

Sensory Thresholds among Construction Trade Painters: A Cross-sectional Study Using New Methods for Measuring Temperature and Vibration Sensitivity

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Instruments that measure quantitatively sensory threshold to vibration and temperature difference were used to test 93 construction trade painters and a reference group of 105 healthy construction and industrial workers who were not painters. A "forced-choice" testing procedure, and an algorithm for threshold estimation (the "Best PEST"), was used for the Temperature Sensitivity Tester and the Vibratron. The method of limits procedure was used for the Biothesiometer. When measured with the Vibratron, painters in the older age stratum were found to have significantly higher vibration thresholds than the reference group. Painters had significantly more temperature sensitivity thresholds classified as "high" than the reference group. Among painters, exposure intensity and cumulative exposure over the past year was positively associated with vibration thresholds estimated using the Vibratron. Lifetime cumulative exposure, cumulative exposure over the previous month, and exposure intensity were positively associated with vibration thresholds estimated using the Biothesiometer.

Peripheral neuropathy is a common neurologic syndrome caused by industrial chemicals and metals. Typically, a mixed sensorimotor axonopathy occurs in which the distal portion of the axons is first affected. The disease progresses in a "dying-back" fashion toward the nerve cell body. The onset and early stages of the disease are insidious. Initial symptoms such as numbness

and tingling occur frequently in the lower extremities. As axonal degeneration proceeds, symmetrical sensory and motor loss develops in a "stocking-glove" fashion.

The disease can continue to progress for several months after cessation of exposure, but thereafter improvement occurs, with all but the most severely affected regaining all or most of motor and sensory function. In severe cases, neuropathy persists for several years after exposure cessation. Irreversible CNS axonal degeneration may occur concomitantly with damage to peripheral nerves.¹

Outbreaks have occurred among workers exposed to carbon disulfide, methyl *n*-butyl ketone, arsenic, organophosphorous compounds, acrylamide, allyl chloride, and chlorinated phenols contaminated with dioxin.²⁻⁸ Suspected agents include methyl bromide, polychlorinated biphenyls, styrene, and ethylene oxide.^{9,10}

Several studies have reported decreased peripheral nerve function among workers in the paint industry with long-term exposure to mixed organic solvents.¹¹⁻¹⁴ Generally, these studies found that, although mean differences in nerve function between painters and controls were usually small and within normal ranges, a greater proportion of the painters than controls had abnormalities. Neurologic examinations of painters also found deficits in vibration sensitivity and other sensory abnormalities.

In these studies, nerve conduction velocity (NCV) tests, electromyography (EMG), and the neurologic examinations were the primary methods used. However, these methods may not be optimum for studies of large work forces exposed to known or suspected neurotoxic substances. Although noninvasive, the neurologic examination is not quantitative and may show high inter-observer variability. NCV and EMG tests provide a

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quantitative measure of function but cause discomfort and require highly trained personnel to perform.

Moreover, the NCV test may be insensitive to the effects of agents that cause axonal disease. Even if secondary demyelination occurs (eg, due to hexacarbon exposure), NCV is rarely reduced by more than 20% to 30% and the onset of NCV slowing may often follow clinical signs of peripheral neuropathy.¹⁶ The EMG test is generally sensitive to axonal degeneration of motor nerve fibers that typically occurs at an advanced stage of the disease.

The Vibratron and the NTE-2 Temperature Sensitivity Tester (TST), both from Sensortek, Inc, Clifton, NJ, are new instruments that measure quantitatively sensory threshold to vibration and temperature difference. Tests performed with these instruments are noninvasive, time-efficient, and easy to administer. Impairment of sensitivity to vibration and temperature difference is an early sign of damage to large and small nerve fibers.

In this study, painters exposed to mixed organic solvents, and a reference group of healthy workers relatively unexposed to neurotoxic substances, are tested with the TST and Vibratron using a microcomputer-based threshold estimation method. Sensory thresholds are compared between painters and the reference group, and the relationship among painters between level of exposure and sensory threshold is examined.

Methods

Subjects

One hundred twelve members of the International Brotherhood of Painters and Allied Trades (IBPAT), age 20 to 70 years, were tested in 1985 with the Biothesiometer, the TST, neurologic examination, and an exposure and health questionnaire. Only 55 of the painters were tested with the Vibratron since the machine was not manufactured until the middle of the testing period. IBPAT members perform construction and maintenance painting that entails the application of coatings to interiors and exteriors of commercial and industrial buildings as well as other structures such as bridges.

