Scand J Work Environ Health 1987;13(4):380-384

<https://doi.org/10.5271/sjweh.2025>

Issue date: Aug 1987

Assessment of impaired tactile sensation. A pilot study.

by [Brammer AJ](#), [Piercy JE](#), [Auger PL](#)

Affiliation: Division of Physics, National Research Council of Canada, Ottawa.

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/3433041

This work is licensed under a [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Assessment of impaired tactile sensation

A pilot study

by Anthony J Brammer, PhD,¹ Joseph E Piercy, PhD,¹ Pierre L Auger, MD²

BRAMMER AJ, PIERCY JE, AUGER PL. Assessment of impaired tactile sensation: A pilot study. *Scand J Work Environ Health* 13 (1987) 380—384. Three methods are compared for assessing impaired tactile sensation in vibration-exposed workers: a medical examination including traditional neurological tests and refined measures of vibrotactile perception and gap detection. Of 18 subjects only 12 were judged free of confounding factors — five forestry workers exposed to chain-saw vibration, aged 28 (SD 5) years, and seven laboratory workers not exposed to vibration, aged 36 (SD 7) years. Each method identified the same subject as suffering the most from tactile impairment, but they differed in their ranking of the severity of sensory changes. The ranking by gap detection and vibrotactile perception at low frequencies was the most consistent [Spearman rank correlation coefficient (r) = 0.90]. The clinical results, when staged according to the neurological component of vibration-induced white finger, ranked the thresholds for gap detection and low-frequency vibrotactile perception equally well (r = 0.70). In contrast, the Taylor-Pelmeur staging of the clinical results poorly represented the ranking of tactile thresholds recorded for these workers (r = 0.00 and -0.20, respectively). It also appeared that improved techniques for measuring vibrotactile and gap perception thresholds can detect sensory changes in the fingers not consistently found by conventional clinical tests.

Key terms: esthesiometer, two-point discrimination, vibration-induced white finger, vibrotactile perception.

Disturbed hand function is a common complaint of workers whose hands have been exposed to vibration (8). Though usually described as loss of fine touch or difficulty performing manipulative tasks involving small objects, it is generally agreed that the primary cause is impaired tactile sensation (2). The interference with a worker's activities is often difficult to assess, particularly in the initial stages, though its impact on productivity and the ability to hold and control a vibrating power tool may become significant.

Recognition that degraded tactile sensation may occur independently of the episodic vasospasms characteristic of the hand-arm vibration syndrome, with the initial neurological symptoms (tingling and numbness) usually reported first, has rekindled interest in the early detection of sensory changes in the hands. A successful method could offer the potential for identifying persons responding to vibration exposure prior to the development of disturbed hand function, as well as for quantifying the degree of tactile impairment.

Clinical methods for assessing impaired hand function have been the subject of research for many years (6). The results have almost invariably been disappointing, with the possible exception of static and moving two-point discrimination tests and some tests

of object recognition by the fingers, such as the Moberg pick-up test (2). In this paper summarizing the results of a pilot study, the details of which will be published elsewhere, the measurement of tactile spatial resolution is further refined and complemented with precise measurements of vibrotactile perception thresholds over a broad frequency range. This latter technique offers the potential for assessing the sensitivity and functional capacity of the three mechanoreceptor populations responsible for the sense of touch in glabrous skin (2, 4, 10). In parallel with this work, clinical procedures, based on methods developed elsewhere, have been evolved to determine tactile function in vibration-exposed hands (9, 11). The clinical results have then been graded using stages for vibration-induced white finger (VWF) in which the neurological and vascular disorders are classified separately (1).

Methods

After giving their informed consent to participate in the experiments, subjects first complete a questionnaire concerning their present and past occupations. Details of exposure to the vibration of any power tool, machine, or work piece for more than 1 h/week throughout any six-month period are requested. Hence occupational or recreational exposures of less than 1 h/week are considered insignificant.

