LONGITUDINAL STUDY OF SUOMUSSALMI FORESTRY WORKERS I - VIBROTACTILE THRESHOLDS

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1. INTRODUCTION

A thirteen-year prospective study has been conducted of an open cohort of forestry workers, who operate low-vibration power tools in the Suomussalmi region of Finland. The purpose of this paper is to report the changes in vibrotactile perception thresholds (VPTs) observed at the fingertips of a subgroup of workers who reported for a required annual medical examination on three occasions (in 1990, 1995, and 2003), when a sensitive tactometer was available to record their thresholds. The same apparatus was used for the first and third evaluation, and a production prototype with equivalent performance was used for the second. The apparatus has been described elsewhere (Brammer and Piercy, 1991; Brammer et al., 2007), and fulfills the requirements of ISO 13091-1:2001 (method A).

During the study, the work practices changed. In 1999, mechanized tree harvesting was introduced into the area, and brush saws were substituted for chain saws for much of the manual work. The change resulted in a reduction in vibration exposure. In this paper, the changes to the VPTs recorded before, and after, the reduction in exposure are examined. The vibration exposure in 2003 is described in a companion paper at this conference. A preliminary report of some aspects of this work was presented at the second North American Conference on Human Vibration.

2. APPARATUS AND METHOD

2.1. Apparatus

Vibrotactile thresholds were recorded at the fingertips with the subject seated, and with his forearm supported horizontally in a comfortable position. The hand and wrist were rotated so that the volar skin could be stimulated by a vertically-mounted probe. As a psycho-physical measurement procedure is employed, an effort was made to ensure the subject was sitting with back and arm fully supported before positioning the stimulator on the skin surface, to reduce discomfort. The stimulator consisted essentially of: 1) a vibration exciter suspended from a beam balance with an adjustable fulcrum, to permit the stimulator to be lowered onto a fingertip; 2) a 3 mm diameter cylindrical plastic probe, to apply the stimulus to a fingertip with a controlled contact force (0.05 N), and; 3) an accelerometer and conditioning electronic circuits, to record skin motion.

2.2. Method

The psychophysical algorithm was generated by computer, as were the values of VPTs. Vibratory tone bursts separated by quiescent intervals were applied to the skin at amplitudes close to the threshold of perception. The change in stimulus intensity between bursts was 2 dB in the first study, and was automatically decreased from 3 dB to 2dB during the other studies depending on the subject's performance, to reduce the measurement time. With the accelerated procedure, VPTs could be obtained at one frequency in about 1 min. Stimulus frequencies were chosen to be little influenced by a subject's age, and were 4, 6.3, 20 and 32 Hz (Brammer et al., 2007).

The consistency of threshold tracking was monitored during the measurement process in 1995 and 2003, and employed to reduce errors in the VPTs. The procedure consisted of comparing either, or both, ascending and descending threshold reversals, and VPTs mediated by the same mechanoreceptor population (Brammer and Piercy, 1995).

The apparatus was calibrated daily before commencing measurements, using a built-in reference stimulus that produced a known acceleration at the probe tip. Long-term variations in calibration were less than 1 dB.

Skin temperature was recorded at the fingertips before the measurements commenced, and was maintained at ≥27 °C.

2.3. Subjects

The study group consisted of almost 20% of the workforce at baseline. Twenty-three forestry workers (23/124) were randomly assigned to the study when attending the annual compulsory medical examination in 1990. Eighteen of these workers (18/109) returned for re-examination in 1995, and ten (10/59) in 2003, who are the subject of the present analysis. The workers' participation in the study was voluntary, and they gave their informed consent. The study protocol was approved by the ethics committees of the participating organizations.

The forest workers felled and de-branched softwood trees, and were paid by their production (piecework) prior to 1999. After this date the workers were paid an hourly rate, and either cleared brush around immature trees, or cut trees.

Table 1. Mean VPTs for LH3 (10 Subjects)

Frequency	VPT (dB re 10^{-6} m.s^{-2})		
(Hz)	1990	1995	2003
4	80.7	87.7	84.4
6.3	85.1	90.9	87.7
20	97.1	102.4	98.7
32	103.9	107.3	107.0

None of the subjects had operated vibrating power tools on the day of the health examination, and so the vibrotactile thresholds are believed to be free of any temporary loss in sensation resulting from acute exposure of the hand to intense vibration.

Symptom reports were obtained during a physical examination conducted by a physician, who also performed a neurological examination to exclude polyneuropathies.

3. RESULTS

Twenty-eight percent of the study group reported numbness in the hands at study inception, at which time the prevalence reported by the complete cohort was also 28%. The mean age of the study group at inception was 39 years (range 25 - 52 years) while that of the cohort was somewhat greater (mean 43, range 24 - 60 years). Of the ten subjects who attended all examinations, two reported hand numbness in 1995, but only one reported hand numbness in 2003.

VPTs were obtained at the fingertips of digits 3 and 5 for both hands on each occasion. For the 10 subjects, the trend was for increasing VPTs (i.e., less sensitive) from 1990-1995, and constant or decreasing VPTs (i.e., more sensitive) from 1995 to 2003. The mean VPTs are shown for digit 3 of the left hand (LH3) in Table 1. The mean VPTs in the other digits replicated those for LH3 from 1990 to 1995, but there was less improvement from 1995 to 2003. It can be seen from Table 2 that the changes in mean VPTs for digit 3 of the left hand reached statistical significance ($p<0.05$) at some frequencies (t-test). The deterioration of acuity from 1990 to 1995 was very significant at frequencies of 4, 6.3, and 20 Hz, but less so at 32 Hz. The changes in acuity of this finger from 1995 to 2003 were not statistically significant, except at 4 Hz. The statistical tests conducted on the changes in VPTs recorded from the other fingers were less definitive, suggesting that a more complex metric of threshold change may be required (Brammer et al., 2007).

4. DISCUSSION

When stimulated in the manner described, thresholds at 4 and 6.3 Hz are believed to be mediated by the same mechanoreceptor population, the Merkel disks, while those at 20 and 32 Hz are believed to be mediated by the Meissner corpuscles (ISO 13091-1, 2001).

Table 2. Statistical Significance of Changes in VPTs for LH3

Frequency	p-value (t-test)	
(Hz)	1990-1995	1995-2003
4	6×10^{-4}	0.03
6.3	2×10^{-6}	0.28
20	0.001	0.31
32	0.02	0.86

An analysis of the change in VPT with time at frequencies mediated by the same receptor population has shown that the *same* change in threshold is to be expected at each stimulation frequency, provided the threshold changes associated with aging are removed (Brammer et al., 2007). For our study, the change in threshold due to aging is, on average, +0.03 dB/year at 4 Hz, and +0.07 dB/year at other frequencies. Thus, the changes in VPTs from year to year are slightly less than those in Table 1. Taken together, the statistical tests for the VPTs of LH3 at 4 and 6.3 Hz provide a conflicting picture for the acuity of the Merkel disks from 1995 to 2003. The tendency towards a lack of improvement in acuity from 1995 to 2003 in the other digits suggests the threshold improvements recorded in LH3 during this period may be fortuitous. However, it does appear that the deterioration in acuity observed in these workers from 1990 to 1995 has subsequently been arrested. The stability of VPTs from 1995 to 2003, coincident with the change in work, suggests that the present vibration exposure is producing no additional sensorineural health effect.

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