

**HAND ARM
VIBRATION**



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Cold response of digital vessels and metrics of daily vibration exposure

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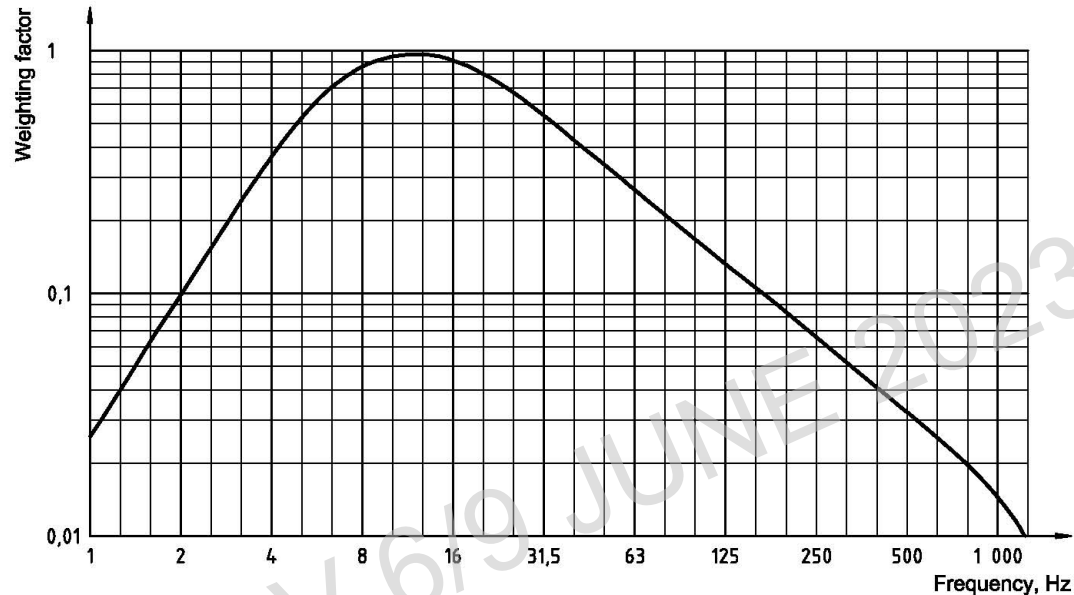


Vascular disorders vs vibration frequency

- Experimental studies have shown that the response of finger circulation to hand-transmitted vibration (HTV) is frequency-dependent;
- Vibration frequencies ≥ 100 Hz can induce a stronger vasoconstriction than lower frequencies in either the human finger or animal models;
- Several epidemiological studies have reported that occupational exposure to intermediate- and high-frequency vibration is associated with an increased risk of VWF.



