EFFECT OF CHANGES IN FINGER SKIN TEMPERATURE ON VIBROTACTILE PERCEPTION THRESHOLD

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Abstract
Objectives: The purpose of the study was to determine the influence of finger skin temperature on the vibrotactile perception threshold at fingertips, determined according to the method described in ISO 13091-1 standard. Materials and Methods: The effect of the cooling and warming of hands on vibration perception was investigated in 21 healthy women. Vibration perception measurements were conducted using P8 pallesthesiometer (EMSON-MAT, Poland) designed according to ISO 13091-1 standard requirements. Vibrotactile perception threshold was measured in two series of experiments performed on the index finger of the right hand at frequencies of 4 Hz, 25 Hz and 125 Hz and skin temperature of 33°C, 28°C, 23°C, 18°C and 15°C. Results: The findings of the study showed that as the finger skin temperature decreased, the vibrotactile perception threshold increased, but only at the frequency of 125 Hz. The changes in finger skin temperature did not affect the vibration perception at 4 Hz and 25 Hz. No significant differences in VPT were found between the two experimental series. Conclusions: A short-time cooling and warming of hands had a significant impact on increasing or decreasing vibrotactile perception threshold, only at the highest frequency mediated by Pacinian mechanoreceptors.

Key words: Vibrotactile perception, Women, Cooling and warming of hands

INTRODUCTION

The vibrotactile perception at fingerprints is mediated by three types of mechanoreceptors, namely the Merkel’s cells, Meissner’s corpuscles and Pacinian corpuscles (SAI, FAI and FAII). Responses from these receptors can be measured psychophysically using vibrotactile stimulation at different frequencies specified in the ISO 13091-1 standard [1]. The evaluation of vibrotactile perception threshold (VPT) at fingertips is one of the basic methods used for an early detection of peripheral neuropathies in the upper extremities in workers employed in hazardous work environment. According to Polish regulations, pallesthesiometry is an obligatory auxiliary diagnostic examination, routinely carried out for medical certification purposes in workers exposed to mechanical vibration [2].

In healthy individuals, VPT depends on several factors including, among others, the characteristics of vibration stimulus, environmental conditions and personal characteristics (age, gender, BMI). The surrounding temperature is an important environmental parameter which may contribute to the changes in finger skin temperature. As laid down in the ISO 13091-1 standard, VPT measurements should be performed in an environment in which the temperature varies from 20°C to 30°C, and the optimal finger skin temperature of the examined person should be between 27°C and 35°C. The VPTs of the SAI, FAI and FAII receptors are not markedly dependent on the skin surface temperature if the stimulation frequency is lower than 200 Hz [1,3]. The national guidelines on the methodology of pallesthesiometric examinations recommend warming up hands before
the measurement to obtain the finger skin temperature of 28°C–30°C [2].
The purpose of the present experiment was to determine the effect of finger temperature on the vibrotactile perception threshold as determined with the method described in ISO 13091-1 standard.

MATERIAL AND METHODS

Vibrotactile perception threshold was measured in a group of 21 women, aged 19–49 years (mean 24.4±7.8 years) recruited from undergraduate students and professional staff of the Medical University of Silesia. They were qualified for pallesthesiometric examinations based on internal and neurological histories and the results of selected examinations of the upper extremities. The following data were recorded in the questionnaire: age, body height, body weight, education, profession and employment history, use of alcohol/tobacco etc., results of arterial blood pressure measurements (both hands), description of the status of the upper extremities, with special regard to movement limitations in wrist joints, occurrence of contractures, scars, thickening of epidermis, as well as data on current complaints and medications used. The persons receiving treatment for diseases evoking peripheral neuropathies, such as hyper- or hypofunction of the thyroid, diabetes, neck pain, and alcohol disease were excluded from the study. The same referred to the persons on medications for peripheral nervous system diseases or complaining of pain, reduced muscle power, numbness, or tingling sensation in the upper extremities.

