

## TWO METHODS OF VIBRATION PERCEPTION ASSESSING IN WORKERS EXPOSED TO HAND-ARM VIBRATION

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It is known that vibration perception could be influenced by the device parameters and technique of measurement. The influence of confounding factors like age, weight and height on VPTs values was assessed in previous analyses in non-exposed subjects. The aim of present study was to compare the results of two techniques of vibrotactile thresholds measurement in workers exposed to hand-arm vibration.

Two methods of vibration perception assessment were compared in 124 workers (21–62 years old, 1–40 years of employment) exposed mainly to hand-arm vibration during the work as: chain saw operator, pneumatic hammers operators, metal grinders, fitters, dentist technician.

One method (named “standard method”) has been used in Poland so far; the second one (named “according to ISO method”) was established on the base of ISO Standard 13091-1-2001. The methods differed not only in technical parameters of stimuli but also in the way of normative values evaluation. In standard method there were no individual features or habits included.

The results of investigation revealed that age and weight play the important role in interpretation of tests results, both in standard and according to ISO method. Moreover, standard method measurements seem to overestimate the number of subjects with recognized vibration sense abnormalities. In both methods exposure to vibration mostly could be revealed by stimuli at frequencies of 125 and 250 Hz.

### 1. Introduction

It is known, that the vibration perception thresholds (VPTs) values depend on the device parameters and the technique of measurement [1]. The diameter of vibrating probe [2], the contact force between the probe and the finger [3], the frequency of vibration stimuli used [4], the method of stimuli presentation and the response acquisition [2] – all these are important in the VPTs assessment. Moreover, the sense of vibration could

be influenced by the individual factors, such as age [4–6], skin thickness, skin temperature, body weight and height [5, 7] and habits as smoking and alcohol consumption.

The influence of stimulus frequency on vibration reception is widely known. Stimulation at minimum three frequencies (4, 25 and 125 Hz) is required to establish the acuity of the three populations of mechanoreceptors primary involved in a sense of touch (slow-adapting SAI and fast-adapting FAI, FAII receptors). However, in standard method there were only high frequencies of vibration stimuli (250, 400 and 500 Hz) necessary to assess the touch sense disabilities.

Our previous findings suggest that more than 20% of healthy and asymptomatic subjects were classified as having abnormal VPTs in the standard method. Moreover, the individual parameters such as age, height or weight, skin temperature and habits were not included to normative values evaluation in this method.

In previous study the authors found that analysis of the linear regression for each sensory threshold in relation to independent variable showed statistically important relationships between VPTs and age, body weight and, at lesser degree, height [8]. The variables were included into further analysis. There were no differences between the left and the right hand but finger II and IV differed significantly thus the normative values were established for two fingers separately.

Range of normative values for every subject examined was evaluated with 95% confidence interval for single observation [8–10], according to equation:

$$\hat{y}_0 \pm t_{\alpha/2; (n-p-1)} \cdot s \cdot \sqrt{1 + \mathbf{x}'_0 (\mathbf{X}'\mathbf{X})^{-1} \mathbf{x}_0},$$

where  $\hat{y}_0$  – perception threshold value, calculated from linear multiple regression model (parameters are presented in Table 5),  $t_{\alpha/2; (n-p-1)}$  – statistics of Student's  $t$ -test (equal to 1.9675 if  $\alpha = 0.05$ ,  $n = 320$ ,  $p = 3$ ),  $\mathbf{x}'_0 = (\text{age}_0, \text{weight}_0, \text{height}_0)$  vector of measured values of variables in individuals,  $s$  – fit error for the model ( $s$  values are presented in Table 5),  $(\mathbf{X}'\mathbf{X})^{-1}$  – inverse product of design matrices; symmetrical matrix  $3 \times 3$ :

$$(\mathbf{X}'\mathbf{X})^{-1} = \begin{bmatrix} 3.194076E-05 & -8.588293E-06 & -1.742191E-06 \\ -8.588293E-06 & 2.577145E-05 & -9.286776E-06 \\ -1.742191E-06 & -9.286776E-06 & 4.253026E-06 \end{bmatrix}.$$

Regression coefficients used in the formula are presented in tables [8].

There is epidemiologic evidence for a greater occurrence of digital paraesthesia or deterioration of finger tactile perception in occupational groups using vibrating tools than in control groups. The prevalence of peripheral sensorineural disturbances varies from a few percent to more than 80%. However the relationships between VPT and vibration exposure is unclear.

