THERMOTACTILE THRESHOLDS BEFORE, DURING AND AFTER EXPOSURE TO HAND-TRANSMITTED VIBRATION

Sue Ann Seah and Michael J. Griffin
Human Factors Research Unit, Institute of Sound and Vibration Research, University of Southampton, SO17 1BJ, UK

1. INTRODUCTION

Thermal perception thresholds are used to assess peripheral neuropathy among workers exposed to hand-transmitted vibration. Studies have found associations between exposure to hand-transmitted vibration and impaired thermotactile thresholds (Nilsson *et al.*, 2008). A recent longitudinal study found thermal sensitivity correlated with daily exposure to hand-transmitted vibration, *A*(8), and finger numbness (Bovenzi *et al.*, 2010).

Thermotactile thresholds in the fingers have been reported to exhibit threshold shifts after acute exposures to hand-transmitted vibration. Hirosawa *et al.* (1992) reported effects on warm thresholds but not cool thresholds after exposing the hand to accelerations between 19.6 and 156.8 ms^{-2} at frequencies between 32 and 500 Hz. Burström *et al.* (2008) found minimal effects of vibration on cool thresholds and no effect on warm thresholds with accelerations between 4.8 and 111 ms^{-2} r.m.s. at frequencies between 31.5 and 125 Hz. Recovery of normal thresholds was reported within minutes in both studies.

It has not previously been reported whether thermotactile thresholds change during exposure to vibration. The study reported here was designed to investigate warm and cool thresholds before, during, and after exposure to vibration.

2. METHODS

2.1. Subjects

Twelve healthy male volunteers with a mean age of 26.3 years (SD 2.8) participated in the study. Subjects were screened to exclude those with prior regular exposure to hand-transmitted vibration, diabetes, vascular or neurological disorders and injuries to the right hand. The study was approved by the Human Experimentation Safety and Ethics Committee of the Institute of Sound and Vibration Research at the University of Southampton.

2.2. Apparatus

A circular aluminium plate (55-mm diameter) varied in temperature (between 10 and 55°C) and was controlled by an *HVLab* Thermal Aesthesiometer control system (version 3.0) connected to a computer running *HVLab* diagnostic software (version 8.4) (see Figure 1). A thermocouple at the centre of the top surface of the circular plate provided temperature feedback to the software. Thermocouples measured skin temperature on the dorsal side of the distal phalanx of the middle finger (digit 3) and the centre of the palm.

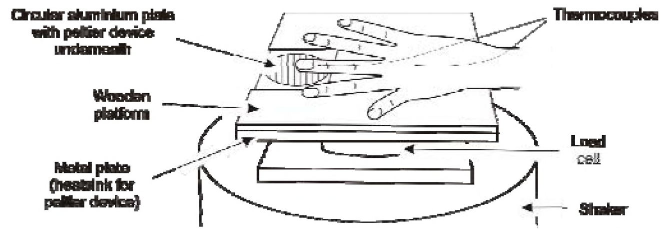

Figure 1. Experimental arrangement.

The temperature-controlled plate was secured to a metal plate mounted on a Tedea-Huntleigh Model 1022 single point load cell and connected to a Derritron VP4 vibrator that supplied sinusoidal vertical vibration to the right hand.

2.3. Experimental Procedure

The experiment was performed in a room with ambient temperature of 23°C (±1°C). Subjects were acclimatised for 10 minutes before the skin temperatures were measured. If either the finger or palm skin temperature was less than 27°C, the hands were warmed. Subjects practiced thresholds using the ring finger of the right hand. Throughout the experiment, subjects applied a force of 5 N, which they monitored on an analogue meter.

Thermotactile thresholds were obtained on the distal phalanx of the middle finger of the right hand using the method of limits. Depending on the threshold (i.e. either a warm threshold or a cool threshold), the temperature of the applicator increased or decreased at 1°C per second from a reference temperature of 32.5°C. Subjects pressed a button when they perceived a change in temperature. Warm and cool thresholds were measured alternately at 30-s intervals.

Subjects attended three sessions at the same time on three days, with the order of sessions randomised. Each session comprised: (i) 5-minutes pre-exposure: 5-N force with no vibration; (i) 30-minutes exposure: 5-N force with vertical vibration at either 16 Hz or 125 Hz or no vibration (control); and (iii) 10-minutes recovery: 5-N force with no vibration. At both frequencies, the vibration magnitude was 5.0 ms^{-2} r.m.s. when weighted according to ISO 5349-1:2001 (5.0 ms^{-2} r.m.s. unweighted at 16 Hz; 39.4 ms^{-2} r.m.s. unweighted at 125 Hz), giving an 8-hour energy equivalent *A*(8) acceleration of 1.25 ms^{-2} r.m.s. This paper compares findings in the control condition and with 125-Hz vibration.