Frequency weighting in ISO 5349



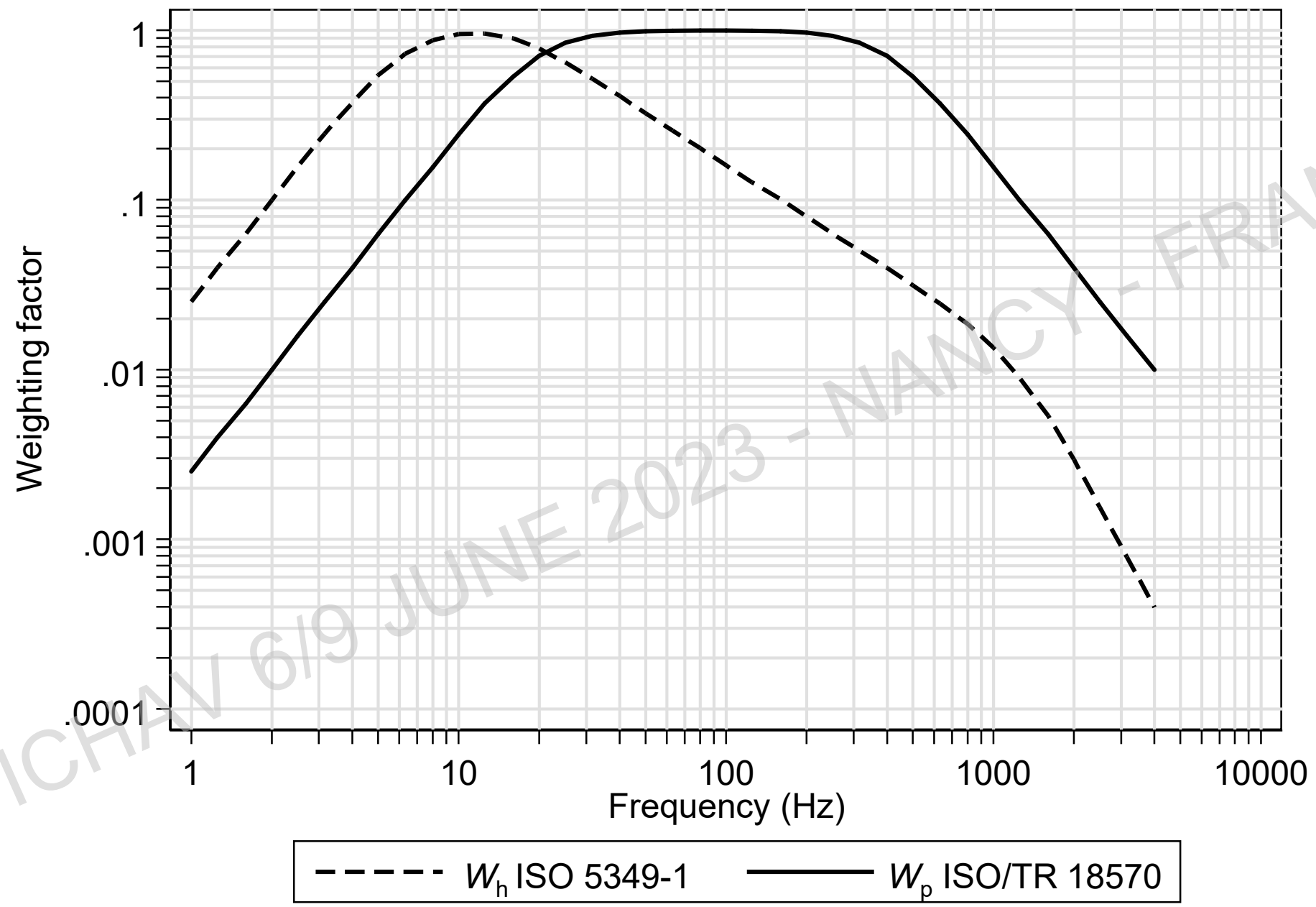
The shape of the frequency weighting (W_h) of ISO 5349 assumes that low frequency vibration (≤ 16 Hz) has more importance for vibration induced adverse health effects than intermediate- and high-frequency vibration.



ISO/TR 18570:2017

- Upon consideration of the findings of biodynamic, physiological and epidemiological investigations, an alternative form of frequency weighting for HTV, called hand-arm vascular weighting (W_p), has been proposed in the Technical Report ISO/TR 18570:2017;
- Compared to the ISO frequency weighting W_h , the hand-arm vascular weighting W_p gives more weight to intermediate- and high-frequency vibration





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Epidemiological validation of ISO/TR 18570

- In the Italian arm of the EU VIBRISKS project, the supplementary hand-arm vascular weighting (W_p) proposed in the ISO/TR 18570, performed better than the ISO W_h curve for the prediction of the occurrence of subjective symptoms of VWF in a cohort of HTV workers;
- *Bovenzi et al. "Risk assessment of vascular disorders by a supplementary hand-arm vascular weighting of HTV". IAOEH 2019; 92:129-139*

Job title	Observed VWF prevalence (%)	Predicted VWF prevalence (%)	
		$A_h(8)$	$A_p(8)$
Forestry workers	7.5	9.5	8.1
Stone workers	47.1	35.6	43.3

Aim of the study

- The aim of the present study was to compare the relative performance of the vibration metrics constructed with either the frequency weighting W_h (ISO 5349-1) or the frequency weighting W_p (ISO/TR 18570) **to predict, in addition to VWF symptoms, the cold response of the digital arteries in the VIBRISKS workers.**



Cohort

- The study population included 249 vibration-exposed workers (215 forestry operators and 34 stone workers) and 138 control men employed at the same companies and unexposed to hand-transmitted vibration who were investigated at the cross-sectional survey and annually over a 4-yr follow-up period.