The aim of the study was to compare vibrotactile thresholds in workers exposed to mechanical vibration using two different techniques of measurement. In both methods the same equipment (P8 of EmsonMat, Cracow, Poland) was used. The first method

named as a standard method is currently used in Poland, the second one was defined by the International Standard (ISO 13091-1-2001). The main differences between the measurements comprised: the mode of stimuli presentation, range of stimuli frequency, contact conditions between the finger and the probe, including pressing force, probe diameter and type of surface.

## 2. Population

123 workers (7 female, 116 male) exposed to mechanical vibration were interviewed and examined by a physician following a prewritten protocol. The protocol included questions on age, profession and work assignment, years of work and general state of health. Moreover, it also contained detailed inquiry on sensorineural disturbances in hands, such as nocturnal numbness, trouble with dropping things easily, difficulties buttoning, and its dependence on the year season. The physical features (height and weight), and habits (smoking, alcohol consumption) were also noticed. The characteristic of the study group is presented in Table 1.

**Table 1.** Population characteristics.

	Nr of subjects	Age (mean $\pm$ SD)	Years of employment	Weight (mean $\pm$ SD)	Height (mean $\pm$ SD)
Mean	123	45.7 $\pm$ 9.4	18.3 $\pm$ 9.7	80.7 $\pm$ 11.8	172.8 $\pm$ 6.7
range		21–62	1–40	52–120	150–189

They were working as: chain saw operators (32), metal grinders, fitters (24), and pneumatic hammers operators (41). 21 men were exposed both to general and hand-arm vibrations working as diggers, tractors and tracks operators/drivers. There were also several dentists technicians and the others.

## 3. Methods

VPTs measurements were conducted on the digital pulp of the right hand (37 subjects) or of both hands (86 subjects).

The device used was the vibrometer P-8. It allows generating the vibration stimuli with increasing levels or the stimuli with the levels automatically increasing and decreasing (Bekesy mode). Moreover, the device allows for and the control of vibration probe pressure on skin and use of two vibrating probes different in size and surface and two different probe contact forces.

The test was performed in a quiet laboratory room with a constant ambient temperature of 22–24° C. Before test starting, the superficial skin temperature at fingertips was measured. If the temperature was below 28° C, the hands were warmed up by the warm

air until temperature reached 28° C. The subject was seating with the tested arm resting on a support and pressing vibrating probe with the constant force. One well-experienced examiner conducted the measurements for all subjects.

VPTs were measured on two fingertips (2nd-index and 4th-ring finger). The measurement was done once for every tested finger and frequency.

Testing procedures were detailed described elsewhere [8]. Technical parameters in both methods are shown at the Table 2.

**Table 2.** Technical parameters of measurements.

Measurement technique parameters	Standard method	Method according to ISO
Stimulus frequency [Hz]	63, 125, 250, 400, 500	2, 25, 32, 125, 250,
Probe diameter [mm]	12	5
Contact force:		
– absolute values [N]	1.2	0.1
– relative values (in relation to probe area) [N/cm <sup>2</sup> ]	1.1	0.5
Acceleration changing rate [dB/s]	2	2 (initial magnitude increment) 4 (test magnitude increment)
Probe surface	rough	plane

In both methods the response data were estimated in root mean square acceleration values and expressed in logarithmic scale, in decibels (rel.  $10^{-6}$  m/s<sup>2</sup>). Then, these values were transformed to velocity units decibels (rel.  $5 \cdot 10^{-8}$  m/s), that were routinely used in Poland as a standard.

#### 4. Results

Questionnaire data revealed that 88 subjects (72%) suffered from sensorineural disturbances such as numbness and tingling when finger blanching was recorded in 64 (52%) of investigated subjects.

*Standard method: the influence of age, weight and height on health status qualification*

The normative data in standard method are based on the mean value of VPTs measured on three fingertips (2nd, 3rd, 4th) and at three frequencies (250, 400, 500 Hz). The result is abnormal if the mean value exceeds 85 dB. According these criteria, 70% of subjects revealed touch sense abnormalities. When the analysis was carried out for the single finger and frequency adjusted to the confounding variables (age, height and weight) instead if the mean value, the results mentioned above seems to be overestimated because finally only 58% subjects had abnormal sense of vibration.

Thus the calculation criteria in the same subjects examined using the same standard method significantly influence the results. The results overlapped in 66%, the method used so far (and calculated as a mean value) overestimate the results in 23% of subjects (Table 3).