The neurologic examination evaluated ankle reflexes as well as strength and sensation to pin pricks and light pressure in the lower extremities. The health questionnaire included questions on lower extremity symptoms such as numbness, tingling, and weakness.

Since diabetes is a major risk factor for peripheral neuropathy, six diabetic painters were excluded. Eight painters who retired more than two years before the testing period were also excluded since recovery of peripheral nerve function can occur within a few years after cessation of exposure. In addition, three IBPAT members who were tested but had never painted were excluded. After these exclusions, two women and 93 men remained among those available for membership in the exposed group. The women were excluded because of their small number, leaving 93 painters. Of these, 51 were tested with the Vibratron.

The reference group consisted of 105 currently employed male members of construction trade or industrial unions, age 20 to 75 years, who were neither painters nor diabetics. Reference group members were expected to have similar working conditions, trauma, and exposure to temperature extremes as painters. These factors may be risk factors for sensory loss and are difficult to control adequately. Hence, a reference group comparable to painters on these factors was chosen.

Members of the reference group had visited an occupational health clinic or participated in health surveys. The primary concern of the surveys and the clinic visits was asbestos-related disease. The reference group was tested with the Vibratron, the TST, and the Biothesiometer. Information on age, injuries to the back and lower extremities, circulation problems in the lower extremities, sensory symptoms in the feet, and alcohol consumption was obtained by interview. Their mean age was somewhat higher than the exposed group. Alcohol consumption in the two groups was similar.

Neurologic examinations and the Biothesiometer tests were performed on the painters by four physicians. One examiner performed all TST and most of the Vibratron tests on the painters. The same examiner performed all Biothesiometer, TST, and Vibratron tests on the reference group. Interexaminer differences among the Biothesiometer results from the painters were minor. Since the protocol for the Vibratron was designed to minimize examiner influence, no interexaminer difference should occur.

Exposure

Indices of solvent exposure used in this study included average lifetime intensity, average intensity during the past year, years worked (mean = 18 years), the proportion of the past year worked (mean = 20 weeks), and the proportion of the past month worked (mean = 9 days). Cumulative exposure over the lifetime, the past year, and the past month were obtained by combining the intensity and duration measures. The description of the methodology for determining exposure intensity from a questionnaire is discussed elsewhere.¹⁶

Apparatus

The TST consists of two 4.8 × 4.6 cm metal plates that are cooled or heated by water circulating through them, with the temperature of each plate controlled separately. The temperature of each plate and the difference in temperature is shown to the examiner on digital displays. One plate is set at a base temperature and the other is set colder. Twenty-four degrees Celsius was chosen as the base temperature so that both plates would feel cold to the subject.

The Vibratron consists of two stimulus boxes with a post 1.6 cm in diameter protruding from each box, and a small control box with a digital reading of the vibration amplitude. A switch determines which post vibrates at 120 Hz.

The Biothesiometer is a hand-held electromagnetic

device with a flat plastic probe 1 cm in diameter vibrating at 120 Hz that is applied to the skin.

Procedure

A two-alternative, "forced-choice" procedure was used for the TST and Vibratron. The great toe of one foot was tested. The subject was asked to use the foot on the side of his body which had no injuries or symptoms such as tingling or numbness in the lower extremities.

The procedure for the TST was as follows: the subject placed his great toe with enough pressure to blanch the nail for 2 seconds on each plate. The subject was asked which plate was colder and a response was required. Guessing was permitted. If the subject refused to give a response, a wrong answer was entered for that trial.

A similar procedure was used for the Vibratron with the exception that the subject was instructed to touch without putting pressure on the posts with his great toe. The subject was then asked which post was vibrating.

To determine the level of stimulus for each trial and to calculate the subject's threshold estimate, a microcomputer-based estimation method was used, the "Best PEST." The Best PEST (parameter estimation by sequential testing) is the most efficient threshold estimation procedure given that the psychometric function is known.¹⁷ The psychometric function describes the relationship between the probability of a correct response and the level of stimulus. A sigmoidal curve is usually assumed. A logit function was used in the algorithm.¹⁷

After each trial, a maximum likelihood estimate of the stimulus level which will elicit a correct response from the subject 75% of the time, given the responses to all previous trials, is calculated. Using that stimulus level in the next trial theoretically produces the maximum amount of information on the location of the subject's threshold. This procedure is repeated an arbitrary number of times, and at the end of the last trial, the PEST's estimate of the 75% correct response stimulus level is taken as the subject's threshold level. (This 75% correct response is used since the subject is forced to make a decision, and by guessing alone, the subject can be correct 50% of the time.)

