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REPEATABILITY OF VIBROTACTILE PERCEPTION THRESHOLDS OBTAINED WITH TWO DIFFERENT MEASURING SYSTEMS

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Abstract
Objectives: The measurement of vibrotactile perception thresholds (VPTs) on the workers' fingertips is one of the diagnostic methods of the occupational peripheral neuropathies. The aim of the study was to compare the repeatability of VPT measurements in two groups of healthy women with different finger skin temperature, using two different types of measuring systems. **Materials and Methods:** One measuring system employed a pallesthesiometer, and the measurement procedure complied with the new ISO 13091-1 standard; the other used vibrotactile meter according to the Polish procedure. Ten healthy women, mean age, 38.5 years, took part in 10 sessions, twice a day for over a five-day period. VPTs were measured on 3 fingers of both hands at eight discrete frequencies from 4 to 500 Hz with a pallesthesiometer, and adequately at five frequencies from 63 to 500 Hz with a vibrotactile meter. **Results:** It was observed that the succession of repeated vibration perception measurements, determined according to the ISO method, did not significantly influence the mean values of vibrotactile thresholds in subjects with the finger skin temperature not lower than 29°C. The repeatability of vibrotactile threshold measurements was similar in both groups only when the ISO method was used. The mean VPT values, obtained with the ISO 13091-1 method, were significantly higher in healthy subjects with lower finger skin temperature, which did not exceed 28°C. **Conclusions:** The results of vibrotactile threshold measurements, obtained according to the ISO 13091-1 method, are repeatable. Repeatability of vibrotactile threshold results obtained with the ISO 13091-1 method, within the range of low frequencies up to 125 Hz does not depend on the finger skin temperature.

Key words:
Vibrotactile perception threshold, Repeatability, Finger skin temperature, Women

INTRODUCTION

Occupational peripheral neuropathies in the upper extremities are unfavorable complications, resulting from exposure to hand-arm vibration or to various chemicals. These neuropathies are often manifested by changes in the tactile function. Detection of impaired vibrotactile

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sense is one of the methods useful in the diagnosis of vibration disease [1,2,3]. Measurement of vibrotactile perception thresholds (VPTs) on the fingertips is the basic requirement for monitoring of peripheral neuropathies in workers during their employment, including initial, periodic and final medical examinations.

Vibrotactile thresholds depend on many factors related with the method used to determine their values such as the diameter and vibration frequency of a stimulating probe, the presence or absence of surroundings around the probe, the contact force between the probe and the finger, the contact area, the psychophysical measurement procedure and the skin temperature [4,5,6]. According to the new international standard ISO 13091-1 that provides a uniform system of requirements for measurement methods, it is necessary to test the usefulness of any new method in determining VPTs and to compare it with methods used hitherto [7,8]. The first question to be answered is whether the repeatability of VPT measurements depends on the measuring system and the finger skin temperature of healthy subjects.

The aim of this study was to assess the repeatability of VPT measurements in two groups of healthy women with different finger skin temperature, using two different measuring systems, i.e., one system designed according to the requirements of the ISO 13091-1 standard and the other used so far in Poland.

MATERIALS AND METHODS

Subjects

Ten healthy women participated in the study as volunteers. All the subjects had no history of neuromuscular or vascular disorders and had not suffered from any serious injures of the upper extremities. Four of the subjects (group G1) had slight hand cyanosis while their finger skin temperature did not exceed 28°C on average. In the second group (G2) finger skin temperature ranged from 29°C to 34°C. The study groups included four nurses, four laboratory technicians and two researchers. Two subjects of group G1 smoked daily about 10 cigarettes, while in group G2 there were no smokers. Their physical characteristics and the mean finger skin temperature are given in Table 1.

Table 1. Characteristics of subjects

Subject	Group	Mean finger skin temperature (°C) and standard deviation (SD)	Age (years)	Weight (kg)	Height (m)
1	G1	25.0 (0.4)	36	54	1.59
2	G1	26.8 (0.7)	50	56	1.56
3	G1	27.2 (0.4)	34	76	1.63
4	G1	27.3 (0.5)	25	58	1.60
5	G2	33.7 (1.2)	30	78	1.72
6	G2	32.8 (1.7)	42	64	1.61
7	G2	30.0 (1.8)	43	55	1.60
8	G2	29.1 (0.4)	35	70	1.70
9	G2	31.7 (1.8)	54	65	1.66
10	G2	29.1 (08)	36	63	1.70
		Mean	38.5	63.9	1.64
		SD	8.8	8.6	0.05

All the subjects were required to be fit and healthy during each session.

