MEASUREMENTS OF DETECTION THRESHOLDS PRESENTING NORMAL AND TANGENTIAL VIBRATIONS ON HUMAN HAIRY SKIN

Tetsu Miyaoka and Toshio Nakamura
Shizuoka Institute of Science and Technology, Japan
miyaoka@cs.sist.ac.jp

Abstract

The purpose of present study was to measure vibrotactile thresholds presenting normal and tangential vibrations to hairy skin and to investigate the mechanoreceptive mechanisms that determine the threshold curve shapes. The normal and tangential thresholds were measured for five subjects at the volar forearm. The normal threshold curve showed a U-shape with the lowest threshold at 100 Hz. The tangential threshold curve decreased linearly from 4 to 50 Hz, increased to 75 Hz, and decreased again above 75 Hz. Based on the results of present and previous studies, it was supposed that the shape of the normal threshold curve was determined by the RA (the hair-follicle receptors) and that the shape of the tangential threshold curve was determined by the SA II and FA II.

Miyaoka (2004, 2005) measured vibrotactile thresholds presenting normal and tangential vibrations to glabrous skin and found that the normal and tangential threshold curve shapes were different from each other. It was supposed that the different types of mechanoreceptors contributed to produce the different curve shapes.

The present study was planned to measure normal and tangential threshold curves on hairy skin. The mechanoreceptor types of hairy skin are different from those of glabrous skin. Therefore the normal and tangential threshold curve shapes measured on hairy skin were supposed not only to be different from each other but also different from the threshold curves measured on glabrous skin.

Method

Subjects: Five male subjects in their twenties participated in the experiment.

Stimuli and Apparatus: Normal and tangential sinusoidal vibrations to the skin surface were adopted as stimuli. Frequencies of the stimuli were 4, 8, 16, 32, 50, 75, 100, 200 and 250 Hz for the normal and tangential vibrations, respectively. The presenting time of each stimulus was 1000 ms and the rise and fall times were 44 ms. The normal and tangential stimuli were presented to hairy skin with two contactors 2.5 mm in diameter. Two contactors were attached to two vibrators that were assembled to produce normal and tangential vibrations (EMIC, 512A for the normal vibrations and AKASHI, MEE-025 for the tangential vibrations). Both of the contactors were set at the centers of 4.5 mm holes in rigid surrounds. The distances between the edges of the contactors and the rigid surrounds were 1 mm, and the contactors were adjusted to the same heights as the surfaces of the rigid surrounds. The temperatures of the forearm and rigid surrounds were maintained at 35 ºC using a temperature control device.

Procedure: The subject was seated and placed his left forearm on the contactor and rigid surround for normal and tangential threshold measurements. Normal and tangential vibrations were presented at the volar forearm 8 cm from the medial epicondyle. The subject responded by pressing a switch on a response box with the two-alternative-forced-choice technique. Stimulus amplitudes were changed by the procedure of the parameter estimation by sequential testing (PEST; Taylor et al., 1967). Each subject executed four measurements for each stimulus frequency and for each of the normal and tangential vibrations. Thus, the total number of experimental trials for each subject was 72.

Results and Discussion

Individual threshold curves were similar for both normal and tangential conditions. Therefore average thresholds were calculated for each condition. The average threshold curves are shown in Fig. 1. The open diamonds and open circles are the average normal and average tangential thresholds, respectively. The vertical bars show standard deviations.

The normal threshold curve showed a U-shaped pattern with the lowest threshold at 100 Hz. The tangential thresholds decreased from 4 to 50 Hz, increased to 75 Hz, and gently decreased again from 75 to 250 Hz. Statistically significant differences were observed between the normal and tangential threshold values at 32, 50, 100, 200, and 250 Hz (32 Hz, $t = 4.45$, $p < 0.02$; 50 Hz, $t = 5.66$, $p < 0.01$; 100 Hz, $t = -6.35$, $p < 0.01$; 200 Hz, $t = 2.82$, $p < 0.05$; 250 Hz, $t = 3.53$, $p < 0.05$). The different threshold patterns and the different threshold values show that the mechanoreceptors that were related to determine the detection thresholds are different between normal and tangential vibration conditions.