Pilot testing revealed the most efficient values for two arbitrary parameters in the procedure: the number of trials and the stimulus level for the initial trial. The number of trials per test was arbitrarily set at 15. Performing more than 15 trials under field testing conditions appeared to tax a subject's attentiveness. For the first trial, the stimulus level was set at 2.0°C (TST) or 2.0 μ m (Vibratron). If the subject had trouble at this level while practicing, the level for the first trial was set at 4.0°C or 4.0 μ m. Levels were set to the nearest tenth of a degree or micrometer. The computer randomly determined which plate to set colder than the base temperature or which post to set to vibrate.

The method of limits was used to measure vibration threshold with the Biothesiometer.^{18,19} While the plastic vibrating probe was applied to the skin, the stimulus

was increased from zero to the point at which the subject first perceived vibration. The threshold was determined by averaging the values obtained from performing the test twice. Both great toes and index fingers were tested with the Biothesiometer.

Room temperatures varied from 20°C to 22°C. Distracting noises were kept at a minimum. Subjects were given a few minutes to acclimate their foot to the room temperature and to practice with the TST and Vibratron. Total time for the interview, practice trials, and tests using the TST, Vibratron, and Biothesiometer was 20 to 25 minutes for each subject.

Univariate and multivariate analyses were performed on a microcomputer using SPSS PC+.²⁰

Results

Painters v Reference Group

Crude and age-stratified univariate statistics for the TST, Vibratron, and Biothesiometer threshold scores are provided in Table 1. Frequency distributions for the original scores were highly skewed. In an effort to improve symmetry and stabilize variances, several transformations of the scores were evaluated using methods described in Hoaglin et al.²¹ Transformations using natural logarithms appeared best for vibration thresholds from the Vibratron and the Biothesiometer. The symmetry of the distribution for the TST threshold scores was most improved by using the square-root transform.

TABLE 1
Descriptive Statistics of Quantitative Sensory Variables for Painters and Reference Group by Age Stratum

Test	Age, yr	Painters			Reference Group		
		Mean	(SD)	n	Mean	(SD)	n
TST, °C	21-40	0.66	(0.48)	52	0.64	(0.37)	29
	41-50	0.82	(0.53)	13	0.68	(0.44)	35
	50+	1.00	(0.80)	28	0.68	(0.41)	41
	All	0.78	(0.61)	93	0.67	(0.41)	105
Transformed* TST thresh- olds	21-40	0.76	(0.29)		0.76	(0.24)	
	41-50	0.86	(0.29)		0.78	(0.26)	
	50+	0.93	(0.37)		0.79	(0.25)	
	All	0.83	(0.32)		0.78	(0.25)	
Vibration mi- croimeters	21-40	0.23	(0.23)	32	0.37	(0.45)	29
	41-50	1.10	(1.20)	8	0.37	(0.37)	35
	50+	1.50	(1.60)	11	0.81	(0.79)	41
	All	0.65	(1.00)	51	0.54	(0.62)	105
Transformed† Vibration thresholds	21-40	-1.7	(0.6)		-1.5	(0.9)	
	41-50	-0.4	(1.2)		-1.4	(0.8)	
	50+	-0.1	(1.1)		-0.7	(1.1)	
	All	-1.2	(1.1)		-1.1	(1.0)	
Biothesiome- ter, ‡ V	21-40	7.6	(5.6)	52	9.5	(5.2)	29
	41-50	11.7	(6.8)	13	9.4	(3.9)	35
	50+	18.2	(14.1)	28	16.8	(8.7)	41
	All	11.4	(10.2)	93	12.3	(7.4)	105
Transformed Biothesiome- ter†	21-40	1.9	(0.5)		2.1	(0.5)	
	41-50	2.3	(0.5)		2.2	(0.4)	
	50+	2.6	(0.7)		2.7	(0.6)	
	All	2.2	(0.7)		2.4	(0.6)	

* Square-root transformation.

† Natural logarithm transformation.

‡ Biothesiometer thresholds shown are for the right great toe.

Vibratron thresholds increased with age in both groups. An effect of age on TST thresholds was evident only among painters. The Vibratron and Biothesiometer threshold scores were highly intercorrelated but neither was correlated with the TST thresholds.

