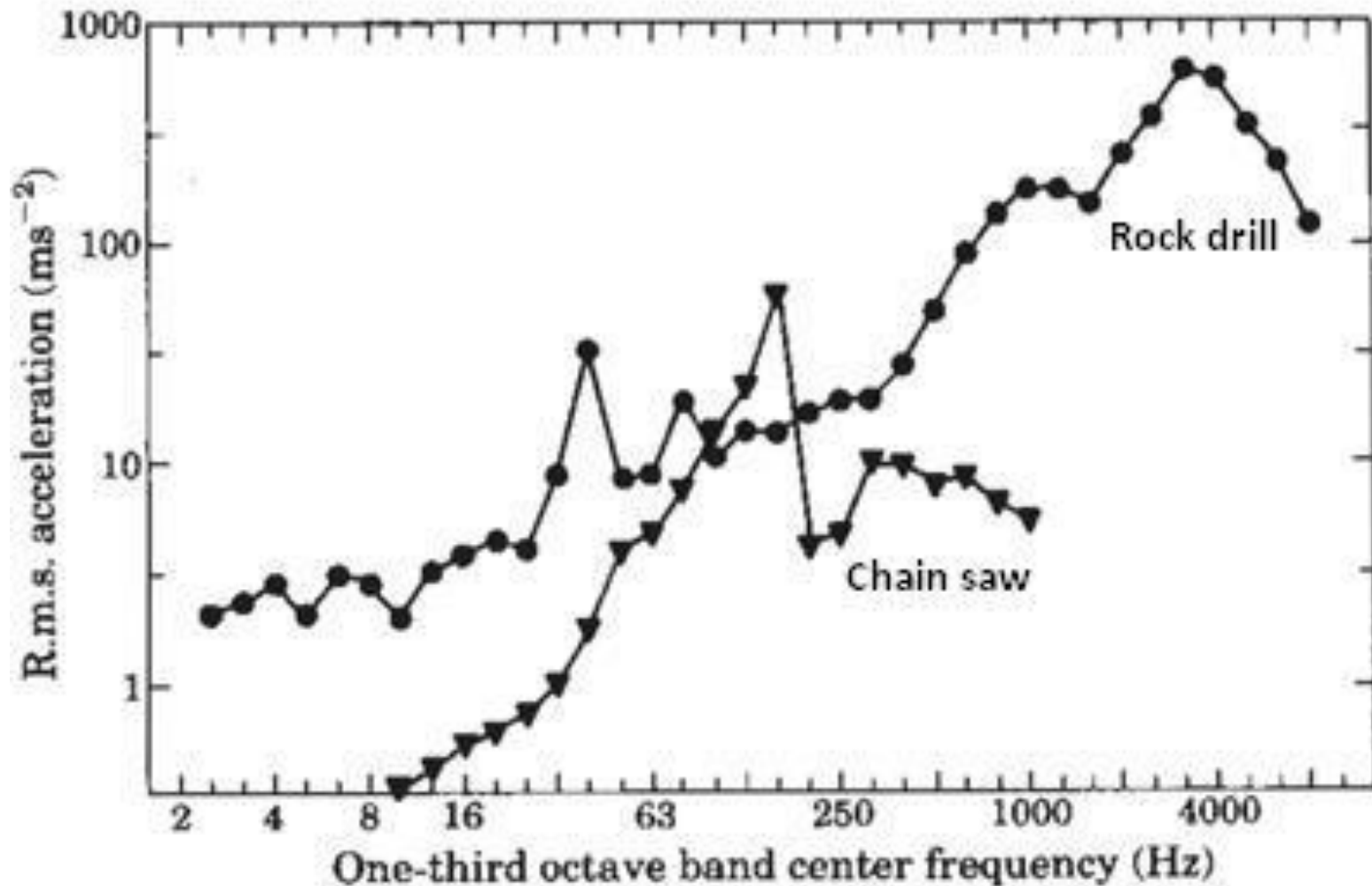
- Carpal Tunnel Syndrome
- Muscular disorders – muscle weakness, reduced hand grip and manual dexterity, inflammation of tendons, and Dupuytren's contracture
- Skeletal disorders – excess wrist and elbow joint stiffness, deformities and swelling
- Excess hearing loss, and non-specific symptoms such as persistent fatigue, irritability, and sleep disturbance

Issues with ISO 5349 from 1990-2000

- Frequency weighting incorrectly assesses the potential hazard of some impact tools
- Need to increase upper frequency limit of measurements
- Exposure-response relation commonly over- or under-estimates the development of VWF
- Concern about the applicability of the standard to shocks