**Table 3.** Standard method: the influence of the changed criteria of normative values calculating on test results.

		Standard method results adjusted to confounding factors No (%) of results		All
		abnormal <sup>1</sup>	normal	
Standard method used in Poland No (%) of results	abnormal <sup>2</sup>	99 (47%)	74 (23%)	146 (70%)
	normal	23 (11%)	40 (19%)	63 (30%)
All		122 (58%)	87 (42%)	209 (100%)

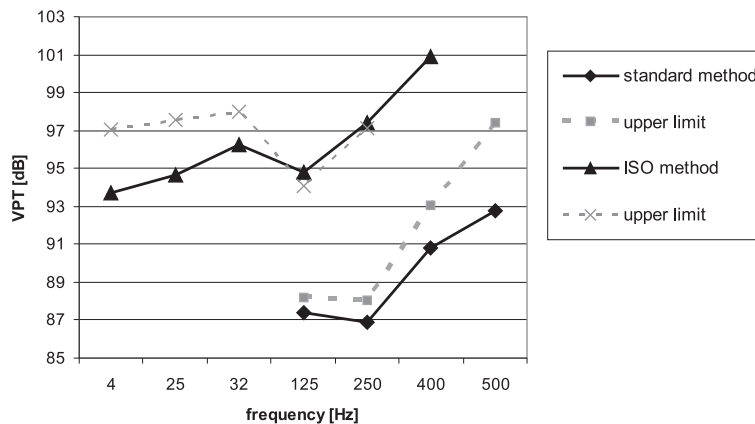
<sup>1</sup> Abnormal result: at last one frequency of 250, 400, 500 Hz and one finger, the measured value exceeded the normative.

<sup>2</sup> Abnormal results: mean value of VPTs measured on three fingertips (2nd, 3rd, 4th) and at three frequencies (250, 400, 500 Hz) exceeded 85 dB (no confounding factors included).

#### *Standard method and according to ISO method*

- The comparison of mean VPTs in frequency range

The mean VPTs were lower than admissible values at all frequency range in standard method. In the same group the method according to ISO revealed higher than normative values of VPTs at 125 and 205 Hz, although the differences were not statistically significant (Fig. 1).



\* Upper limit of normative value calculated individually for every subject on the base of 95% confidence intervals for single observation.

**Fig. 1.** Mean values of VPT measured in the same group of workers using two methods: standard method and according to ISO method and upper limits of normative values calculated individually for every subject, adjusted to age, weight and height.

- The comparison of tests results

Mean values of VPTs exceeded 85 dB in 146 cases in standard method. Only 125 results could be found as abnormal in according to ISO method.

The results of both methods overlapped in 78% of cases (the presence or the absence of abnormalities). The results in the standard method were overestimated in 16% of subjects (Table 4).

**Table 4.** Standard and according to ISO methods: the comparison of the tests results.

		According to ISO method No (%) of results		All
		Abnormal <sup>1</sup>	Normal	
Standard method No (%) of results	Abnormal <sup>2</sup>	113 (54%)	33 (16%)	146 (70%)
	Normal	12 (6%)	51 (24%)	63 (30%)
All		125 (60%)	84 (40%)	209 (100%)

<sup>1</sup> abnormal test result: at at least one frequency and one finger the measured value exceeded the normative calculated for the examined person.

<sup>2</sup> abnormal results: mean value of VPTs measured on three fingertips (2nd, 3rd, 4th) and at three frequencies (250, 400, 500 Hz) exceeded 85 dB (no confounding factors included).

*According to ISO method: the frequency dependence*

125 subjects revealed the abnormal perception thresholds when according to ISO method was used. Mostly (94% of subjects) the vibration perception disturbances were revealed at frequencies 125 and 250 Hz while 52% of subjects showed vibration perception thresholds diminished in whole frequency range. Disturbances detected by low frequency stimulus (4 Hz) were seen in 53% of subjects but almost never (1%) as isolated. 84% of subjects had middle frequency (25-32 Hz) abnormalities.

## 5. Conclusions

1. Age and weight play the important role in interpretation of tests results, both in standard and according to ISO methods.
2. Standard method measurements seem to overestimate the number of subjects with recognized vibration sense abnormalities comparing to ISO method.
3. In both methods exposure to vibration mostly could be revealed by stimuli at frequencies of 125 and 250 Hz.

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