Results of analyses of variance including the effects of being a painter and of age strata on sensation threshold are presented in Table 2. The painters had statistically significantly higher untransformed TST and Vibratron thresholds. Using the transformed thresholds, the analysis indicated that painters had statistically significantly higher Vibratron scores especially in the older age strata ($P < .01$ for the interaction effect of age strata and being a painter). However, there was no

significant difference between the painters and the reference group for the transformed TST thresholds.

The square-root transformation of TST thresholds improved the symmetry of the distribution but consequently reduced considerably the mean threshold difference between painters and the reference group. A further analysis of the transformed TST thresholds was performed by determining "high" threshold scores in the two groups. Thresholds more than 2 SD higher than the mean score in the reference group were classified as "high." Nine painters had high TST thresholds compared with three in the reference group. An odds ratio of 3.64 was obtained (95% confidence interval = .99, 14.0).

Multiple regression was used to determine whether other possible risk factors besides age should be included in the analysis. *Reference group* threshold scores for the three sensory tests were regressed on age, alcohol consumption, trauma to the back and lower extremities, and circulation problems in the lower extremities. After inclusion of an age variable in the model, no other variable had a statistically significant coefficient with transformed vibration threshold scores as the dependent variable. Various power functions of age were examined for inclusion in the model, but none were found to fit better than the actual age of the subject. The same results were found for the Biothesiometer.

Regression of *reference group* TST threshold scores (original and transformed) on age, alcohol consumption, and trauma to the back and lower extremities yielded no statistically significant coefficients.

When threshold scores for the three sensory tests were regressed on age, alcohol consumption, trauma to the back and lower extremities, and circulation problems in the lower extremities and whether or not the individual was a painter, results were similar to those found in the previous analysis of variance analysis (Table 2).

Internal Analysis

The transformed Vibratron and Biothesiometer thresholds were regressed on the exposure variables and potential confounding variables. For the Vibratron, the regression coefficients for the variables "exposure intensity over the past year" and "cumulative exposure over the past year" were statistically significant.

In the regression analyses of the Biothesiometer, coefficients for "exposure intensity over the lifetime," "lifetime cumulative exposure," and "cumulative exposure over the past month" were statistically significant. For the transformed TST thresholds, no exposure variable was statistically significant.

Fourteen (15%) of the painters had slight, symmetrical abnormal readings in the lower extremities for the pin prick and/or the light pressure portions of the neurologic examination. Sixteen (17%) of the painters had slightly reduced ankle reflexes. Overall, abnormal results on the neurologic examination tended to be among the older painters who had been painting for

TABLE 2

Results of Analyses of Variance of the Sensory Threshold Scores for Painters and the Reference Group

Dependent Variable and Source of Variation	Sum of Squares	df	Mean Square	F	P*
TST					
Age stratum	1.30	2	.65	2.52	NS
Exposure group†	1.03	1	1.03	3.99	<.05
Two-way interactions	.82	2	.41	1.58	NS
Explained	2.85	5	.57	2.21	NS
Residual	49.56	192	.26		
Transformed TST thresholds					
Age stratum	.35	2	.17	2.19	NS
Exposure group†	.22	1	.22	2.75	NS
Two-way interactions	.20	2	.10	1.29	NS
Explained	.69	5	.14	1.73	NS
Residual	15.33	192	.08		
Vibration					
Age stratum	16.64	2	8.32	17.30	<.01
Exposure group†	5.25	1	5.25	10.92	<.01
Two-way interactions	5.72	2	2.86	5.95	<.01
Explained	20.68	5	4.14	8.60	<.01
Residual	72.17	150	.48		
Transformed Vibration thresholds					
Age stratum	31.20	2	15.60	17.83	<.01
Exposure group†	5.07	1	5.07	5.79	<.05
Two-way interactions	7.76	2	3.88	4.44	<.01
Explained	37.03	5	7.41	8.46	<.01
Residual	131.27	150	.88		
Biothesiometer‡					
Age stratum	2,969.0	2	1485.0	24.25	<.01
Exposure group†	14.2	1	14.2	.23	NS
Two-way interactions	144.0	2	71.9	1.17	NS
Explained	3,447.0	5	689.5	11.30	<.01
Residual	11,755.0	192	61.2		
Transformed Biothesiometer thresholds					
Age stratum	15.14	2	7.57	27.69	<.01
Exposure group†	.05	1	.05	.17	NS
Two-way interactions	1.05	2	.52	1.91	NS
Explained	19.23	5	3.85	14.04	<.01
Residual	52.52	192	.27		

* Two-tailed P value; NS, not statistically significant, $P > .05$.