Comparison of Spectra of Two Power Tools

Produce the same latency and prevalence of white fingers



ISO 5349 Revised – Second Edition, 2001

Part 1 General Requirements

- Replaced measuring dominant (single) component accelerations with 3-dimensional vector sums using same frequency weighting (termed WAS)
- Inserted description of health effects and the Stockholm Workshop Scales for vascular and neurological disorders
- Specified exposures be assessed in terms of 8 h energy-equivalent daily exposure
- Provided prediction only for exposures to produce 10% VWF for $3 \leq \text{WAS} \leq 25 \text{ m/s}^2$ based on 1982 model, responding to criticism of inaccuracy

ISO 5349 Revised – Second Edition, 2001

Part 2 Practical Guidance

- Introduced a second part of the standard to provide practical guidance for measurements conducted at the workplace
- Described precautions to be taken to make representative vibration measurements and to determine the daily exposure time for each operation in order to calculate the 8-h energy-equivalent daily vibration exposure

Directive 2002/44/EC of the European Parliament (2002)

- Specified exposure limits and action values now used by countries both inside and outside the European Union
- Requires measurements performed according to provisions of ISO 5349-1 and 5349-2 (2001)

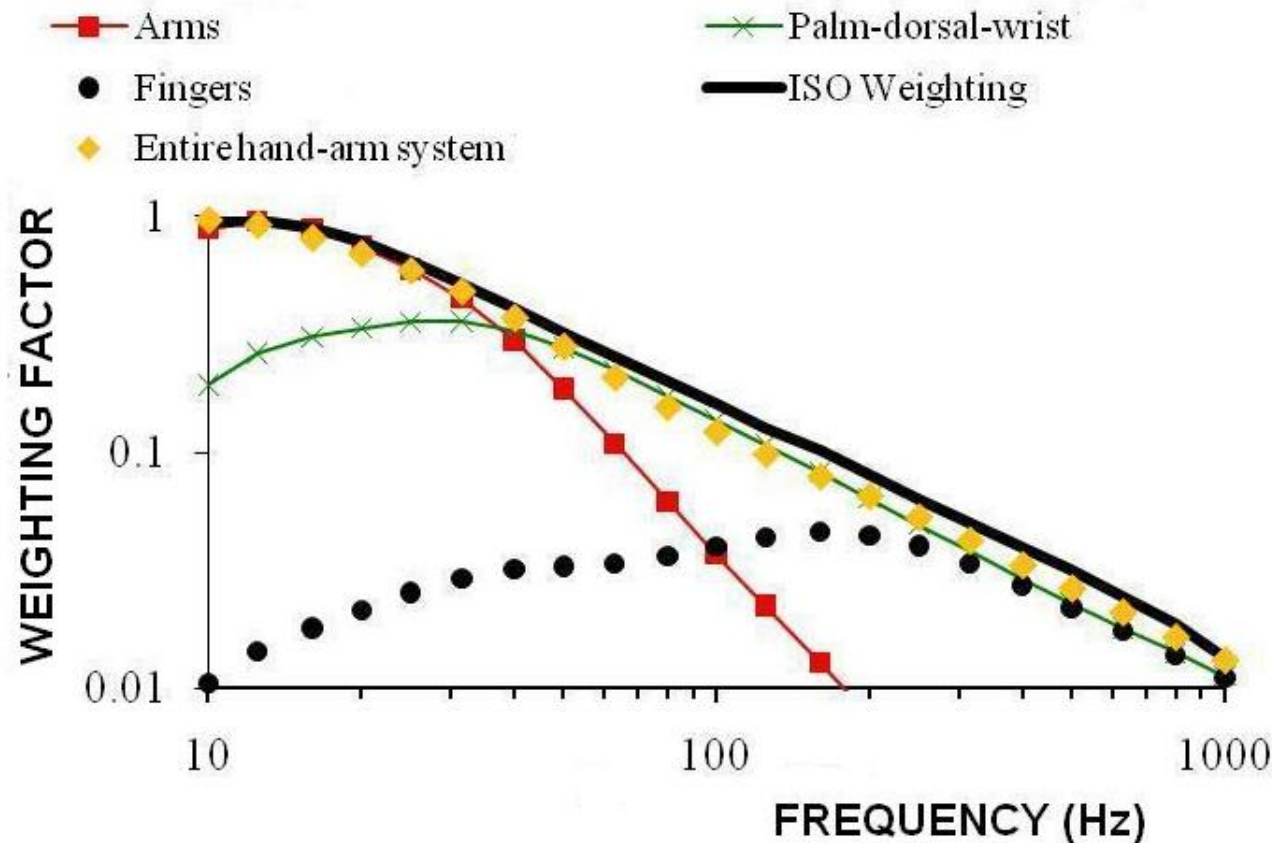
Issues with ISO 5349-1 and -2 (2001) from 2005-

- Same frequency weighting may not apply to all components of HAVS
- Current frequency weighting incorrectly assesses the hazard of some impact tools and shocks
- Need to reconsider upper frequency limit of measurements
- Need to reconsider how daily and lifetime exposures are included in the calculation of daily and total exposure durations
- Exposure-response relation commonly over- or under-estimates the development of VWF