Medical evaluation

The questionnaire also screens subjects for known causes of white fingers (8) and peripheral neurological dysfunction (diabetes, alcoholism, poisoning — eg, solvents, pesticides, heavy metals — peripheral neuropathy, pernicious anemia and carpal tunnel syndrome). Details of injuries to the fingers, hands, arms, shoulders, and neck are requested, as well as

¹ Division of Physics, National Research Council of Canada, Ottawa, Canada.

² Département de Santé Communautaire du Centre Hospitalier de l'Université Laval, Ste Foy, Quebec, Canada.

Reprint requests to: Dr A J Brammer, Division of Physics, National Research Council of Canada, Montreal Road, Ottawa, Ontario K1A 0R6, Canada.

smoking habits and the consumption of alcoholic beverages and medication. Subjects are asked where and under what conditions, if any, they experience tingling, numbness, or finger blanching, and whether it restricts their ability to hold, control, or manipulate objects.

The physical examination includes careful inspection of the hands for calluses, evidence of past injuries, deformity, swelling, and muscle wasting. Attention is paid to the fingertips, particularly to the area between the center of the whorl and the nail, which is used for both vibrotactile and esthesiometer measurements. Tests of peripheral neurological function include the perception of vibration (128 Hz tuning fork), stereognosis (identifying sides of a coin held between thumb and one finger), and Weber (static) two-point discrimination. Traditional neurological tests for the sense of pain, temperature, and light touch are also conducted throughout the territories innervated by the median and ulnar nerves. In addition, clinical tests are performed for evidence of carpal tunnel and thoracic outlet syndromes.

Measurement of vibrotactile perception thresholds

Vibrotactile perception thresholds are determined at the tip of the third finger (right hand) with the subject comfortably seated and forearm restrained on a horizontal support. The fingers are supported in a natural, curved position with the palm upwards so that the fingertips are approximately 45° to the vertical. The movement of both the hand and the finger under examination is restricted by straps.

A flat-topped, cylindrical vibrating probe (8-mm diameter), mounted on a beam balance to provide a constant contact force of 0.1 N, is next lowered onto the finger between the center of the whorl and the nail. Sinusoidal bursts of vibration (duration and separation 1.5 s or 10 oscillations, whichever is longer) are then applied to the fingertip, the amplitude increasing or decreasing by 2 dB between successive bursts. The perceived appearance or disappearance of the stimulus is signaled by the subject pressing a switch, which both records the threshold and reverses the signal progression (from increasing to decreasing amplitude, or vice versa). The arithmetic mean of the thresholds recorded in decibels with ascending and descending stimulus amplitudes is taken to be the perception threshold at this frequency.

Measurement of tactile spatial resolution

The threshold for gap detection is measured at the fingertip with an improved esthesiometer (7). The instrument consists essentially of a horizontal plate containing, on its upper surface, a lengthwise groove of constant depth but progressively increasing width. The plate is supported from below by four vertical springs. These springs surround vertical guide rods attached to a wheeled trolley which may be driven at

a constant speed along a horizontal track. The trolley and track are covered by an opaque plastic enclosure that also serves as an arm rest. With the palm of the hand supported by the enclosure, a finger is inserted down a 'V' slot oriented at 60° to the horizontal until the tip contacts the grooved plate. Vertical movement of this plate is sensed by a displacement transducer calibrated in terms of the contact force. In this way the position and orientation of the finger with respect to the test surface are controlled, as is the contact force.

To commence a threshold determination, the trolley is first returned to the beginning of the track, the digital counter that records the position of the trolley is reset, and the trolley is then moved a short distance to a random starting position. The subject then rests a finger on the finger rest and establishes the required contact force (0.6 N), whereupon the trolley is restarted. When the gap is first sensed, the trolley is stopped by the subject, and the threshold is derived from the distance traveled along the track.

The threshold for gap detection is taken to be the arithmetic mean of up to eight such measurements.

Results

Clinical findings

Eighteen subjects (8 forestry and 10 laboratory workers) completed the questionnaire and underwent the medical examination and clinical tests. A differential diagnosis was based on this information. Only 12 (67 %) of the subjects were considered free of confounding factors: five forestry workers [mean age 28 (SD 5) years], all of whom had been exposed to chain-saw vibration, and seven laboratory workers [mean age 37 (SD 7) years]. The latter seven had not been exposed to vibration.