Measuring system 1 (MS1)

A new pallesthesiometer P8 (EMSON-MAT, Poland) was developed according to the ISO 13091-1 standard [8]. Measuring system 1 (MS1) consisted of a vibrometer unit, a subject response button, a set of vibrotactile meter working state indicators and the vibrometer software. In the vibrometer unit, a counterbalanced vibration exciter was used to drive a stimulating probe and a piezoelectric accelerometer to measure the acceleration magnitude. The stimulating probe was a flat-ended perspex cylinder, 5 mm in diameter. The subject kept the forearm and hand on the unit box resting the palm on a special support, which ensured required contact between the fingertip and the probe. The center of the stimulating probe tip was located on the distal phalanx at a point midway between the center of the whorl and the fingernail. The probe was pressed by the subject's finger with a constant force of 0.1 N. The static force between the probe and the finger was monitored by the subjects themselves. Adopting the method for counterbalancing the weight of the stimulator, the subjects watched two small diodes placed at the panel of the vibrometer unit near the stimulating probe. Whenever the static force was too strong or too weak, one of the diodes lit up.

The vibrometer unit was equipped with the acceleration monitoring system. It allowed us to carry out measurements even if the interference significantly exceeded the input vibration level. The acceptable noise-to-signal ratio was 20 dB; it was measured and displayed in the indicator of the vibrotactile meter working state [9].

The P8 vibrometer software was used with an IBM PC compatible computer. It controlled the course of the measuring procedure, displayed measurement data as well as computed and stored the results in the database.

Von Bèkèsy algorithm was used to determine vibrotactile perception thresholds. In this method the vibration magnitude was increasing until the subject was able to perceive it. Then the subject pressed the button held in the other hand. This caused a decrease in the vibration level until the subject no longer perceived a vibration stimulus. Released button caused the vibration level to increase again. Direction of continuous stimulus magnitude change was then reversed. The vibration magnitude was increased and decreased with a continuous stimulus at a constant rate of 2 dB/s (4 dB/s until the first response).

This procedure was repeated three times by the automatic test program to establish the threshold level at a selected vibration frequency. The VPT value was calculated from arithmetic mean of the mean peak (ascending thresholds) and the mean through (descending thresholds) for each frequency. The values of the levels were expressed in dB (re. $10^{-6}ms^{-2}$). The vibrometer software monitored the measurement, rejecting the acceleration values that differed from the mean value by more than ± 2 dB. The measurements were continued until 3 ascending thresholds and 3 descending thresholds were obtained, each with acceleration values within ± 2 dB. The results were recorded by the computer and printed after the examination was completed.

Measuring system 2 (MS2)

The vibrotactile meter, type MCW 2K, manufactured in Poland since 1980, was used in measuring system 2 (MS2). It consisted of a vibrometer unit, a counterbalanced vibrator and a perspex-tipped circular stimulating probe with a force indicator and a subject response button. The probe protruded through a circular hole of 16 mm diameter in a rigid plate. The subject put the pulp of the finger on the 10 mm diameter probe, approximately in the center of the whorl of the distal phalanx. The static force exerted by the finger on the probe was 2 N. This force was monitored by the subjects who watched a mobile red line, which moved under a transparent plate near the stimulating probe. The force was correct if the red line was exactly under a white line painted on the surface of the transparent plate. The force exerted by the finger on the plate was not controlled. The subject rested the palm on the surface of the table to which equipment with the probe and the force indicator were attached. The subject was asked to press the response button held in the other hand as soon as the stimulus was perceived. Vibration magnitude was increased manually by the person conducting the examinations until the subject was able to detect vibration. Vibration magnitude level of the stimulating probe was read in dB (re. $5 \cdot 10^{-8}ms^{-1}$) directly from the vibrotactile meter monitor.

The mean VPT value expressed in the velocity level was calculated from the arithmetic mean of three ascending thresholds and then was recalculated into the acceleration level (in dB re.$10^{-6}ms^{-2}$).

Comparison of two measuring systems is summarized in Table 2.