Fig. 2 shows the normal threshold curves measured on hairy skin and on glabrous skin (Miyaoka, 2005). The open diamonds and the open squares are the thresholds measured on hairy skin and on glabrous skin, respectively. These two curves are different from each other. The lowest thresholds are 100 Hz on hairy skin and 250 Hz on glabrous skin. In glabrous skin the mechanoreceptive units that determine the threshold curve shape are the FA I below 50 Hz and the

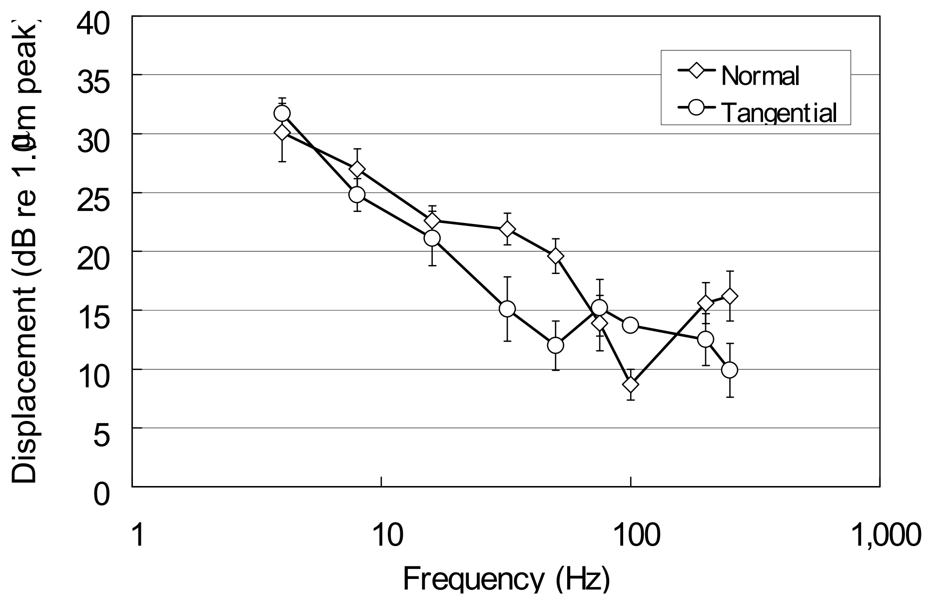

Fig. 1. Average normal and average tangential thresholds curves calculated from the experiment data. The open diamonds show the average thresholds for normal vibrations, and the open squares show the average thresholds for the tangential vibrations. Vertical bars attached to the diamonds and circles indicate standard deviations.