Diagnosis of white finger

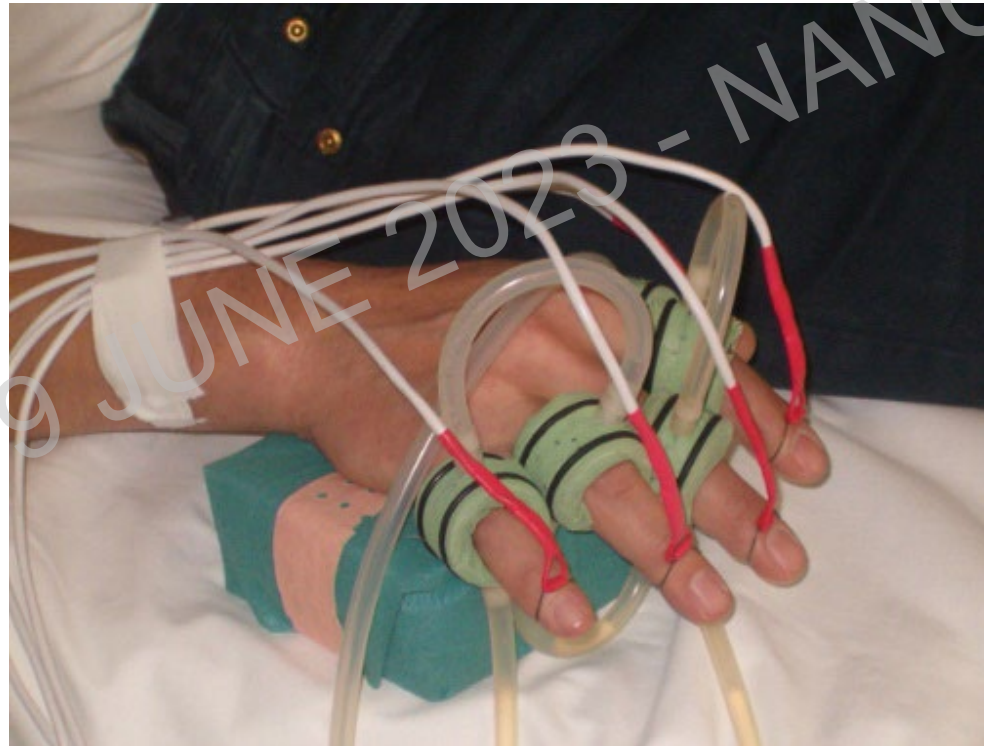
- Medical interview according to the criteria of the Stockholm Workshop '94
- Administration of colour charts



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Cold test with measurement of FSBP

$$\%FSBP_{10^{\circ}} = (FSBP_{t,10^{\circ}} \times 100) / [FSBP_{t,30^{\circ}} - (FSBP_{ref,30^{\circ}} - FSBP_{ref,10^{\circ}})] \quad (\%)$$



Vibration exposure

$$a_{vi}(W_f) = \sqrt{a_{xi}^2(W_f) + a_{yi}^2(W_f) + a_{zi}^2(W_f)} \quad (\text{ms}^{-2} \text{ r.m.s.})$$