Table 2. Description of two measuring systems, MS1 and MS2

	MS1	MS2
Frequency, Hz	4; 25; 31.5; 63; 125; 250; 400; 500	63; 125; 250; 400; 500
Diameter probe, mm	5	10
Probe-surround gap, mm	No surround	3
Contact force, N	0.1	2
Stimulation	Automatic	Manual
Psychophysical algorithm	Von Békésy	Ascending threshold
Subject response	Automatic	Automatic
Vibrotactile threshold report	dB (re: $10^{-6}ms^{-2}$)	dB (re: $5 \cdot 10^{-8}ms^{-1}$)

Procedure

Prior to the experiment, a pre-test was performed to familiarize the subjects with the vibration stimuli and the measurement procedure. The subjects performed the test once with each measuring system. Each subject took part in 10 sessions twice a day (in the morning and in the afternoon) over a five-day period.

The VPT measurements were taken for the index, middle and ring fingers of both hands, using first MS1 and then MS2. VPTs were determined using MSI with frequencies of 4, 25, 31.5, 63, 125, 250, 400 and 500 Hz. As compared to the ISO 13091-1 standard, the range of applied frequencies was widened and additional VPT measurements at 250, 400 and 500 Hz were performed. The higher frequencies were taken into consideration when comparing the ISO method with that used in Poland. VPT measurements with MS2 were performed with frequencies of 63, 125, 250, 400 and 500 Hz. The range of chosen frequencies resulted from measurement abilities of applied MCW 2K meter. The order of vibration stimuli ranged from the lowest to the highest frequencies for each measuring system. The VPTs were determined successively at each stimulation frequency for each finger of both hands. Duration of one session did not exceed 40 min.

The finger skin temperature of both hands was measured on the distal phalanx of all 10 digits before, during and after the VPT measurement, using a non-contacted infrared thermometer. If the finger skin temperature was by 3–4°C lower than the average, the subject was asked to remain in the measurement room until her hands got warmer.

The subjects wore earmuffs to attenuate the sound generated by the vibrotactile meters at a frequency higher than 125 Hz.

Smoking was not allowed for at least 1h prior to VPT measurements. Room temperature was maintained within the range between 21 and 24°C.

Statistical analysis

The statistical analysis of vibrotactile perception thresholds was performed using the Statistical Package for Statistica 6, StatSoft Poland.

One-way analysis of variance was used to assess the influence of data of ten successive sessions on the mean values of VPTs. The subject's VPT, obtained in a given session was determined as the mean threshold value for six fingers. The mean VPT values were calculated for all the subjects from one group, for each measurement frequency, separately for each session. For a given frequency, separately for groups G1 and G2, we determined whether one variable, i.e., examination sequence, influences the mean VPT value. We assumed that with $p < 0.01$ there was a significant difference between individual VPTs in particular sessions, which suggested the lack of repeatability of VPT measurements.

Standard deviations were compared using the homogeneity test of variance in order to compare repeatability of vibrotactile perception thresholds between two groups of subjects at any measurement frequency for MS1.

For MS1 and for successive frequencies, the mean values of VPTs were compared between the G1 and G2 groups using Students' t-test. The mean VPT values were calculated for all the subjects from one group, for any measurement frequency on the basis of ten sessions.

RESULTS

Repeatability of vibrotactile perception threshold values

The mean vibrotactile perception threshold values and standard deviations obtained with two measuring systems, MS1 and MS2, are shown in Table 3. VPTs determined by MS1 are higher than those obtained by MS2.

Tables 4 and 5 present statistical significance of the influence of 10 successive sessions on the mean VPT values obtained by MS1 and MS2 in groups G1 and G2 at particular vibration frequencies. Significant differences in the results of particular experiments proved the lack of repeatability. The succession of the sessions had no influence on the mean VPT values in group G2 composed of subjects with warm fingers, determined according to the ISO method and using MS1. In subjects with cold fingers, however, VPTs for the frequencies of 4 Hz and above 125 Hz were significantly dependent on the succession of experiments (Table 4). The mean values of VPTs obtained by MS2 depended to a significant degree on the experiment succession in both groups, G1 and G2 (Table 5).

Comparison of statistical significance of repeatability of VPT measurements between two groups (G1 and G2) for MS1 showed similar repeatability in both groups (Table 6).