† An indicator variable: 1 = painter, 0 = reference group.

‡ Biothesiometer results shown are for the right big toe.

many years but who had worked relatively less than other painters in the previous year.

Expected threshold values for the painters were calculated using the regression coefficients from models developed for the reference group's transformed thresholds. A painter was considered to have a "high" threshold if it was 2 or more SDs from the expected value. Correlation analysis was used to compare high sensory thresholds, abnormal neurologic examination results, and reported lower extremity symptoms among painters.

High TST thresholds were not correlated with abnormal neurologic examination results nor with foot symptoms, although they were correlated with leg symptoms ($r = .20, P < .05$). High Vibratron thresholds were correlated with ankle reflex ($r = .27, P < .05$) but were not correlated with other neurologic examination results or with symptoms. High Biothesiometer thresholds were also correlated with ankle reflex ($r = .18, P < .05$) but were not correlated with other neurologic examination results or with symptoms. There were no correlations between high TST scores and high scores for the Vibratron or the Biothesiometer. However, painters with high Vibratron scores tended to have high Biothesiometer scores ($r = .48, P < .05$).

Discussion

In this study, painters were found to have significantly higher Vibratron scores than the reference group, especially in the older age strata. In addition, significantly more painters had "high" TST scores than the reference group. In the internal analysis, exposure intensity and cumulative exposure over the past year were associated with the Vibratron thresholds. Associated with Biothesiometer thresholds were lifetime exposure intensity, lifetime cumulative exposure, and cumulative exposure over the past month.

The TST and Vibratron were devised to avoid the shortcomings of the neurologic examination and the electrophysiologic tests. Tests using the TST and Vibratron yield quantitative results, are more objective than the neurologic examination, and require little training to perform. Because they are noninvasive, they are more appropriate for field studies than electrophysiologic methods.

The sensitivity and specificity of the TST and Vibratron tests are difficult to assess since there is no diagnostic "gold standard" for comparison. Symptoms, signs, and electrophysiologic results may not agree since the disease appears diversely with a wide spectrum of severity. No clear demarcation between preclinical dysfunction and clinical disease exists.²²

In this study, results on the quantitative sensory tests were not correlated with neurologic examination results for pin prick and light touch or with reported foot symptoms. One explanation is that the tests are detecting early, presymptomatic effects. Another explanation is that individual differences in labeling intensity of

symptoms may attenuate any correlations between symptoms and the sensory tests.

A standard method has been established for the Biothesiometer (the method of limits) but not for the Vibratron or the TST. The manufacturer of the TST and Vibratron suggests a testing algorithm for determining threshold, but the validity of the method is uncertain. The algorithm starts with the level of stimulus the subject can identify correctly 100% of the time and then reduces the stimulus by 10% until the first error occurs. The level is then repeated twice more and if it is correctly identified both times, the level is again reduced by 10%. If not, then the level is increased by 10%. The test ends when five errors are committed by the subject. To calculate threshold, the five lowest correct and the five highest incorrect values are determined. The highest and lowest values are discarded and the remaining eight values are averaged.

There are three major problems to this algorithm. This algorithm appears to be somewhat related to the "Up-and-Down Transformed Response" rules developed by Wetherill and Levitt,²³ who provide theoretic justification of what point on the psychophysical curve each rule estimates. These authors never discussed the suitability of these rules for two alternative forced-choice experiments.²⁴ Since the algorithm departs somewhat from the up-and-down transformed response rules, it is unclear what point on the psychophysical curve it estimates.

A second problem is that, to our knowledge, no reliability information for this protocol has been published. Finally, the algorithm is not very time-efficient. Too many trials may be performed depending on the initial stimulus setting. We recommend that the Best PEST be used in conjunction with forced-choice procedures.

The TST, Vibratron, and Biothesiometer may be useful in cross-sectional and longitudinal studies to compare exposure subgroups in a population.²⁵ These studies can assess the safety of exposure levels and trigger efforts to reduce or eliminate exposures. However, further study of these devices is necessary before they can be used to monitor the progression of disease in persons with mild sensory loss.

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References

- Schaumburg H, Spencer P: *Disorders Of Peripheral Nerves*. Philadelphia, F. A. Davis Co., 1983, Chapter 2.
- Corsi G, Maestrelli P, Picotti G et al: Chronic peripheral neuropathy in workers with previous exposure to carbon disulphide. *Br J Ind Med* 1983;40:209-211.