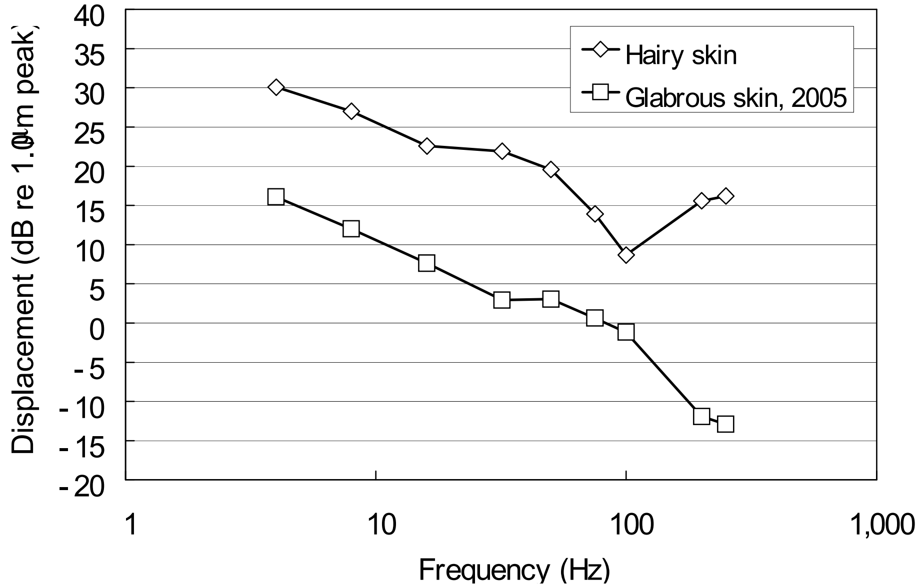

Fig. 2. Normal threshold curves measured on hairy skin (open diamonds) and on glabrous skin (open squares) (Miyaoka, 2005).

FA II above 75 Hz. However the FA I (Meissner's corpuscles) is not found in hairy skin (Bolanowski et al., 1988, Gescheider et al., 2002, Miyaoka, 2005). Bolanowski et al. (1994) asserted that the RA (the hair-follicle receptors) was the mechanoreceptor that determined the shape of the threshold curve between 4 and 150 Hz when a small contactor was used. In the present study the size of the contactor was rather small and the frequency of the lowest threshold was much lower than the frequency of the lowest threshold of the FA II. These facts support the

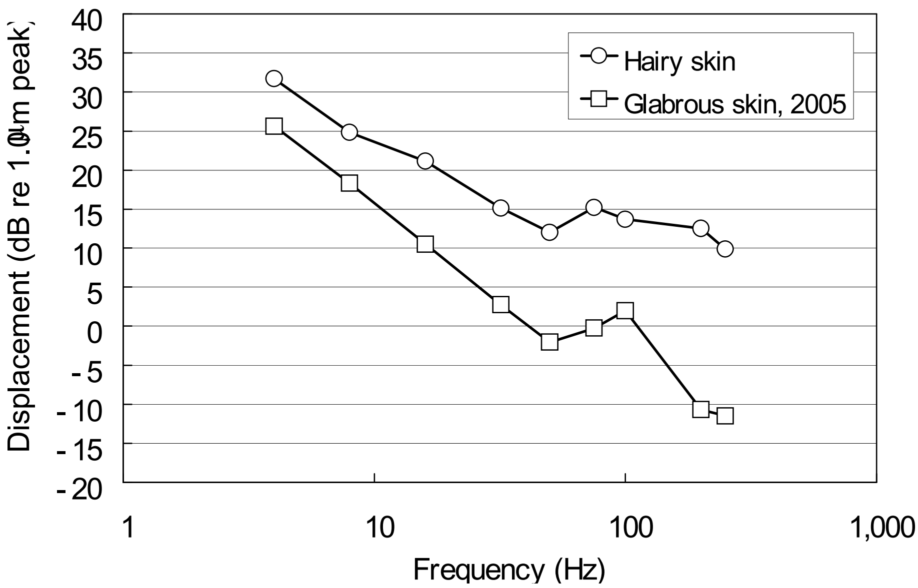

Fig. 3. Tangential threshold curves measured on hairy skin (open circles) and on glabrous skin (open squares) (Miyaoka, 2005).

hypothesis that the hair-follicle receptors determine the pattern of the threshold curve of hairy skin.

Fig. 3 shows the tangential threshold curves measured on hairy skin and on glabrous skin (Miyaoka, 2005). The open circles and open squares are the thresholds measured on hairy skin and on glabrous skin, respectively. Although absolute values of the thresholds are different between the two curves, the curve patterns are similar. Miyaoka (2005) asserted that below 100 Hz the SA II and over 100 Hz the FA II determined the tangential threshold curve pattern in glabrous skin. Previous studies have suggested that in hairy skin mechanical activation of the SA I (the tactile disk) produced no sensation (Bolanowski, 1994). These facts may support that the tangential threshold curve shape of hairy skin is determined by the SA II below 75 Hz and by the FA II above 75 Hz.

Ambiguous aspects remain between the threshold curves of hairy skin and the mechanoreceptive mechanisms that determine the patterns of threshold curves. We need further studies to have clear results.

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