A summary of the reports of numbness, its interference with activities, and the results of the clinical sensory tests is given in table 1. Note that, for simplicity, the seven laboratory workers have been omitted as they were symptom-free and judged normal in all these clinical tests. In addition the data are restricted to the third finger of the right hand, in order to provide a direct comparison of the clinical findings with the results of the vibrotactile and esthesiometer measurements.

Table 1. Occurrence of the neurological symptom (numbness) and the effects on activities reported by each subject and the results of the clinical sensory tests.^a

Subject number	Symptom and effects reported ^b				Clinical sensory tests ^c			Stage (see table 2)
	Numbness	Area affected	Control of objects	Manipulation of small objects	Perception		Tactile resolution	
					Mechano-receptors	Other receptors		
1	None	None	None	None	OK	R ^d	OK	ON, OV
2	E	H	E	E	OK	R	OK	1N, 1V
3	E	FT	None	E	OK	R ^d	OK	1N, OV
4	E	FT	None	E	OK	R ^d	OK	1N, 1V
5	P	FT	P	P	R	R	A	3N, OV

^a Subjects 6–12, all laboratory workers, were judged normal in these tests and were symptom free.

^b E = episodic, P = persistent, H = hand; FT = fingertips.

^c OK = normal, R = reduced, A = abnormal.

^d Mainly due to thick skin (not present at the fingertip).

Table 2. Tentative neurological (N) and vascular (V) stages of vibration-induced white finger proposed by Brammer et al (1).^a (Reproduced with the permission of the *Scandinavian Journal of Work Environment & Health*)

Stage	Signs and symptoms	Interference with activities
ON,OV	No signs or symptoms	None
1N	Intermittent tingling and/or numbness	None
1V	Episodic blanching of one or more fingertips	None
2N	Intermittent numbness; reduced tactile perception	Possible interference with activities involving fine tasks
2V	Episodic blanching of one or more fingers, usually confined to winter	Some interference with social activities
3N	Degraded tactile resolution; numbness	Interference with activities involving fine tasks at work and at home
3V	Extensive finger blanching, frequent episodes summer and winter	Restriction of hobbies and social activities to avoid vasospasms

^a Alternative sensorineural and vascular stages of the hand-arm vibration syndrome are proposed elsewhere in this volume.

Figure 1. Vibrotactile perception thresholds for five vibration-exposed subjects, identified by number in table 1, and for seven laboratory workers.

The data from the sensory tests have been combined into two measures of perception and a single measure of tactile resolution. One of the perception measures involves mechanoreceptors (light touch and vibration) and the other nociceptors and thermoreceptors (pin prick and temperature). In forming the results of the sensory tests, more weight was given to the data for light touch, pin prick, and two-point discrimination, as these were believed to have been more reliably determined.

A clinical assessment of the severity of the tactile sensory changes and neurological symptoms presumed to be caused by vibration is then possible through reference to table 2 (1). Application of this classification, which has evolved from that proposed by Taylor & Pearn to permit the neurological and vascular components of VWF to be evaluated separately, gives

the neurological stages shown in the right-hand column of table 1. Only subjects 2 and 4 reported any episodic vasospasms (in each case fingertip blanching) and so are also considered to be in vascular stage IV.

Vibrotactile perception thresholds

Vibrotactile perception thresholds are shown in figure 1 for frequencies from 2 to 400 Hz, expressed in terms of the peak displacement. Measurements at 400 Hz were not conducted on subjects 2 and 5, and at low frequencies the stimulus could not be increased sufficiently in amplitude to be perceived by subject 5, even though the displacement was clearly visible (consisting of up to 4-mm movement).

It is evident from figure 1 that the perception thresholds of subject 5 were significantly elevated (ie, degraded) at all frequencies at which the measurements were conducted. At low frequencies, the thresholds of the other vibration-exposed subjects appeared to be close to the mean value of the laboratory workers, though this was not the case at frequencies from 50 to 200 Hz. With the exception of subject 2, the thresholds of the vibration-exposed workers appeared to be significantly degraded at these frequencies. This effect was particularly evident at 100 Hz.