The subjects’ finger skin temperature ranged from 21.1°C to 33.8°C (mean 28.0±3.2°C) and BMI from 17.0 to 27.7 (mean 21.4±2.9). VPT measurements were performed using P8 pallesthesiometer (EMSON-MAT, Poland) designed according to ISO 13091-1 standard. The stimulating probe, without a surround, was a flat-ended perspex cylinder, 5 mm in diameter. The probe was applied on the distal phalanx between the centre of the whorl and the fingernail and it was pressed by the subject’s finger with a constant force of 0.1 N. The von Békésy algorithm was used to determine VPTs for which continuous stimulation at a constant rate of 2 dB/s either increased or decreased the vibration magnitude.

This procedure, controlled by an automatic program, was repeated three times to determine the threshold level for a selected vibration frequency. The VPT value was calculated from the arithmetic mean of the mean peak (ascending thresholds) and the mean trough (descending thresholds) for each frequency. The VPT 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 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. Background vibration was measured with sufficient bandwidth and was lower than the VPT at the frequency for which the threshold was calculated. Moreover, the vibrometer unit was equipped with an acceleration monitoring system. This made it possible to carry out the 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 at an indicator of the vibrotactile meter.

Prior to the experiment, a pre-test had been performed to familiarize the subjects with the vibration stimuli and measurement procedure. Then the skin temperature of the index fingertip was measured using non-contacted infrared thermometer (FR 260 MV, Ahlborn, Germany). Smoking was not allowed for at least 1 h prior to VPT measurements. The study was conducted in two series. In each series, VPT measurements were made on the subject’s right index finger (II) at the frequencies of 4, 25 and 125 Hz. In the first series, the perception thresholds were set for the following decreasing finger skin temperatures: 33°C, 28°C, 23°C, 18°C and 15°C. When the initial skin temperature of the index finger was below 33°C, both the hands were warmed up using an infrared lamp. To obtain lower levels of skin temperature, we asked the subject to immerse both her hands in cold water. In the second series, the perception thresholds were set for the following increasing levels of finger skin temperature: 15°C, 18°C, 23°C, 28°C and 33°C. Like in the first series, an infrared lamp was used to warm the hands up and obtain the
predefined temperature levels. The whole experiment was performed within less than 40 minutes. The study was conducted in the morning hours in the seasons of spring and autumn. Room temperature was maintained at 21–25°C and noise level was lower than 50 dB-A. Statistical analysis of vibrotactile perception thresholds was performed using the Statistical Package for Statistica 6, StatSoft Poland. Analysis of variance (ANOVA) and Tukey’s test were used to determine the effect of the cooling and warming of hands and the direction in temperature changes (i.e. whether rising or falling) on vibration thresholds. The statistical analyses were carried out separately for the three frequencies: 4 Hz, 25 Hz and 125 Hz.

RESULTS

The mean VPT values determined during the cooling and warming of the subjects’ hands are shown in Figure 1. Decreasing the finger skin temperature to 15°C and then increasing it again to 33°C had no influence on the level of VPT set for the frequencies of 4 Hz and 25 Hz (Tables 1, 2). No significant differences in VPT could be found between the two experimental series.

Table 1. Assessment of the effect of changes in finger skin temperature (33°C, 28°C, 23°C, 18°C and 15°C) due to the cooling and warming of hands (two series) on the vibrotactile perception threshold determined for three frequencies: 4 Hz, 25 Hz and 125 Hz

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Skin temperature (°C)</th>
<th>33</th>
<th>28</th>
<th>23</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>A series</td>
<td>1</td>
<td>222.583</td>
<td>40</td>
<td>123.220</td>
</tr>
<tr>
<td></td>
<td>B temperature</td>
<td>4</td>
<td>3537.165</td>
<td>160</td>
<td>22.649</td>
</tr>
<tr>
<td></td>
<td>A×B</td>
<td>4</td>
<td>30.489</td>
<td>160</td>
<td>22.649</td>
</tr>
<tr>
<td></td>
<td>A series</td>
<td>1</td>
<td>47.049</td>
<td>40</td>
<td>99.106</td>
</tr>
<tr>
<td>25</td>
<td>B temperature</td>
<td>4</td>
<td>17.947</td>
<td>160</td>
<td>8.287</td>
</tr>
<tr>
<td></td>
<td>A×B</td>
<td>4</td>
<td>8.322</td>
<td>160</td>
<td>8.287</td>
</tr>
<tr>
<td></td>
<td>A series</td>
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<td>53.707</td>
<td>40</td>
<td>81.933</td>
</tr>
<tr>
<td>4</td>
<td>B temperature</td>
<td>4</td>
<td>15.295</td>
<td>160</td>
<td>6.648</td>
</tr>
<tr>
<td></td>
<td>A×B</td>
<td>4</td>
<td>7.502</td>
<td>160</td>
<td>6.648</td>
</tr>
</tbody>
</table>