3. Allen N: Identification of methyl n-butyl ketone as the causative agent, in Spencer PS, Schaumburg HH (eds): *Experimental and Clinical Neurotoxicology*. Baltimore, Williams & Wilkins, 1980, pp 834-845.
4. Feldman RG, Niles CA, Kelly-Hayes M, et al: Peripheral neuropathy in arsenic smelter workers. *Neurology* 1979;29:939-944.
5. Cherniak MG: Organophosphorus esters and polyneuropathy. *Ann Intern Med* 1986;264-266.
6. LeQuesne PM: Acrylamide in Spencer PS, Schaumburg HH (eds): *Experimental and Clinical Neurotoxicology*. Baltimore, Williams & Wilkins, 1980, p 309-325.
7. He F: Occupational toxic neuropathies—An update. *Scand J Work Environ Health* 1985;11:321-330.
8. Moses M, Lillis R, Crow KD et al: Health status of workers with past exposure to 2,3,7,8-tetrachloro-dibenzo-p-dioxin in the manufacture of 2,4,5-trichlorophenoxyacetic acid: Comparison of findings with and without chloracne. *Am J Ind Med* 1984;5:161-182.
9. Schaumburg HH, Spencer PS, Thomas P: *Disorders of Peripheral Nerves*. Philadelphia, F. A. Davis Co., 1983.
10. Seppalainen AM: Electrophysiological evidence of chemically induced lesions in the peripheral nervous system. In WHO Environmental Health Document 3, Neurobehavioral Methods in Occupational and Environmental Health. Copenhagen, 1985, pp 25-29.
11. Seppalainen AM, Husman K, Martenson C et al: Neurophysiological effects of long-term exposure to a mixture of organic solvents. *Scand J Work Environ Health* 1978;4:304-314.
12. Elofsson SA, Gamberale F, Hindmarsh T, et al: Exposure to organic solvents: A cross-sectional epidemiologic investigation on occupationally exposed car and industrial spray painters with special reference to the nervous system. *Scand J Work Environ Health* 1980;6:239-273.
13. Husman K, Karli P: Clinical neurological findings among car painters exposed to a mixture of organic solvents. *Scand J Work Environ Health* 1980;6:33-39.
14. Orbaek P, Risberg J, Rosen I: The effects of long-term exposure to solvents in the paint industry. *Scand J Work Environ Health*, 1985;11(suppl 2):3-28.
15. Kimura J: Nerve conduction studies and electromyography, in Dyck P, et al (eds): *Peripheral Neuropathy*. Philadelphia, W.B. Saunders, Vol 1, 1984, pp 919-966.
16. Fidler AT, Baker EL, Letz RE: Estimation of long-term exposure to mixed solvents from questionnaire data: A tool for epidemiologic investigations. *Br J Ind Med* 1987;44:133-141.
17. Lieberman H, Pentland A: Microcomputer-based estimation of psychophysical thresholds: the best PEST. *Behav Res Methods Instrumentation* 1982;14:21-25.
18. Maurissen, J: Psychophysical testing in human populations exposed to neurotoxicants. *Neurobehav Toxicol Teratol*, 1985;7:309-317.
19. Goldberg JM, Lindblom U: Standardized method of determining vibratory perception thresholds for diagnosis and screening in neurological investigations. *J Neurol Neurosurg Psychiatr* 1979;42:793-803.
20. Norusis MJ: *SPSS/PC+ For the IBM PC/XT/AT*. Chicago, SPSS Inc, 1986.
21. Hoaglin D, Mosteller F, Tukey J: *Understanding Robust and Exploratory Data Analysis*. New York, John Wiley & Sons, 1984.
22. Moody L, Arezzo J, Otto D: Screening occupational populations for asymptomatic or early peripheral neuropathy. *J Occup Med* 1986;28:975-986.
23. Wetherill G, Levitt H: Sequential estimation of points on a psychometric function. *Br J Math Stat Psych* 1965;18:1-10.
24. Kershaw OD: Statistical properties of staircase estimates from two interval forced choice experiments. *Br J Math Stat Psychol* 1985;38:35-43.
25. Bove FJ, Litwak MS, Arezzo JC, Baker EL: Quantitative sensory testing in occupational medicine. *Semin Occup Med* 1986;1:185-189.