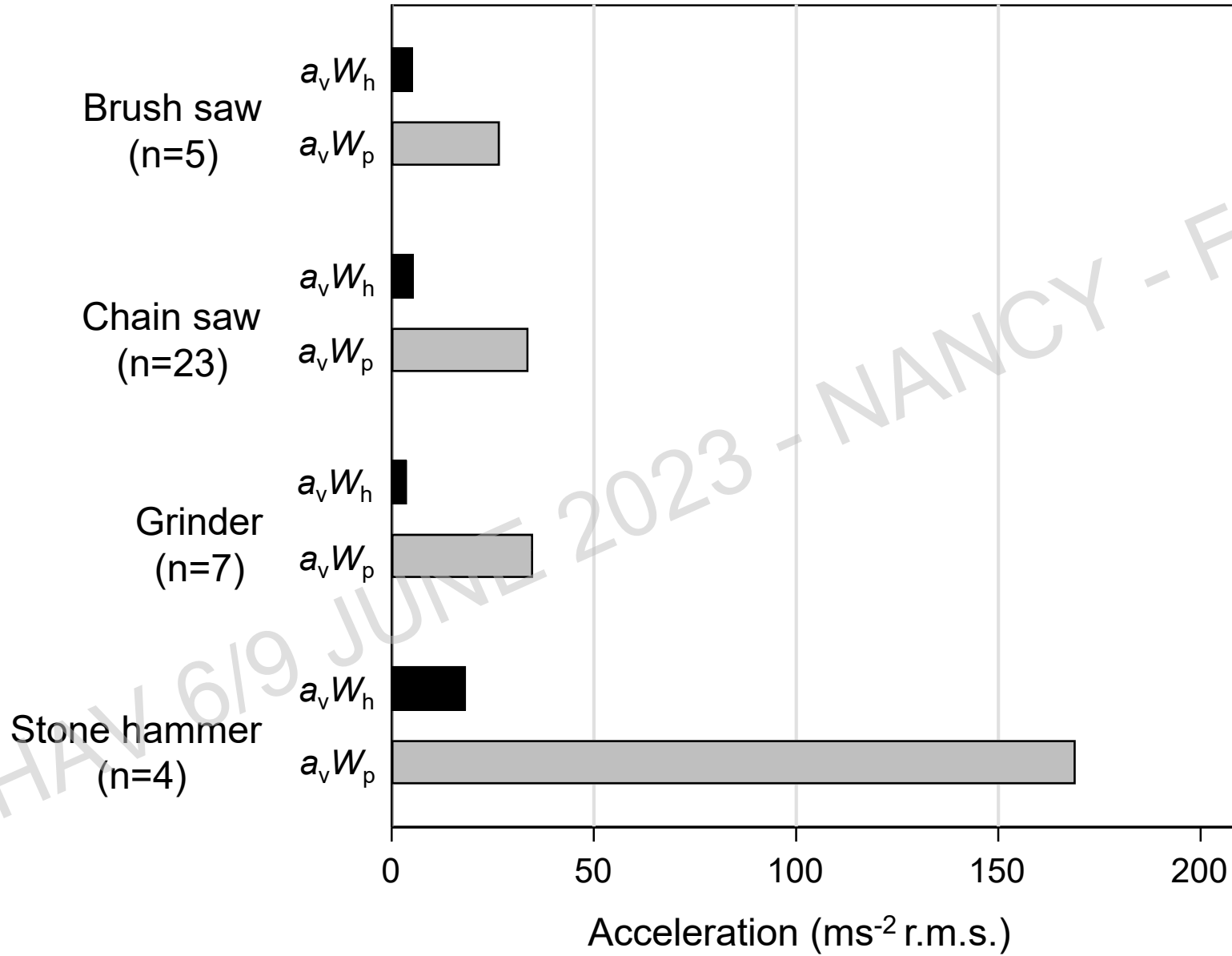
$$A(8)_{(W_f)} = \sqrt{\sum_{i=1}^n a_{vi}^2(W_f) \frac{T_i}{T_0}} \quad (\text{ms}^{-2} \text{ r.m.s.})$$



Statistical modelling

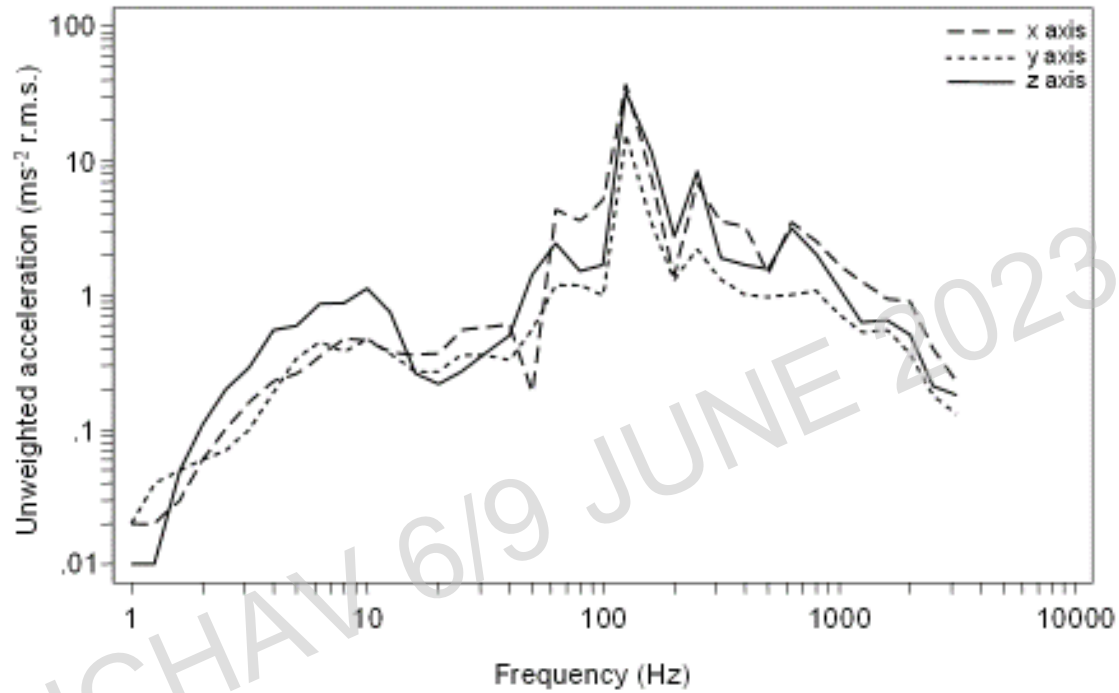
- The fit of maximum-likelihood random-effects regression models for repeated measures including alternative measures of daily vibration exposure was assessed by means of the “Bayesian Information Criterion” (BIC):
 - $\Delta\text{BIC} \leq 2$ suggests no difference in the fit between models,
 - $2 < \Delta\text{BIC} \leq 6$ tends to give support for the model with the smaller BIC,
 - $6 < \Delta\text{BIC} \leq 10$ means that the model with the smaller BIC provides a substantial better fit to the data.