An attempt was made to estimate the upper limit of normality at the frequency 100 Hz from the data for the laboratory workers. The level below which thresholds for 95 % of normal persons would occur was calculated for the *t* distribution with six degrees of freedom (12). In view of the small number of subjects in this pilot study, which renders any prediction of population values subject to some uncertainty, a similar calculation was performed using data from a larger group of symptom-free persons (*N* = 55) drawn from the general population (5). Though the experimental technique and frequency of measurement are somewhat different, both of which are expected to reduce the perception thresholds below those obtained in this study, the upper limit of normality so defined is compatible with that derived from the laboratory workers. Both values are presented in figure 2, where they are compared with the vibrotactile thresholds recorded from individual vibration-exposed workers. In this diagram the clinical assessment of each subject is shown as the ordinate.

It is evident from figure 2 that four of the five vibration-exposed workers possessed abnormally insensitive perception thresholds at the frequency of 100 Hz (subjects 1, 3, 4, and 5), irrespective of the data used to define the upper limit of normality.

Gap detection thresholds

The minimum gap widths detected by both vibration-exposed and normal subjects are shown in figure 3. As already noted, more confidence in the value for the upper limit of normality can be obtained by compari-

Figure 2. Vibrotactile perception threshold at 100 Hz expressed by neurological stage of vibration-induced white finger (VWF) (see table 2) for five vibration-exposed subjects, identified by number in table 1, and for seven laboratory workers (mean: triangle). The upper limit of normality (defined in the text), estimated from the laboratory workers and from the general population, aged less than 45 years (5), is shown by the continuous and broken lines, respectively.

son with other work. Therefore the limit calculated from the hands of nonvibration-exposed, industrial manual workers ($N = 61$) screened for causes of Raynaud's phenomenon and peripheral neurological disorders (Behrens, personal communication) has been included. It is evident from this diagram that three of the five subjects possessed abnormally large thresholds for gap detection (subjects 3, 4, and 5). The threshold of the vibration-exposed but symptom-free subject (subject 1) can be seen to lie on the limit of normality derived from the laboratory workers but within the normal range defined by the larger, industrially based population.

Discussion

Three methods have been described for assessing impaired tactile sensation. The clinical evaluation is based on traditional neurological tests, whereas the psychophysical measurements of vibrotactile and gap perception involve highly developed techniques.

Only subject 5 was found to possess abnormal tactile sensation by the clinical tests, though all the vibration-exposed subjects experienced reduced sensation in nociceptors and thermoreceptors (table 1). In contrast, controlled psychophysical measurements of tactile function revealed that three out of five of the vibration-exposed subjects possessed abnormal spatial resolution (figure 3) and up to four out of five had abnormal vibrotactile perception at some frequencies (figure 2). Each of the methods identified the same subject (subject 5) as suffering the most from tactile sensory impairment.

Figure 3. Gap width detection threshold expressed by neurological stage of vibration-induced white finger (VWF) (see table 2) for five vibration-exposed workers, identified by number in table 1, and for seven laboratory workers (mean: triangle). The upper limit of normality (defined in the text), estimated from the laboratory workers and from industrial manual workers ($N = 61$) not exposed to vibration (Behrens, personal communication), is shown by the continuous and broken lines, respectively.

The three methods also differed in their rank ordering of the severity of tactile changes. At low frequencies, the ranking by vibrotactile and esthesiometer measurements was almost identical; at 4 Hz, the Spearman rank correlation coefficient (r) was 0.90 (3). If the staging given in table 2 is taken to be a measure of the severity of VWF, then this ranking was equally consistent with individual gap detection and vibrotactile thresholds at low frequencies ($r = 0.70$). However, if the clinical results were staged according to the Taylor-Pelmear classification, little association was found between this ranking of the severity of VWF and either gap detection or vibrotactile thresholds at low frequencies ($r = 0.00$ and $r = -0.20$, respectively). Hence this classification inadequately represents the magnitude of tactile sensory changes recorded for these vibration-exposed subjects.

