Scand J Work Environ Health 1987;13(4):375-379

<https://doi.org/10.5271/sjweh.2026>

Issue date: Aug 1987

A new principle for assessing vibrotactile sense in vibration-induced neuropathy.

by [Lundborg G](#), [Sollerman C](#), [Stromberg T](#), [Pyykko I](#), [Rosen B](#)

Affiliation: Department of Hand Surgery, Malmo General Hospital, Sweden.

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/3433040

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

A new principle for assessing vibrotactile sense in vibration-induced neuropathy

by Göran Lundborg, MD, PhD,¹ Christer Sollerman, MD, PhD,² Trygve Strömberg, MD,² Ilmari Pyykkö, MD, PhD,³ Birgitta Rosén²

LUNDBORG G, SOLLERMAN C, STRÖMBERG T, PYYKKÖ I, ROSÉN B. A new principle for assessing vibrotactile sense in vibration-induced neuropathy. *Scand J Work Environ Health* 13 (1987) 375-379. The vibrotactile perception threshold has been evaluated in 20 manual workers not exposed to occupational vibration and in 27 workers using hand-held vibrating tools. Threshold values were evaluated with a Békesy type of vibrometer at frequencies ranging from 8 to 500 Hz. The earliest sign of vibration lesion was a reduction of sensation at frequencies of 125 to 250 Hz, indicating dysfunction in receptors of the fast adapting type II (stage 1 curve), followed in more severe cases by a prominent loss of sensation at all frequencies higher than 65 Hz (stage 2 curve). The stage 3 curve indicated the most severe loss of sensation in which the function of slowly adapting type I receptors, as well as fast adapting type I receptors, was deteriorated; consequently the vibrotactile thresholds at low-, median-, and high-frequency ranges were impaired. The vibrotactile changes corresponded well to numbness and the presence of vibration-induced white finger.

Key terms: occupational vibration exposure, receptor sensitivity, vibrometer, vibrotactile perception.

Although periodic blanching of the fingers has long been known to be caused by occupational exposure to vibration (1, 8), the nature and extent of the involvement of peripheral nerves have not been fully acknowledged (12, 18). Recently, there has been increasing interest in exploring neurological disturbances occurring in the upper extremities after long-term use of hand-held vibrating tools (2, 5, 7). The symptoms of peripheral nerve involvement may vary from intermittent tingling to permanent numbness and, in extreme cases, pain and muscle wasting (19). Usually either the median or the ulnar nerve is involved (12), but some authors report simultaneous involvement of both nerves (17).

The early diagnosis of vibration-induced neuropathy is associated with several difficulties. Although nerve conduction velocity may be impaired in advanced stages (3, 5), neurophysiological tests and two-point discrimination tests may be perfectly normal (15). It has, however, been reported that the impairment of vibrotactile sense may be one of the first changes observed after occupational exposure to vibration (4, 11). Thus changes in vibrotactile threshold may predict the onset of vibration injury. We present a method for determining the vibrotactile sense at several frequencies. The purpose was to develop a diagnostic method for the early detection of vibration-induced neuropathy.

Materials and methods

The vibrometer

An audiometer of the Békesy type was modified in accordance with a previous description (14). To evoke stable vibration without compression circuitry, a powerful vibrator (Brüel & Kjaer, type 4809) was used (figure 1). The area of the vibrating head was 5 mm². The vibration exciter consisted of an audiometer (Brüel & Kjaer, type 1800) modified to operate at low frequencies. The signal was amplified with a power amplifier (Brüel & Kjaer, type 2706). The vibrating head of the exciter was placed into the center of a small opening in a testing table. The system provided a sinusoidal signal at controlled frequencies and amplitudes, and it could be applied to a finger pulp placed on top of the table (figure 2). Vibration at seven fixed frequencies ranging from 8 to 500 Hz were automatically delivered to the probe on the top of the exciter.

The signal was recorded on an X-Y recorder with a built-in test signal generator. The test frequency was presented on the X axis, the frequencies being automatically changed by the instrument itself. The Y axis deflection represents the perception threshold for vibration. The level of vibration is controlled by an automatic attenuator, operated by the subject by means of a hand-held switch (figures 3 and 4). Instructions were given to press the switch when the vibration of the probe could be felt, thus causing the automatic attenuator to decrease the intensity (amplitude). When vibration could no longer be felt, the switch was released. In this way the subjects could regulate the intensity of the vibration and thereby track their threshold levels. The perception threshold was recorded on a preprinted chart at frequencies of 8, 16, 33, 65, 125, 250, and 500 Hz, the frequencies being automatically changed through this frequency range. The level was recorded in decibels as acceleration $\times 10^{-6} \text{ m/s}^2$.