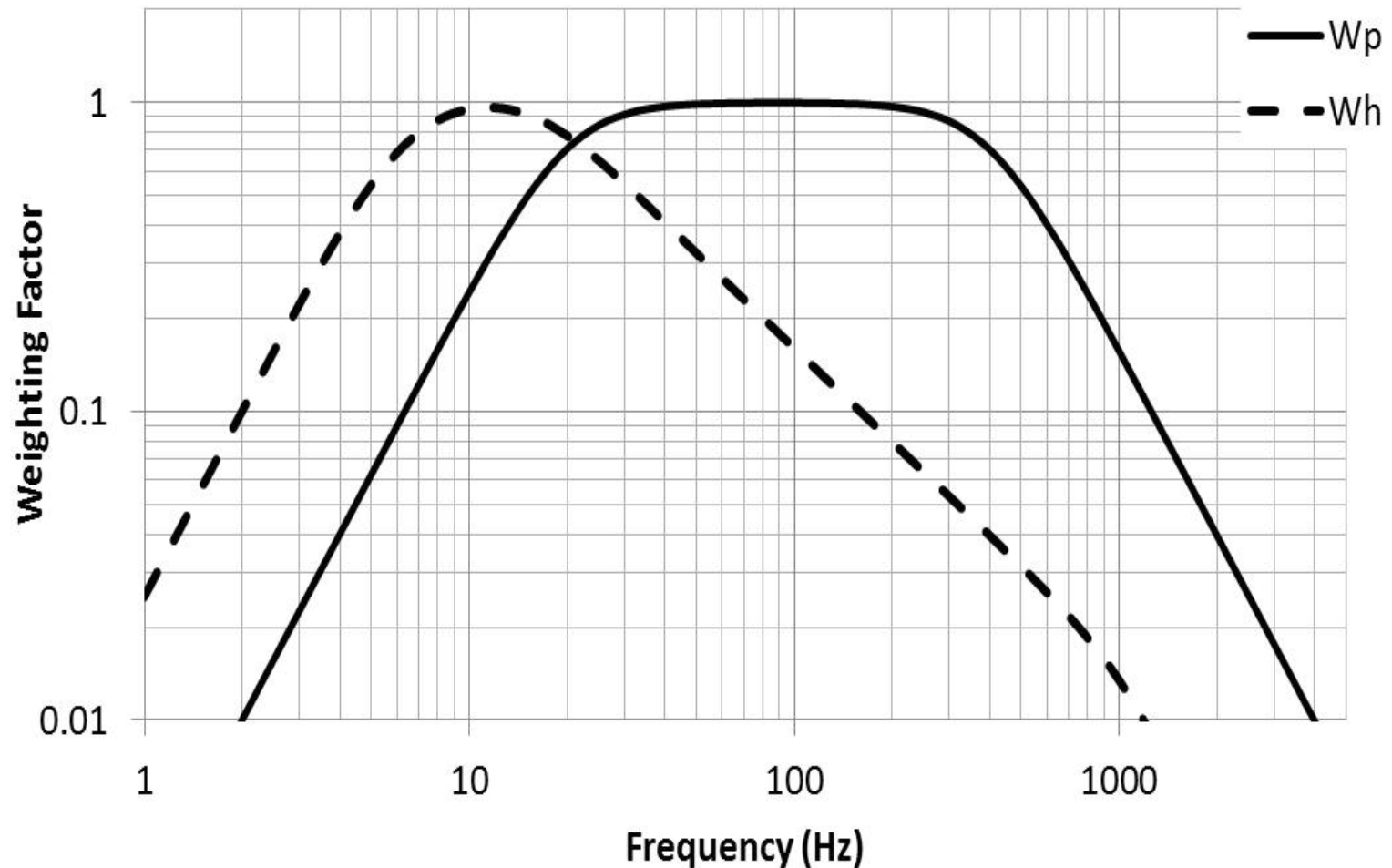
Frequency Weighting for Different Components of HAVS

The power absorbed in different parts of the hand-arm system are plotted as weighting factors – compare black dots (fingers) with the black curve (ISO weighting)

[Dong et al., 2012]



ISO Frequency Weighting for the Vascular Component of HAVS (W_p) in ISO/TR 18570, 2017



A Summary of 100 Years of HAVS

- While in many countries there continues to be limited recognition of the health hazard posed to the hands by vibration, ISO 5349 has enabled exposure limits to be introduced and the incidence of HAVS is diminishing
- EU mandated changes to the vibration of power tools and to work practices are underway
- Procedures for identifying affected persons have been refined, and severe cases are being compensated for disability in some countries
- The health issues need to be better communicated to the medical community, and to the broader public
- Gaps in knowledge need to be addressed