

High-frequency vibration and sensory nerves

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SEPPÄLÄINEN AM, STARCK J, HÄRKÖNEN H. High-frequency vibration and sensory nerves. *Scand J Work Environ Health* 12 (1986) 420–422. In 1977 a Finnish foundry implemented the use of new wheels of zirconium corundum for pedestal grinding. Within a year the workers developed vibration-induced white finger (VWF). Ten were studied electroneuromyographically in 1979, and again in 1980 and 1983 after the zirconium corundum had been replaced by normal corundum. In 1979 the mean distal sensory conduction velocity (dSCV) of the median nerve was below the lower normal limit, and that of the ulnar nerve was close to the normal limit. Only two workers had a normal dSCV of the median nerve bilaterally, whereas four had a normal ulnar nerve value bilaterally. The results had improved slightly in 1980 and 1983, the mean values being within normal limits with some individual values still abnormal. Subjective symptoms were still frequent in 1983, the same nine workers still complaining of paresthesias in the hands and fingers and five reporting hand-arm pain. All still had VWF attacks, at least occasionally. The higher impulsiveness of the vibration from the zirconium corundum wheels, together with high-frequency components of vibration, was considered to be the major cause of the quick development of the sensory nerve damage that was found in 1979.

Key terms: electromyography, high impulsiveness of vibration, nerve conduction velocity, pedestal grinding, sensory neuropathy.

Vibration syndrome or vibration-induced white finger (VWF) is well known among workers exposed to hand-arm vibration. Paresthesias and pain in the hands and arms are usual symptoms in VWF, and neurophysiological measurements have shown neuropathic changes in the hand and arm nerves of lumberjacks and users of pneumatic tools (1, 3, 4). As VWF developed in a year in workers doing pedestal grinding in a Finnish foundry after a change was made in the abrasion material of the wheels, we decided to study the nerve functions of the workers, as well as changes in the vibration characteristics of the grinding wheels.

Subjects and pedestal grinding

We studied 10 men who had worked for several years grinding small metal castings of various shapes. The castings were cleaned manually by an operator who pressed them against a grinding wheel. Two different types of grinding wheels were used, one made of corundum and in use until 1977 and another of zirconium corundum put into use in 1977. In 1980 the zirconium corundum wheels were abandoned, and wheels of the older type were used again. The roughness, hardness, and the bond of the wheels were the same, but the abrasion material was either corundum or zirconium corundum mixed with silica.

No major symptoms had been evident earlier, but within a year after the change of the abrasion material to zirconium corundum, VWF appeared in all the workers. In 1979 the mean age of the subjects was 33.3 years. The three youngest workers were 26 years, the oldest was 54 years, and the next oldest was 38 years. In general the subjects were healthy. One had been treated for hypertension since 1977. Two of the subjects were current smokers; the others did not smoke.

Methods

Neurophysiological measurements

Neurophysiological examinations were carried out on three occasions, namely, in August 1979, November 1980, and November 1983. Two subjects did not attend the 1983 examination. One of them was, however, studied in 1981, and those results were compiled with the 1983 studies. The following measurements were taken: the motor conduction velocity (MCV), the motor distal latency (6), and the distal sensory conduction velocity (dSCV) from finger to wrist (5) of the median and ulnar nerves bilaterally with the use of skin electrodes for recording and stimulation. The MCV of the right deep peroneal nerve and the SCV of the right sural nerve were measured in 1979. Conduction velocity measures outside the normal limits of the laboratory (5) were considered abnormal. Diagnostic electromyography with a concentric needle electrode and a Disa electromyograph was studied of the opponens pollicis, first dorsal interosseus, and extensor digitorum communis muscles of both hands and arms. The

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symptoms related to vibration syndrome were inquired about in a semistructural way.

Vibration measurements

Vibration was measured from the castings according to the ISO/DIS 5349.2 standard proposal, which recommends that the assessment of risk be based on a daily exposure time of 4 h (2). The one-third octave band analyses were taken from the tape recordings and displayed as the average one-third octave spectrum of 20 spectra using an averaging time and sampling interval of 0.5 s (7). The rise time of the peak detector was 50 μ s. In addition to the standardized measurements the impulsiveness of the vibration was expressed as a difference between peak and root-mean-square (rms) levels denoted by I. The shorter the impulse, the greater the difference between the peak and rms levels. The difference I is known as the crest factor of the signal, and it is in relation to the frequency distribution of the signal. The frequency range of the sampling was 2 Hz–10 kHz. The analytic function was the cumulative distribution function of the difference I. From the cumulative distribution function the impulse index I_1 was selected with which to compare the impulsiveness of the different signals. The impulse index I_1 gave impulsiveness I in decibels that corresponded to one percentage value (8).