In all the subjects the third and fifth fingers of both hands, innervated by the median and ulnar nerves, respectively, were tested. The testing time for one finger was 5-6 min. Since the test is psychophysical and requires cooperation from the patient, a preliminary test was done for training purposes, before the actual testing procedure was carried out. The testing was usually performed by an occupational therapist.

The equipment was mobile and could be brought to any desired place. The testings were performed in various local health care centers associated with the workplaces.

¹ Department of Hand Surgery, Malmö General Hospital, Malmö, Sweden.

² Department of Orthopaedics, University Hospital, Lund, Sweden.

³ Institute of Occupational Health, Helsinki, Finland.

Reprint requests to: Dr G Lundborg, Department of Hand Surgery, Malmö General Hospital, S-214 01 Malmö, Sweden.

Figure 1. Testing table with vibration exciter in place and a finger resting on top of the probe.

Figure 2. Pulp of the finger placed on top of the vibration exciter.

Figure 3. Hand switch enabling control of increase and decrease in vibration intensity.

Figure 4. Vibrometer equipment in place.

Figure 5. Normal vibrogram obtained from 20 heavy manual workers not exposed to vibration. The curve indicates mean values ± 2 SD.

Reference subjects

Curves were obtained from 20 manual workers not exposed to vibration (carpenters, glass factory workers), and a "normal vibrogram" based on the values obtained ± 2 SD was established (figure 5).

Workers exposed to occupational vibration

Twenty-seven workers who had been using hand-held vibrating tools for various periods of time formed the exposed group. The mean age was 35 (range 18–60) years, the exposure time averaging 9 years (range 9 months — 27 years). The subjects tested included car mechanics and factory workers exposed to vibration from hand-held vibrating tools. In a questionnaire each patient indicated the occurrence of white fingers and/or numbness of the hand. The investigation did not include objective assessments of vasospastic disease. Vibrograms were obtained from the third and fifth fingers of both hands no less than 2 h after the cessation of exposure to vibration.

Results

Reference subjects

Vibrograms obtained from the reference group showed a typical shape with a mainly horizontal course in the lower frequencies, followed by a peak within the range of 125–250 Hz, indicating a better perception threshold for fast adapting type II (FA II) receptors (pacinian corpuscles) than for fast adapting type I (FA I) or slowly adapting type I (SA I) or II (SA II) receptors (figure 5). At 500 Hz there was an increase in the perception thresholds, indicated by a slope of the curve.

The level and shape of the curve was identical to curves obtained from 55 referents from the hospital staff, who were not involved in heavy manual work (14).

Workers exposed to vibration

There was a striking correlation between the subjective symptoms presented by the patients and the changes in the curve of the vibrogram. With increasing symptoms, changes in the curve corresponding to the results obtained from material of nerve entrapment patients were observed (14) so that "stage 1" was indicated by a flattening of the peak within the FA II receptor range of 125–250 Hz, "stage 2" was indicated by, in addition, a steeper slope of the curve starting at a frequency of 65 Hz, and "stage 3" was indicated by the dis-

appearance of the vibration sense at the highest frequencies and deterioration of sensation also in the very low frequency range corresponding to the vibrotactile perception of the SA I receptor population. Typical curves are shown in figures 6–8, representing workers having used hand-held vibrating tools for 6 months, 18 months, and 27 years, respectively.

The changes in the vibrogram corresponded remarkably well to the subjective experience of numbness in the hand and to the occurrence of white fingers. Of six workers suffering from white fingers, the vibrogram was abnormal in five cases. Of five workers suffering from numbness of the hand, the vibrogram was abnormal in four cases. For seven workers with symptoms of *both* disturbed peripheral circulation *and* neuropathy the vibrogram was abnormal in six cases. Out

Figure 6. Vibrograms from a car mechanic exposed to vibration for six months. Intermittent wrist pain, no numbness of the hand. Normal vibrogram.