3. RESULTS

Median thresholds were determined over five periods: before exposure (minutes 1 to 5), during exposure (minutes

6 to 15, minutes 16 to 25, minutes 26 to 35), and after exposure (minutes 36 to 45).

Control Condition

In the control condition (no vibration), cool thresholds were unchanged over the five periods (p = 0.399, Friedman; Figure 2), starting with a median of 29.3°C and ending with 29.4°C. However, warm thresholds increased over time, from a median of 39.5°C to 41.6°C (p = 0.006). Warm thresholds differed between the first and last periods (i.e. before and after the exposure period; p=0.007, Wilcoxon) but not between the first and any other period ($p \geq 0.062$).

During the 'pre-exposure period', there was no significant difference in thresholds between the control condition and the 125-Hz session (warm thresholds: p=0.388; cool thresholds: p=0.721; Wilcoxon). Both thresholds were highly correlated between the two sessions (warm thresholds: p=0.003; cool thresholds: p<0.001; Spearman).

Cool Thresholds

With 125-Hz vibration, there was no change in cool thresholds over the five periods (p=0.181, Friedman) or over the three periods with vibration (p=0.076).

Within each of the three periods of the 'exposure period', there were no significant differences between cool thresholds obtained with 125-Hz vibration and thresholds during the control condition (period 1: p=0.109; period 2: p=0.223; period 3: p=0.285; Wilcoxon). During the recovery period, the median cool threshold was 28.4°C following vibration, 1.0°C cooler than in the corresponding period of control condition (p=0.050).

Warm thresholds

With 125-Hz vibration, warm thresholds increased over the five periods (p=0.001; Friedman) and also over the three periods during application of vibration (p=0.006).

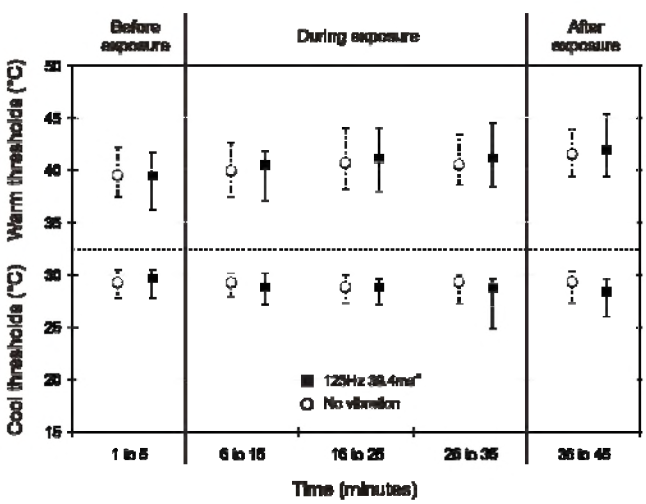

Figure 2. Median and inter-quartile range of warm and cool thresholds.

Compared to the pre-exposure period, warm thresholds during period 1 of the 125-Hz exposure did not differ (p=0.195; Wilcoxon), but thresholds were higher in periods 2 and 3 ($p \leq 0.041$). Within each of the three periods of the 'exposure period', there were no significant differences between warm thresholds during 125-Hz vibration and during the corresponding period of the control condition (period 1: p=0.824; period 2: p=0.722; period 3: p=0.754).

During the recovery period after 125-Hz vibration, warm thresholds were higher than during the pre-exposure period (p=0.017; Wilcoxon). Warm thresholds during recovery after 125-Hz vibration did not differ from those in the corresponding period of the control condition (p=0.754).

4. DISCUSSION AND CONCLUSIONS

Previous studies have found inconsistent changes in thermotactile thresholds after exposure to hand-transmitted vibration of similar magnitudes, but have not investigated thresholds during vibration.

In the present study, cold thresholds were unaffected by 45-minutes of force and unaffected by 125-Hz vibration. Warm thresholds increased during the 45-minute control condition, but there is no statistical evidence of an additional effect of the 125-Hz vibration on the warm thresholds.

It may be concluded that for the vibration magnitudes investigated, any acute effects of hand-transmitted vibration on thermotactile thresholds are small. The effects are less than intersubject variability in thermotactile thresholds and may be less than the changes associated with maintaining constant force. It is concluded that the perception of temperature is not greatly reduced during exposure to this type of hand-transmitted vibration.

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