Table 3. Vibrotactile perception thresholds obtained with two measuring systems. Mean values and SD based on 240 and 360 measurements for group G1 and group G2, respectively

Measuring system	Group	Mean vibrotactile perception threshold values and standard deviation (SD) in dB (re.$10^{-6}ms^{-2}$)							
		4 Hz	25 Hz	31.5 Hz	63 Hz	125 Hz	250 Hz	400 Hz	500 Hz
MS1	G1	87.1 (4.9)	101.5 (6.6)	104.6 (5.8)	109.1 (6.2)	114.7 (6.7)	126.7 (7.7)	137.0 (8.9)	142.2 (8.4)
	G2	88.0 (4.9)	99.9 (5.2)	103.5 (5.4)	108.7 (6.8)	110.6 (6.9)	115.5 (6.8)	124.5 (8.4)	130.7 (8.7)
MS2	G1	–	–	–	99.7 (4.5)	103.7 (3.9)	115.5 (7.4)	125.4 (8.4)	132.4 (10.6)
	G2	–	–	–	102.1 (7.2)	105.2 (5.5)	110.4 (5.1)	120.1 (6.5)	126.4 (7.6)

Table 4. One-way analysis of variance to assess significance of differences between mean VPTs in successive 10 examinations performed separately for two groups, G1 (240 measurements) and G2 (360 measurements). Measuring system 1 (MS1)

Frequency (Hz)	Group	Source of variation	DF	SS	MS	F	P
4	G1	ST	9	567.3	63.0	2.75	0.004
		R	230	5265.0	22.9		
	G2	ST	9	278.7	31.0	1.32	0.224
		R	350	6788.1	23.4		
25	G1	ST	9	151.9	16.9	0.38	0.942
		R	230	10135.5	44.1		
	G2	ST	9	351.7	9.1	1.44	0.169
		R	350	7853.5	27.1		
31.5	G1	ST	9	357.2	39.7	1.19	0.302
		R	230	7664.0	33.3		
	G2	ST	9	407.4	45.3	1.58	0.120
		R	350	8301.7	28.6		
63	G1	ST	9	126.7	14.1	0.36	0.954
		R	230	9049.8	39.4		
	G2	ST	9	701.1	77.9	1.71	0.087
		R	350	13220.3	45.6		
125	G1	ST	9	330.4	36.7	0.82	0.595
		R	230	10246.3	44.6		
	G2	ST	9	688.5	76.5	1.62	0.110
		R	350	13720.6	47.3		
250	G1	ST	9	2381.5	264.6	5.16	< 0.0001
		R	230	11785.4	51.2		
	G2	ST	9	444.8	49.4	1.06	0.396
		R	350	13580.2	46.8		
400	G1	ST	9	4519.9	502.2	8.11	< 0.0001
		R	230	14239.0	610.9		
	G2	ST	9	946.8	105.2	1.52	0.142
		R	350	20127.9	69.4		
500	G1	ST	9	2215.9	246.2	3.82	0.0002
		R	230	14810.1	64.4		
	G2	ST	9	1180.4	131.2	1.76	0.076
		R	350	21622.2	74.6		

ST – successive tests. SS – sum squares.
R – residual. MS – mean square.
DF – degrees of freedom. F – statistic F. Snedecor.

Table 5. One-way analysis of variance to assess significance of differences between mean VPTs in successive 10 examinations performed separately for two groups, G1 (240 measurements) and G2 (360 measurements). Measuring system 2 (MS2)

Frequency (Hz)	Group	Source of variation	DF	SS	MS	F	P
63	G1	ST	9	368.2	40.9	2.09	0.031
		R	230	4503.8	19.6		
	G2	ST	9	1051.6	116.8	2.38	0.013
		R	350	14251.8	49.1		
125	G1	ST	9	219.8	24.4	1.66	0.099
		R	230	3381.4	14.7		
	G2	ST	9	817.3	90.8	3.19	0.001
		R	350	8259.5	28.5		
250	G1	ST	9	1930.6	214.5	4.42	< 0.0001
		R	230	11162.9	48.5		
	G2	ST	9	886.9	98.5	4.06	0.0001
		R	350	7035.4	24.3		
400	G1	ST	9	2300.8	255.6	4.05	0.0001
		R	230	14498.4	63.0		
	G2	ST	9	1289.2	143.2	3.70	0.0002
		R	350	11220.9	38.7		
500	G1	ST	9	3635.0	403.9	4.01	0.0001
		R	230	23189.9	100.4		
	G2	ST	9	1225.0	136.1	2.45	0.010
		R	350	16080.1	55.4		

Abbreviations are explained in Table 4.

Table 6. Test of homogeneity variances to compare repeatability of vibrotactile perception thresholds between two groups G1 (240 measurements) and G2 (360 measurements). Measurement system 1 (MS1)

Frequency (Hz)	Standard deviation in dB (re.10^{-6}ms^{-2})		F	P
	Group G1	Group G2		
4	4.9	4.9	1.03	0.791
25	5.6	5.2	1.57	0.201
31.5	5.8	5.4	1.15	0.246
63	6.2	6.8	1.21	0.119
125	6.7	6.9	1.09	0.491
250	7.7	6.9	1.26	0.055
400	8.9	8.4	1.11	0.378
500	8.4	8.7	1.07	0.583

F – statistic F. Snedecor.