Results

All the subjects suffered in 1979 from VWF, usually also in the summer, especially if swimming or on the sea. Nine subjects complained of paresthesias, which were bilateral in seven. Pain in the hands or wrists was complained of by six subjects. Four men complained of diminished strength in their hands and arms. Paresthetic feelings were similarly present still in 1983, when five continued to complain of hand-arm pain.

The mean MCV of the arm nerves was close to the normal mean of the laboratory and as published for control persons in previous studies (5) (table 1), and only two men had an abnormally slow MCV of the arm nerves in 1979: one in the right median nerve, the other in the right ulnar nerve. The mean motor distal latency of the median nerve in 1979 was bilaterally symmetrical and longer than the normal mean (4.0 ms), but it had returned to the normal mean level already in the first follow-up examination (table 1). An abnormally long distal latency of the median nerve was detected in three men in 1979, in two in 1980, and in one in 1983. Similarly, the mean distal latency of the ulnar nerve was long in 1979, but had returned to normal in 1980. Two men had a prolonged distal latency of the ulnar nerve in 1979, and one in 1983.

The dSCV of the median nerve was definitely low in 1979, when the mean value was below the lower normal limit (5). It was slightly above the lower normal limit in 1980 and just below it again in 1983 on the

Table 1. Motor conduction velocity (MCV), motor distal latency (MDL), and distal sensory conduction velocity (dSCV) of the right median and ulnar nerves of the same 10 (in 1983 only 9) pedestal grinders studied on three occasions.

Nerve	1979		1980		1983	
	Mean	SD	Mean	SD	Mean	SD
Median nerve						
MCV (m/s)	54.8	4.5	56.3	3.2	55.0	2.8
MDL (ms)	4.4	0.6	4.1	0.7	4.0	0.6
dSCV (m/s)	38.9	2.9	41.4	4.3	40.3	6.2
Ulnar nerve						
MCV (m/s)	59.2	5.3	57.4	4.9	55.7	3.4
MDL (ms)	3.7	0.4	3.3	0.3	3.2	0.4
dSCV (m/s)	44.7	4.3	49.1	2.3	50.1	5.2

Table 2. Results of the vibration measurements of two types of grinding wheels. (a_{w4} = frequency-weighted 4-h energy equivalent acceleration, I_1 = impulse index for the value of 1 %)

Type of grinding wheel	a_{w4} (m/s^2)	I_1 (dB)
Corundum	20	18
Zirconium corundum	20	21

right side; the left-sided dSCV values were slightly higher in all the measurements. In 1979 only two men had a normal dSCV of the median nerve bilaterally; the others had abnormal values at least on the right side. The mean dSCV of the ulnar nerve was below the lower normal limit on the right side in 1979. At other measurements and on the left side the mean was within the normal limits. In 1979 six men had an abnormally slow dSCV of the ulnar nerve, four of them bilaterally. In 1980 and 1983 only one man had an abnormally slow dSCV of the ulnar nerve. The distal sensory branches of the hand nerves thus showed abnormalities more often and more clearly than the motor nerves. The individual conduction velocities usually improved during the follow-up time, especially among the subjects with the most abnormal initial results.

Electromyography also revealed abnormal findings. Denervation activity, namely, fibrillations, were detected in the intrinsic hand muscles of eight men, both in 1979 and 1980, whereas fibrillations remained in only two men in 1983. Other neurogenic changes, namely, a prolonged duration of motor unit potentials, were seldom seen. They were actually detected in one man in the 1983 examination.

The MCV of the deep peroneal nerve was normal in all the men. The SCV of the sural nerve was slightly slowed in three men in 1979, but it was back within the normal limits in the 1980 examination.

