VIBROTACTILE PERCEPTION AS A TEST FOR NUMBNESS AND PAIN

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1. INTRODUCTION

Quantitative sensory testing (QST) has long been used in clinical medicine for investigating peripheral neuropathies. The tests were originally primitive – pin prick (for pain), hot/cold objects (for temperature sense), and a cotton wool swab (for fine touch) applied to the skin. While there have been many attempts to devise instruments to quantify symptoms of numbness or pain, none has achieved broad acceptance by the medical community.

In this paper, a vibrotactile test for assessing the presence, or absence, of sensory symptoms in the hands is described based on perception thresholds believed mediated selectively by different types of mechanoreceptors. It is constructed from the summed differences between the thresholds recorded at the fingertip of an individual and the mean values of the threshold for healthy persons at the same stimulation frequencies. The metric is found to be related to reports by subjects of numbness and pain using two statistical tests for evaluating the significance of associations in 2x2 contingency tables (Altman, 1991). The performance of the test is evaluated by adjusting the magnitude of the metric that is to serve as the boundary for the onset of symptoms reported by individual subjects.

A detailed report of this work has been submitted for publication elsewhere (Brammer et al., 2009).

2. APPARATUS AND METHOD

2.1 Apparatus

Vibrotactile thresholds have been determined at the fingertips with the forearm supported horizontally below the shoulder (palm up). The apparatus has been described elsewhere (Brammer et al., 2007), and conforms to method A of ISO 13091-1 (2001). It consists essentially of: 1) a vibration exciter suspended from a beam balance with adjustable fulcrum, to permit the stimulator to be lowered onto a fingertip; 2) an arm rest for the back of the hand and forearm; 3) a 3 mm diameter cylindrical plastic probe, to apply the stimulus to a fingertip with a contact force of 0.05 N; 4) an accelerometer and conditioning electronic circuits, to record the motion of the skin, and; 5) a computer, to apply the psychophysical algorithm and calculate perception thresholds.

Thresholds were obtained at the fingertips of digits 3 and 5 for both hands at frequencies of 4, 6.3, 20 and 32 Hz. Thresholds at 4 and 6.3 Hz are believed to be mediated by the slowly adapting, type I receptors (Merkel disks), and at 20 and 32 Hz by the fast adapting, type I receptors (Meissner corpuscles) (ISO 13091-1, 2001).

2.2 Method

When all thresholds are expressed in dB (re 10^{-6} m/s^2), the summed threshold shift can be expressed as (Brammer et al., 2007):

$$TS_{Sum(SD)} = TS_{SAI(SD)} + TS_{FAI(SD)}$$

In this expression:

$$TS_{SAI(SD)} = [TS_4 + TS_{6.3}]/2SD_{SAI}$$

and $TS_{FAI(SD)}$ has been similarly constructed. The shift in threshold at a given stimulus frequency, that is, TS_4, $TS_{6.3}$, TS_{20}, and TS_{32}, is given by the difference between the observed threshold and the mean threshold recorded from the hands of healthy persons at that frequency. As the thresholds of healthy persons appear to approximate a Gaussian distributions with similar variance at each stimulation frequency mediated by the same receptor type, the ranges are expressed by the standard deviations, TS_{SAI} and TS_{FAI}. The last mentioned parameters are used to normalize the threshold shifts. In order to compare values of $TS_{Sum(SD)}$ with the reported symptoms, it is necessary to construct a single metric for each subject, which is taken to be the largest of the threshold shifts recorded from either digit, in either hand.

Tests for the statistical significance of an association between symptoms reported by individuals and values of $TS_{Sum(SD)}$ recorded from their hands have been conducted (Chi-squared test, and Fisher's exact test). For this purpose, 2x2 contingency tables are formed to segregate the reported presence or absence of the symptom of interest, and a fence value, t, is selected for $TS_{Sum(SD)}$ to correspond to the boundary between the presence and absence of the symptom (Altman, 1991). The null hypothesis is that there was no association between the test statistic and the target

symptom, and the alternative hypothesis is that there was a positive association (one-sided test). A probability value of p=0.05 was considered significant.

2.3 Subjects

A group of manual workers was selected from forest workers in the Suomussalmi region of Finland (18/109 persons). Their participation was voluntary, and subjects gave their informed consent according to the provisions of the ethics committees of the participating organizations. The work involved operation of lightweight chain saws, except for three subjects who were foremen.

Thirty-nine percent of the subjects reported numbness in the hands, 17% reported nocturnal numbness in the arms, and 33% reported pain in the hands, forearm, or throughout the upper extremity. The symptoms were obtained during a physical examination conducted by a physician, who also performed a neurological examination to screen for polyneuropathies.

3. RESULTS

The association derived from contingency tables between the metric constructed from $TS_{Sum(SD)}$ for each subject and their report of numbness in the hands is given in Table 1. The statistical significance of the association (p-value) is shown for different fence values, t. Each test identifies fence values that produce a statistically significant association, which are underlined. While the tests differ somewhat in the range of fence values calculated to be associated with numbness, values of $3.4 < t < 4.0$ are most significant, with probability values reaching $p < 0.01$ in mid range (i.e., $t = 3.5$).

Results similar to those in Table 1 were obtained for reports of numbness at night and, perhaps surprisingly, for arm pain (but not for neck pain). The fence values in both cases, however, were somewhat greater, namely in the range from 3.5 to 4.5.

4. DISCUSSION

Current clinical practice commonly employs electrically-stimulated nerve conduction for diagnosis of peripheral sensory neuropathies, which: 1) does not include the functionality of the nerve endings (the transducers), and; 2) records the response of the fastest nerves fibers, leaving unanswered questions concerning the biochemical function of most fibers.

The effectiveness of mechanoreceptor-specific vibrotactile perception as a QST for sensory symptoms has been shown by the present work, where the sensitivity ranged from 100% to 80%, and the specificity from 63% to 78%, for fence values possessing a statistically significant association with numbness (Table 1), numbness at night, and pain

(Altman, 1991). The small number of subjects in our study restricts more precise calculation of parameters for assessing the performance of the test. The similarity in fence values for reports of numbness at night, and pain could imply that the two symptoms are related in this group of subjects. As the sensory test is responsive to the tactile end organs, and not those sensing pain, it is possible that the test is reflecting functional changes in nerve fibers innervating the end organs, rather than changes in the end organs themselves.

Table 1. Tests of association for numbness in the hands

$TS_{Sum(SD)}$	p-value	
Fence, t	Chi-squared test	Fisher's Test
1	0.945	1.000
2	0.945	1.000
2.5	0.244	0.200
3	0.110	0.077
3.4	0.044	0.026
3.5	0.015	0.007
4	0.067	0.040
4.5	0.201	0.132
5	0.200	0.119
5.5	0.897	0.569
7	0.388	0.200

Finally, it is interesting to note that the statistically significant fence values obtained when using the magnitude of $TS_{Sum(SD)}$ as a QST encompass the boundary between "normal" and "abormal" theresholds derived previously for these subjects. The latter boundary corresponded to thresholds for which the probability of occurrence in healthy persons was p=0.05.

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