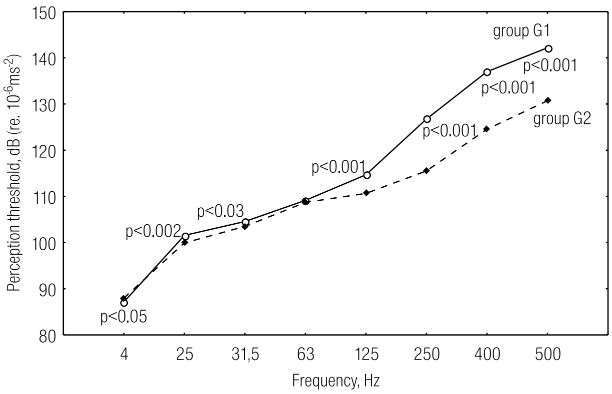

Fig. 1. Mean values of vibrotactile perception thresholds obtained with measuring system 1 (MS1). G1 – group with cold fingers, G2 – group with warm fingers.

Effect of finger skin temperature on the frequency dependence of vibrotactile thresholds

Comparison of the mean VPT values between two groups, obtained according to the ISO 13091-1 standard, revealed that group G1 (with cold fingers) had significantly higher vibrotactile perception thresholds (above 125 Hz) compared to those in group G2 (Fig. 1). The statistical analysis indicated that VPTs were significantly higher in the whole range of frequencies except for 63 Hz.

DISCUSSION

Repeatability of measurements

The measurement of VPTs is one of the basic diagnostic methods in peripheral nervous system dysfunction, especially in hand-arm vibration syndrome, carpal tunnel syndrome or diabetes. The estimation of VPTs is based on a psychophysical procedure that requires proper reaction of the subject to a vibrating stimulus. The measurement results obtained with the psychophysical method are characterized by high variability and depend on the measurement system applied to quantify vibration perception. Estimation of variability in results is very important for standardization of measurement method used in diagnosis of peripheral neuropathy. Reliability of the measurement method significantly depends on the repeatability of the results obtained in the same subjects. The repeatability of VPT results may be defined as consistence of successive measurements taken in the same conditions. Measurement repeatability may be quantitatively expressed using dispersion characteristics, i.e., standard deviation, coefficient of variation, and the range of values.

So far, only few papers have addressed the problem how to estimate the repeatability of VPT measurements. Rosecrance et al. [10], De Neeling et al. [11], Gerr and Letz [12] as well as Claus et al. [13] compared VPT results obtained in two sessions performed on two different days, applying Pearson product-moment correlation coefficient for test-retest reliabilities. Similar procedure was performed by Grunert et al. [14] who estimated the results of three successive VPT measurements in subjects examined during one day. Aaserund et al. [15] analyzed intra- and inter-individual variation in VPT results during four successive days, determining standard deviations and range of individual mean values (%) with reference to mean value of all measurements. Thomson et al. [16] determined VPT results variability, obtained in 6 successive days, applying coefficient of variation. Ess and Dupuis [17] measured VPTs on 10 successive days, showing only graphically, variability of mean values at different frequencies. In aforesaid studies, the authors applied different parameters and units of vibrating stimulus movement (e.g., ms^{-2}, dB (re.$10^{-6}ms^{-2}$), µm, lgµm, arbitrary units, volts), which makes the comparison of the measurement variability very difficult.

It is suggested in international standard ISO/DIS 13091-2: 2001 that test-retest variability in thresholds should be expressed in decibels (dB) as one standard deviation from the mean value of the VPTs determined by repeated measurements at a given frequency [18]. The variability in the results may be estimated at thresholds obtained on at least ten separate occasions on ten different days.

In this study, standard deviations of VPT values, measured according to the ISO 13091-1 method, ranged from 4.9 to 8.9 dB (Table 3). Using the same method, Zamysłowska-Szmytke et al. [19] obtained similar values, ranging from 4.5 dB at 4 Hz to 7.4 dB at 400 Hz. Similar results to those produced by MS2 at a frequency range of 250-500 Hz, applying a MCW 2K meter, were obtained by Zamysłowska-Szmytke et al. [20]. Maeda and Griffin [21], using the method close to ISO 13091-1, obtained in three repeated measurements of VPTs, standard deviations ranging from 3.6 dB at 31.5 Hz to 6.1 dB at 250 Hz. Similarly, Cock et al. [22] obtained standard deviations of 6.2 dB at 63 Hz and 8.2 dB at 250 Hz.