The weighted acceleration and impulsiveness of the vibration are shown in table 2. The old corundum and the new zirconium corundum grinding wheels gave off the same weighted acceleration values, but the impulsiveness of the vibration generated by the zirconium

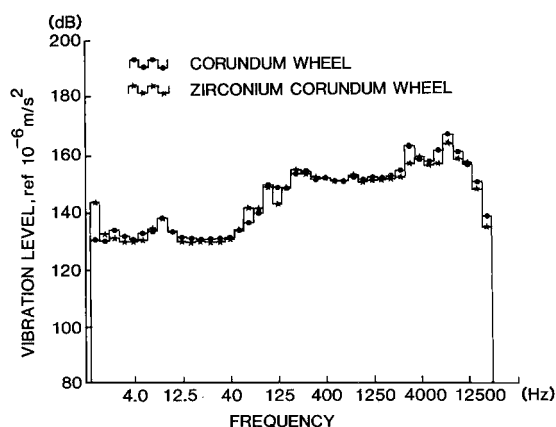


Figure 1. Vibration levels when castings were pressed against corundum or zirconium corundum wheels.

corundum was higher than that generated by the corundum wheel. Figure 1 shows the results from the frequency analyses revealing the presence of high-frequency components during the cleaning of castings with the corundum or zirconium corundum wheels.

Discussion

Workers exposed to high-frequency vibration in pedestal grinding quickly developed VWF. They also complained of paresthesias and pain in their hands and wrists; these symptoms are usual in cases of peripheral nerve lesions and similar to those complained of by lumberjacks and rock drillers suffering from vibration syndrome. The neurophysiological findings showed similarities to those detected in lumberjacks and rock drillers (1, 3, 4), namely, slowing of the nerve conduction velocity, especially in the peripheral branches of the median and ulnar nerves, and neuropathic abnormalities in the electromyography of the hand muscles. Among grinders, however, the sensory nerve conduction velocity of the distal branches was more often affected than the motor distal latency, while, among lumberjacks and rock drillers, the motor nerves showed abnormalities more often. For example in 1970 half of 103 lumberjacks then working had an abnormally long distal latency of the median nerve (4). In the study by Alaranta & Seppäläinen (1), which employed all the nerve conduction measures used in the present study, only the most affected group had a dSCV of the median nerve of the same order as in the present study, while the distal latency of their

median nerves was longer. In that group the dSCV of the ulnar nerve was greater, namely, 48.3 m/s, when compared to the 44.7 m/s measured in the present study. The distal latency of the ulnar nerve, as well as the MCV of the median and ulnar nerves, was therefore similar to the corresponding values in the present study. One main difference between the vibration of power saws and that of grinding wheels was the presence of high-frequency components in the latter.

The quick development of VWF after a change in the abrasion material of grinding wheels raises thoughts of differences in the vibration characteristics of the wheels. No difference was noted in the weighted acceleration values of the two wheels, and the distribution of the vibration frequencies was similar. High-frequency components were present in both. However, differences were detected in the impulsiveness of the vibration. The zirconium corundum wheels generated a higher impulsiveness than the old corundum wheels. It is probable that the higher impulsiveness of the vibration was a dominant factor in the quick development of VWF, as well as in the determined nerve damage. The amelioration of findings after the workers returned to the use of the old type of wheels also emphasizes the greater effect of zirconium corundum wheels in the occurrence of nerve damage.

References

1. Alaranta H, Seppäläinen AM. Neuropathy and the automatic analysis of electromyographic signals from vibration exposed workers. *Scand J Work Environ Health* 3 (1977) 128–134.
2. International Organization for Standardization. Guide for the measurement and the assessment of human exposure to vibration transmitted to the hand. Geneva 1984. (ISO DIS 5349.2 — 1984).
3. Lukáš E, Kužel V. Klinische und elektromyographische Diagnostik der Schädigung des peripheren Nervensystems durch lokale Vibration. *Int Arch Arbeitsmed* 28 (1971) 239–249.
4. Seppäläinen AM. Peripheral neuropathy in forest workers: A field study. *Work Environ Health* 9 (1972) 106–111.
5. Seppäläinen AM, Hernberg S, Kock B. Relationship between blood lead levels and nerve conduction velocities. *Neurotoxicology* 1 (1979) 313–332.
6. Smorto M, Basmajian JV. Clinical electroneurography. Williams & Wilkins, Baltimore, MD 1972.
7. Starck J. High impulse acceleration levels in hand-held vibratory tools: An additional factor in the hazards associated with the hand-arm vibration syndrome. *Scand J Work Environ Health* 10 (1984) 171–178.
8. Starck J, Färkkilä M, Aatola S, Pyykkö I, Korhonen O. Vibration syndrome and vibration in pedestal grinding. *Br J Ind Med* 40 (1983) 426–433.