Statistical significance of the results was tested with a two-way analysis of variance (ANOVA).
The dependence of VPT on the skin temperature was detected only for the highest frequency of mechanical vibrations, i.e. at 125 Hz. It was found that when the finger skin temperature decreased, starting from the temperature of 28°C, the vibrotactile perception threshold increased. Detailed statistical analysis proved a significant difference between the mean VPT values determined during the warming and cooling of hands to the following finger skin temperatures: 23°C, 18°C and 15°C.

DISCUSSION

Vibrotactile perception is influenced by finger skin temperature. The problem of the mechanoreceptor sensitivity depending on temperature changes was reported for the first time in early 1960s. The first study was conducted on the Pacinian corpuscles isolated in cats [4,5]. In 1961, Inman and Peruzzi described the phenomenon of nerve impulse disappearance at the Pacinian corpuscles at temperatures between 15°C and 16.7°C and the generation of numerous impulses on mechanical stimulation at 25°C [6].

A number of human volunteer studies were conducted to estimate the range of finger skin temperatures that have influence on the vibrotactile perception threshold. Koradecka reported on VPT measurements in 30 men who were cooling down and warming up hands at temperatures ranging from 16°C to 34°C. The findings showed that VPT values were increasing with the decreasing values of finger skin temperature. The most significant influence that finger skin temperature had on the VPT was noted for the frequencies of 400 Hz, 500 Hz and 640 Hz. The author concluded that in pallesthesiometric examinations, the skin temperature of the fingertips should be maintained between 27°C and 32°C [7]. Similar results were obtained by Harada et al. who examined five men to estimate VPT at the frequency ranging from 16 Hz to 500 Hz and finger skin temperatures of 15°C, 20°C, 25°C, 30°C and 35°C. They found that VPT increased with the decreasing skin temperature. At higher frequencies, of 125 Hz, 250 Hz and 500 Hz, the changes were more significant than at lower frequencies. A decrease in skin temperature from 35°C to 15°C induced VPT increase by 10 dB at 125 Hz, and 20 dB at 500 Hz, respectively [8,9]. In the study by Ge Scheider, a VPT increase by 7 dB was recorded for the skin temperature rising from 20°C to 30°C at the frequency of 250 Hz [10]. In their study on male subjects, Bolanowski and Verillo, noted changes in VPT values below 3 dB for 150 Hz at skin temperatures ranging from 20°C to 43°C [11]. The literature lacks data on the effect of skin temperature on VPT at low frequencies, below 16 Hz.

In the present study, no statistically significant effect was found of the changes in finger skin temperature from 15°C to 33°C on the response of Merkel's and Meissner's mechanoreceptors to vibration stimuli at 4 Hz and 25 Hz. Such
an effect was shown only for the Pacinian mechanoreceptors, i.e. for the frequency of 125 Hz (Fig. 1). After a short-term cooling of hands to below 28°C, VPT was increasing with the decreasing skin temperature. At the lowest temperature of 15°C, the mean VPT was higher by 20 dB than the level determined for the skin temperatures of 28°C and 33°C. Hayward and Griffin have found that VPT determined for the right-hand index finger of one subject started to rise only at the finger skin temperature below 20°C and the frequency of 125 Hz [12]. The findings of the present study revealed that a short-time cooling and warming of hands had a significant impact on increasing or decreasing the vibrotactile perception thresholds only at the highest frequency mediated by the Pacinian mechanoreceptors.

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REFERENCES