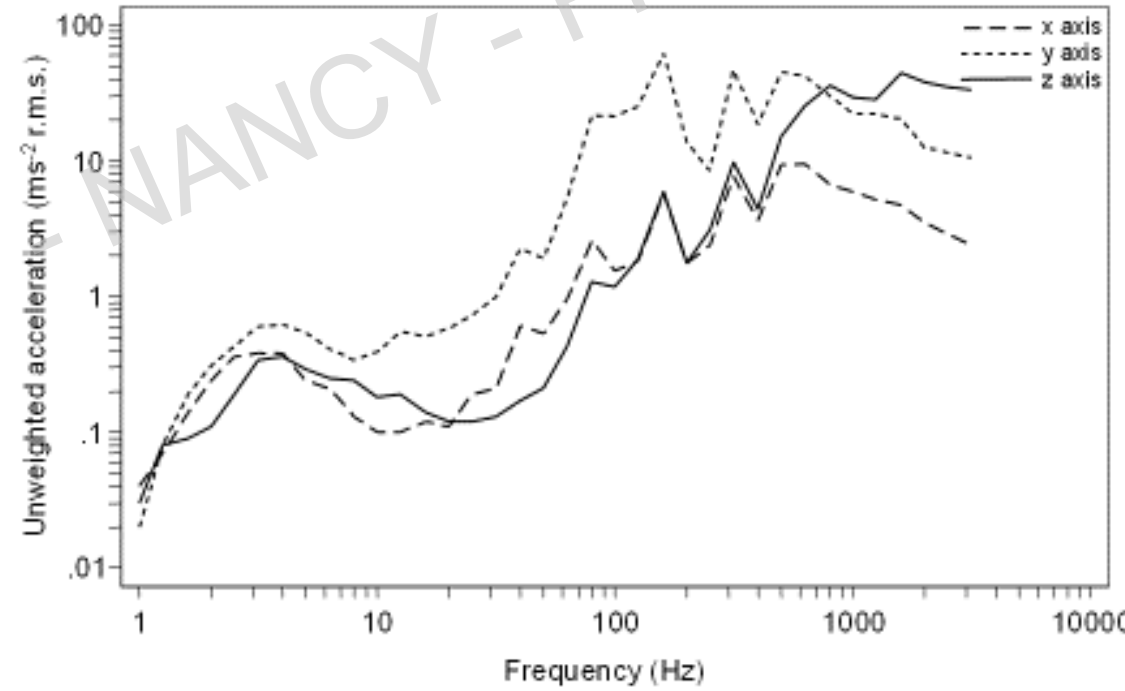




Chain saw



Stone hammer



Characteristics of the controls and the HTV workers

Factors	Controls (n=138)	HTV workers (n=249)	
		Non-VWF (n=195)	VWF (n=54)
Age (yr)	38.8 (34.1 – 45.9)	42.1 (33.6 – 46.8)	43.0 (34.8 – 52.2)
Current smokers (n)	29 (21.0)	85 (43.6)	28 (51.8) ^a
$A_h(8)$ (ms^{-2} r.m.s)	-	3.59 (2.48 – 5.21)	4.54 (3.44 – 7.94) ^b
$A_p(8)$ (ms^{-2} r.m.s)	-	17.9 (12.5 – 27.4)	26.5 (16.1 – 78.9) ^b
Duration of exposure (yr)	-	15 (7 – 21)	17 (11 – 23)
FSBPt,30° (mmHg)	120 (110 – 135)	130 (115 – 140)	125 (110 – 140)
FSBPc,30° (mmHg)	130 (118 – 140)	130 (120 – 140)	130 (115- 140)
Cold test results (%FSBP _{10°})	92.9 (85.7 – 100)	91.7 (81.8 – 100)	81.7 (60.0 – 94.7) ^c

χ^2 test: ^ap<0.001; Mann-Whitney test: ^bp<0.001; Kruskal-Wallis test: ^cp<0.0001

Point prevalence at baseline and overall prevalence over the study period for symptoms of white finger in the controls and the vibration exposed workers

	Controls (n=138)	Forestry workers (n=215)	Stone workers (n=34)	Total HTV sample (n=249)
Point Prevalence	8 (5.8%)	30 (14.0%)	13 (38.2%)	43 (17.3%)
Overall Prevalence	10 (7.2%)	38 (17.7%)	16 (47.1%)	54 (21.7%)

Relation of %FSBP_{10°} to measures of daily vibration exposure expressed in terms of either $A_h(8)$ (ISO 5349-1) or $A_p(8)$ (ISO/TR 15870).

Factors	$A_h(8)$ ($\times 1 \text{ ms}^{-2}$ r.m.s.)	$A_p(8)$ ($\times 10 \text{ ms}^{-2}$ r.m.s.)
	Coeff. (95% CI) ^a	Coeff. (95% CI) ^a
$A_f(8)$	-1.23 (-1.63; -0.84)	-1.30 (-1.68; -0.92)
Exposure duration (y)	-0.07 (-0.25; 0.12)	-0.03 (-0.22; 0.15)
VWF	-7.59 (-11.1; -4.03)	-7.02 (-10.6; -3.44)
LR test $\chi^2 A_f(8)$ ^b	20.4	26.8
BIC	7780	7773
Δ BIC		7

^aRegression coefficients adjusted by age-at-entry, smoking, drinking, BMI, hand trauma or surgery, systemic disorders, daily use of medicines, leisure activity with vibrating tools, survey time, and %FSBP_{10°} at baseline

^b $p < 0.0001$ for $A_f(8)$ in both models

Conclusions (1)

In this study, the metric $A_p(8)$ performed better than $A_h(8)$ for the assessment of the vasoconstrictor effect of cold in the digital arteries of HTV workers;

This is consistent with our previous epidemiological findings that $A_p(8)$ was a better predictor of the occurrence over time of VWF symptoms in the VIBRISKS cohort compared to the measure of daily vibration exposure $A_h(8)$ recommended by ISO 5349-1



Conclusions (2)

The results of pathophysiological and morphological investigations provide biological plausibility to the epidemiological findings of an increased occurrence of VWF symptoms in HTV workers operating power tools generating high frequency vibration.



Conclusions (3)

Overall, the present study and previous epidemiological surveys suggest that the evaluation of vibration exposure by means of a **frequency weighting** which assigns **more weight to intermediate- and high-frequency vibration** (31.5 – 250 Hz) is more appropriate for the assessment and the **prediction of subjective symptoms and objective signs of vibration related vascular disorders** compared to the assessment method recommended by the current ISO 5349-1 standard which tends to overestimate the vascular effects of lower frequency vibration (≤ 16 Hz).



Conclusions (4)

The measurement and evaluation of vibration exposure by means of the frequency weighting W_p may have some implications for the implementation and management of preventative measures at the workplace, including guidance to design and to manufacture tools, work equipment, and personal protective equipment (e.g. the choice of gloves with effective antivibration properties) that lower vibration exposures at the workplace and reduce the risk of vibration-induced disorders to a minimum according to the provisions of the EU Directive on mechanical vibration.