Figure 7. Vibrogram obtained from a car mechanic working with hand-held vibrating tools for 18 months. Intermittent numbness of the hand, normal two-point discrimination. Abnormal vibrogram, stage 2–3 in both hands.

Figure 8. Vibrogram obtained from a car mechanic exposed to hand-held vibrating tools for 27 years. Constant numbness and pain. Abnormal curve in both hands, stage 3.

of ten workers with no symptoms, three showed abnormal vibrograms (stage 1).

Discussion

Vibration-induced neuropathy of the hand represents a puzzling condition, often imitating carpal tunnel syndrome. The nerve conduction velocity is often normal across the wrist level, and these cases are not always cured by decompression of the median nerve. These facts strongly indicate that the nerve lesion may be located more distally than in the carpal canal, and hypotheses have been proposed that intraneural edema in distal median nerve branches may constitute an important etiologic factor in early vibration-induced neuropathy (13).

In compression neuropathies changes in vibrotactile sense represent early signs, always appearing before changes in two-point discrimination and often appearing before impairment in nerve conduction velocity (6). Changes in the vibrotactile sense of the skin have been reported to represent an early objective sign also in vibration-induced neuropathy (4). The physiology of the vibrotactile sensation of the skin is complex in that vibration is perceived by several receptor systems of the skin. Two receptor populations have been defined on the basis of their properties for adaptation to constant pressure, ie, the SA and FA types. Depending on their response to sharp edges, each of these receptor types can be further divided into receptors responding to sharp contours (type I) and into diffuse contours (type II) (9). SA I receptors are anatomically linked to neurite complexes of Merkel's cells and SA II receptors to Ruffini's corpuscles, both of which respond to lower frequencies of vibration (0.1–60 Hz) at psychophysical threshold values. FA I receptors have been anatomically linked to Meissner's corpuscles, and FA II receptors to pacinian corpuscles, the latter perceiving higher frequencies of vibration at psychophysical thresholds (10).

The psychophysical threshold (vibrogram) curve is linked to the activation of SA I receptors at low frequencies (below 16 Hz), to FA I receptors at middle frequencies (32 to 65 Hz), and to FA II receptors at high frequencies (above 65 Hz). The most sensitive frequency range in the evaluation of psychophysical vibrotactile perception is 250–350 Hz, where the FA II receptors in normal subjects can detect displacement of the skin at an amplitude of 0.1 μ m (16). In our study this sensitive threshold of FA II receptors has been expressed in the peak of the vibrogram curve.

The earliest sign of decreased vibrotactile sensation was a flattening of this peak (stage 1). Abnormalities in the curve within the lower frequencies occurred only at an advanced stage, which — paralleled by an increase in 2 PD — reflects a lesion in the SA I receptor population.

It is interesting to note that abnormalities of the curve correlated not only to numbness of the hand, but also to the occurrence of white fingers. This finding emphasizes the difficulties in separating neurological and vascular problems in the vibration syndrome and suggests a common etiology. Intraneural nerve fibers in vascular walls may play a role in the initiation of vasospasm. On the other hand, all peripheral nerve trunks are well vascularized, and disturbances in intraneural vascular function will rapidly interfere with nerve function. The fact that the intraneural microvessels are sympathetically innervated makes the picture even more complicated. A disorder of sympathetic nerve fibers may have consequences for the blood flow in the vessels of the hand and for the vessels in the peripheral nerves and hereby contribute to an even further impairment of peripheral nerve function.

The vibrotactile sense is dependent on local temperature, as well as on time and space variables such as frequency, temporal and intensity relationships between stimuli, area of stimulation, and surface gradients on the skin (20, 21). The significance of the transient threshold shifts for vibration perception is well known (11). These factors have to be considered when vibrotactile sense is used as an indicator of damage to components of peripheral nerves. All these factors can be completely controlled only under well-defined laboratory conditions. Our method, however, was developed with the purpose of using mobile equipment for screening tests in the field. By necessity, all factors considered in the preceding discussion could not be completely controlled. This deficiency has to be judged against other advantages of the method. However, as long as the testing procedure is standardized maximally in each individual case, we feel that the main sources of error have been excluded.