Only few papers containing the VPT values in healthy workers, obtained according to the method recommended by ISO 13091-1 [8], have been published to date. Some of them presented the VPT values at a frequency of 4 Hz. In our study, perception thresholds at a frequency of 4 Hz were by almost 10 dB higher than those obtained by Brammer et al. [23], or Löfvenberg and Johannson [24], and the same compared to the results obtained by Zamysłowska-Szmytke et al. [19]. The reason for this difference in the levels of thresholds remains unclear. At higher frequencies, the perception threshold values were closer to each other. This seems to justify the necessity for further research in order to obtain more reliable reference levels of vibration for healthy subjects.

In the present study, the variability in the results obtained in tenfold measurements of perception thresholds was estimated. We also checked the repeatability of the results produced during particular measurement sessions, and determined the significance of differences between mean VPTs, applying one-way analysis of variance. The repeatability of results was revealed only for measurements performed according to the ISO 13091-1 standard, whereas the succession of measurements influenced the results in subjects with cold hands (group G1) at frequencies exceeding 125 Hz. To determine whether the repeatability of perception thresholds in subjects with cold (G1) and warm hands (G2) was the same, the test of homogeneity variance was applied. It appeared that the variance for both studied groups did not differ if the measurement system was consistent with the ISO standard.

No repeatability of results obtained with MS2 may be among others due to manual administration of vibrating signals and lower precision of subjects in maintaining constant pressure on the vibrating probe of vibrotactile MCW 2K meter.

Finger skin temperature

The vibrotactile perception threshold values determined in the same experimental conditions and with the same measurement method may depend only on the physiological and psychophysical state of the examined subject. The same repeated examinations of the subjects enable us to reveal the influence of the constant organic characteristics, e.g., temperature of the finger skin, depending on the peripheral circulation, irrespective of the subject's psychophysical state. The influence of the finger skin temperature on the VPT values was already indicated long time ago [25,26].

This study indicates that even the finger skin temperature of about 27°C, considered acceptable in standard VPT examinations [8], may have a significant influence on the measured thresholds.

The mean VPTs are significantly higher in subjects with cold hands than in those with warm ones. Differences in VPTs are particularly distinct at higher frequencies, starting from 125 Hz, and range from 4.1 dB to 11.5 dB at a frequency of 500 Hz. Such a large difference in VPT levels cannot result from the age difference (only 3.7 years between group G1 and G2) (Table 1). If we assume for example, the regression coefficient of 0.13 at a frequency of 250 Hz [20], describing an annual increase in VPT, then we should introduce the correction of only 0.48 dB of the mean VPT value in the older group (G2) of subjects with warm hands.

A question arises whether the recommended, (e.g., in Poland) warming of too cold hands before the VPT measurement should be accepted as a proper procedure. It remains debatable whether it is possible to reach the finger skin temperature of 27–36°C in subjects with cold hands, required by the ISO 13091-1 standard [8]. Warming of hands may be ineffective if the hand temperature is below 25°C since in one way or the other, the temperature of subject's hands naturally decreases after some time. Should this happen while the vibrotactile thresholds are being determined, then the obtained thresholds values would change in the course of time. Another question to be considered is whether cold hands should be warmed at all. The determined vibrotactile threshold of warmed fingers does not actually constitute the real vibrotactile threshold. It seems proper to warm the hands until the required temperature is reached only in case of subjects without any vascular dysfunctions. That is why the hands of the subjects were not warmed in the present examinations.

It seems justified to develop the principles of determining the finger skin temperature before VPT examinations. Moreover, a larger group of subjects should be examined in order to find out the lowest finger skin temperature for which the VPT values may be considered as representative for the healthy population. The dependence of vibrotactile thresholds on the finger skin temperature must be considered when determining the reference values for vibrotactile thresholds [27]. Taking account of the results, presented in this paper, it may be assumed that the low limits of temperature (e.g., 23°C), accepted by other authors as correct, may significantly influence a scatter of measurement results [21,28].

CONCLUSIONS

Preliminary findings based on this study suggest that:

1. the results of vibrotactile threshold measurements obtained according to the ISO 13091-1 method are repeatable.
2. the repeatability of vibrotactile threshold results obtained with the ISO 13091-1 method, within the range of low frequencies up to 125 Hz, does not depend on the finger skin temperature.

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