With the present combination of parameters controlling contact between the fingertip and stimulator the vibrotactile thresholds of all but the stage 3N case remained within the limits of normality at low frequencies, whereas three out of the four symptomatic workers (two in stage 1N and one in stage 3N) possessed abnormal gap detection thresholds. Nevertheless, the best separation of vibration-exposed from nonvibration-exposed subjects (four out of five) was obtained by vibrotactile stimulation at 100 Hz. More recent work, to be published elsewhere, has revealed that the selection of different contact parameters resolves other features of tactile perception.

Although in view of the small number of subjects it is not possible to generalize the results of this pilot study, it does appear that highly developed methods for measuring vibrotactile perception and spatial

resolution can detect changes in mechanoreceptor function not consistently found by traditional clinical tests, perhaps as early as stage 1N, OV (that is, stage O_N in the Taylor-Pelmeur classification). Conversely, a symptom pattern reported by a vibration-exposed worker does not always appear to be supported either by clinical tests or by sensitive tactile sensory measurements (subject 2). The reason for this inconsistency remains unclear.

Acknowledgments

We wish to acknowledge many helpful discussions with Professor W Taylor during the design of this study, and we are indebted to Ms V Behrens, US National Institute for Occupational Safety and Health, for performing additional statistical analyses on the Institute's data at our request. We also wish to express our gratitude to all the subjects for participating in the experiments.

All arrangements and expenses associated with the forest workers' participation were provided by the Forest Products Accident Prevention Association.

References

1. Brammer AJ, Taylor W, Piercy JE. Assessing the severity of the neurological component of the hand-arm vibration syndrome. *Scand J Work Environ Health* 12 (1986) 428—431.
2. Dellon AL. Evaluation of sensibility and re-education of sensation in the hand. Williams and Wilkins, Baltimore, MD 1981.
3. Gibbons JD. Nonparametric methods for quantitative analysis. Second edition. American Sciences Press, Columbus, OH 1985.
4. Löfvenberg J, Johansson RS. Regional differences and interindividual variability in sensitivity to vibration in the glabrous skin of the human hand. *Brain Res* 301 (1984) 65—72.
5. Lundborg G, Lie-Stenström AK, Sollerman C, Strömberg T, Pyykkö I. Digital vibrogram: A new diagnostic tool for sensory testing in compression neuropathy. *J Hand Surg* 11 (1986) 693—699.
6. Moberg E. Criticism and study of methods for examining sensibility in the hand. *Neurology* 12 (1962) 8—19.
7. Reif ZF, Marshall D, Brammer AJ, Piercy JE, Taylor W. Improved esthesiometer for measuring tactile perception in hands exposed to vibration. In: Canadian Acoustical Association. Proceedings 12th international congress on acoustics. Toronto 1986, p F2—5.
8. Taylor W, Brammer AJ. Vibration effects on the hand and arm in industry: An introduction and review. In: Brammer AJ, Taylor W, ed. *Vibration effects on the hand and arm in industry*. John Wiley & Sons, New York, NY 1982, pp 1—12.
9. Taylor W, Ogston SA, Brammer AJ. A clinical assessment of seventy-eight cases of the hand-arm vibration syndrome. *Scand J Work Environ Health* 12 (1986) 265—268.
10. Vallbo AB, Johansson RS. Properties of cutaneous mechanoreceptors in the human hand related to touch sensation. *Hum Neurobiol* 3 (1984) 3—14.
11. Wasserman D, Taylor W, Behrens V, Samueloff S, Reynolds D. Vibration white finger disease in US workers using pneumatic chipping and grinding hand tools: I Epidemiology. US Department of Health and Human Services, National Institute for Occupational Safety and Health, Cincinnati, OH 1982. (DHHS/NIOSH pub no 82—118).
12. Wonnacott TH, Wonnacott RJ. Introductory statistics. Second edition. John Wiley & Sons, New York, NY 1972.