The results of this pilot study, with a striking correlation between subjective symptoms of neurological and circulatory disturbances and pathological vibrograms, as well as between exposure time and pathological vibrograms, indicate that our method is very useful for screening test purposes. Further investigations are needed to prove the statistical significance of the method. In an ongoing prospective field study including 350 manual workers doing heavy work, the method is now being used as a screening test to study the course of the neuropathy as related to factors such as continuous exposure to vibration and modifications of the work situation.

Acknowledgments

This work was supported by grants from the Swedish Work Environment Fund.

References

1. Agate JN. An outbreak of cases of Raynaud's disease of occupational origin. *Br J Ind Med* 6 (1949) 144–163.

2. Ahlborg G, Voog L, de Laval G, Holm Glad G. Vibration exposure and distal compression of the median nerve ("Carpal tunnel syndrome"). *Läkartidningen* 79 (1982) 4905—4908.
3. Alaranta H, Seppäläinen A-M. Neuropathy and the automatic analysis of electromyographic signals from vibration exposed workers. *Scand J Work Environ Health* 3 (1977) 128—134.
4. Brammer AJ, Taylor W, Piercy J. Assessing the severity of the neurological component of the hand-arm vibration syndrome. *Scand J Work Environ Health* 12 (1986) 428—431.
5. Chatterjee DS, Barrwick DD, Pertrie A. Exploratory electromyography in the study of vibration-induced white fingers in rock drillers. *Br J Ind Med* 39 (1982) 89—97.
6. Dellon AL. Evaluation of sensibility and re-education of sensation in the hand. Williams & Wilkins, Baltimore, MD 1981, p 263.
7. Färkkilä M, Starck J, Aatola S, Pyykkö I, Korhonen O. Vibration-induced neuropathy among forestry workers. *Acta Neurol Scand* 71 (1985) 221—225.
8. Hamilton A. A vasomotor disturbance in the fingers of stonecutters. *Arch Gewerbepathol Gewerbehyg* 1 (1930) 348—358.
9. Johanson RS, Wallbo ÅB. Detection of tactile stimuli: Thresholds of afferent units related to psychophysical thresholds in the human hand. *J Physiol (London)* 297 (1979) 405—422.
10. Johanson RS, Wallbo ÅB. Tactile sensory coding in the glabrous skin of the human hand. *Trends Neurosci* 6 (1983) 27—32.
11. Lidström IM, Hagelthorn G, Bjerker N. Vibration perception in persons not previously exposed to local vibration and in vibration-exposed workers. In: Brammer AJ, Taylor W, ed. *Vibration effects on the hand and arm in industry*. John Wiley & Sons, New York, NY 1982, pp 59—65.
12. Lukáš E. Peripheral nervous system and hand arm vibration exposure. In: Brammer AJ, Taylor W, ed. *Vibration effects on the hand and arm in industry*. John Wiley & Sons, New York, NY 1982, pp 39—43.
13. Lundborg G, Dahlin LB, Danielsen N, Hansson HA, Necking LE, Pyykkö I. Intraneural edema following exposure to vibration. *Scand J Work Environ Health* 13 (1987) 326—329.
14. Lundborg G, Lie-Stenström AK, Sollerman C, Pyykkö I, Strömberg T. Digital vibrogram — A new diagnostic tool for sensory testing in compression neuropathy. *J Hand Surg* 11 A (1986) 693—699.
15. Lundborg G, Sollerman C, Stenström AK. Digital vibrogram — A new diagnostic tool for sensory testing. *J Hand Surg* 10A (1985) 424.
16. Mountcastle VB, Talbot WH, Sakata H, Hyvärinen J. Cortical neuronal mechanisms in flutter-vibration studied in unanesthetized monkeys: Neuronal periodicity and frequency discrimination. *J Neurophysiol* 32 (1967) 452—484.
17. Seppäläinen AM. Peripheral neuropathy in forest workers — A field study. *Work Environ Health* 9 (1972) 106—111.
18. Stewart AM, Goda DF. Vibration syndrome. *Br J Ind Med* 27 (1970) 19—27.
19. Teleky L. Pneumatic tools. *Occup Health* 1 (1938) 1—12.
20. Verillo RT. Investigation of some parameters of the cutaneous threshold for vibration. *J Acoust Soc Am* 34 (1962): 11, 1768—1773.
21. Verillo RT. Effect of contactor area on the vibrotactile threshold. *J Acoust Soc Am* 35 (1963): 12, 1962—1966.