

Peripheral nerve responses to hand-arm vibration

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SAKURAI T, MATOBA T. Peripheral nerve responses to hand-arm vibration. *Scand J Work Environ Health* 12 (1986) 432–434. Electromyograms from the arm, shoulder, and neck were recorded with surface electrodes, and the transmission of vibration to the hand, arm, shoulder, and forehead was measured. Nerve conduction velocity in the median nerve of the forearm and palm was assessed in vibrating tool operators. Low-frequency components of less than 20 Hz in electromyograms of the arm and shoulder were significantly intensified with increasing levels of vibration amplitude and gripping strength during the experiment. The amplitude of the transmitted vibration particularly influenced the electromyographic results. The maximal motor and sensory nerve conduction velocities of vibrating tool operators were significantly lower than those of a healthy reference group.

Key terms: electromyogram, low-frequency components, nerve conduction velocity, vibration transmission.

The transmission of vibration to the hand-arm system is influenced by various parameters of the vibration, such as amplitude, frequency and direction, and by ergonomic conditions, such as gripping and pushing strength and arm posture (6, 7). In this report, the relation between transmitted vibration and the electromyogram of arm muscles was studied in healthy subjects, and patterns of peripheral nerve disturbances among vibrating tool operators were analyzed.

Subjects and method

First examination

While in a sitting position 16 healthy subjects, aged 27 to 50 years and having no experience with the operation of vibrating tools, were asked to grip the handle of an electrodynamic vibrator (Akashi ASE-385). Their gripping and pushing strengths and the arm posture were monitored during the experiment with strain-gauge force transducers. The meter was placed so that the test subject could see it, and the subject tried to keep the force constant. The vibration was applied to a subject in the direction of the horizontal axis of his arm with the combination of characteristics and levels shown in table 1. Each subject repeated the test 10 times. The amplitude of the applied vibration was defined as the frequency-weighted acceleration, with a frequency characteristic of 6 dB/octave from 16 to 1 000 Hz and flat below 16 Hz. It was simulated according to the vibration sensation of the hand-arm system standardized by the International Organization for Standardization (3, 4).

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The vibration transmission was measured on a hand grip set on a vibrator, the ipsilateral arm, the scapula, and the forehead. The measurements were made with small, light accelerometers, 1.2 g in weight and 6 × 10 mm in size.

Electromyograms of the flexor, extensor, and trapezius muscles of the forearm and the neck muscles were recorded during the vibration exposure test. The recordings were made with a high-speed level recorder with surface electrodes of the bipolar disc type with a diameter of 10 mm (7). The frequency components between 4 and 20 Hz were selected by a band-pass filter. The average amplitude of the electromyogram for 1 min from the start of the gripping (Vs) and for 1 min before the end of the gripping (Ve) was read at each examination. The rate of increase was calculated as $(Ve/Vs-1) \times 100 \%$.

Second examination

The maximal motor nerve conduction velocity (MCV) and the maximal sensory nerve conduction velocity (SCV) were measured in the forearm between the elbow and wrist and in the palm between the wrist and finger in 171 vibrating tool operators [49.8 (SD 7.4) years old] and 30 healthy men [47.5 (SD 7.2) years old] unexposed

Table 1. Vibration exposure conditions used in the first examination.

	Level 1	Level 2
Vibration amplitude ^a (m/s ²)	5	10
Vibration exposure time (min)	2	6
Gripping force (kg)	3	6
Handle diameter (cm)	3	5
Elbow joint angle (degree)	135	180

^a Vibration amplitude was given as the frequency-weighted acceleration, as proposed by the International Organization for Standardization.

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to vibration. The measurements were made at a room temperature of $27 (\pm 1) ^\circ\text{C}$ after the subject's skin temperature on his arm and palm became greater than $30 ^\circ\text{C}$, because skin temperature enhances nerve conduction velocity in those areas of the body. The group of vibrating tool operators had operated vibrating tools for $12.7 (\text{SD } 4.8)$ years.

In the evaluation of the peripheral circulatory function of the hand, finger skin temperature was measured every minute before, during, and after a 10-min cold provocation test in which the hands were immersed in water with a temperature of $10 ^\circ\text{C}$, and a nail compression test was performed before and after the cold provocation test at a room temperature of $23 (\pm 1) ^\circ\text{C}$. For the nail compression test, one investigator pressed the nail of the subject for 10 s with his fingers, to reduce the subject's nail color, and the time was measured until the color returned to normal. Recovery activity was calculated as $1/3 [T1 - TO + 1/2 (T2 - TO) + 1/3 (T3 - TO)]$, where TO was the finger skin temperature at the end of the cold provocation test, T1 was the finger skin temperature 1 min after the end of the test, T2 was the finger skin temperature 2 min after the end of the test, and T3 was the finger skin temperature 3 min after the end of the test.

Results

An average of 76.4 % of the vibration with a frequency of 30 Hz was transmitted from the vibrator handle to the arm. Doubling the gripping strength made the vibration transmission to the arm 1.37 times greater. At a vibration frequency of 125 Hz about 12.9 % of the vibration was transmitted to the arm and 3.8 % to the shoulder. When the frequency was 30 Hz, about 15 % of the vibration was transmitted to the shoulder and about 5.3 % to the forehead. At 125 Hz the percentage of vibration transmitted was too small to be detected in the forehead. When the elbow was extended, the vibration transmitted from the handle to the shoulder was about twice that transmitted through a flexed arm.

The special difference between the electromyograms recorded before and after the vibration was applied was evident for the electromyographic components below 20 Hz (1, 7). An analysis of variance was performed for the levels of electromyographic amplitude and different vibration parameters. The results are shown in table 2. Vibration amplitude and gripping strength correlated significantly with the levels of electromyographic amplitude for each muscle. The results of the electromyograms of the shoulder muscles did not correlate with the handle vibration. A Strong correlation was observed however between vibration magnitude on the scapula and an increase in the rate of low-frequency components of the electromyograms of the shoulder (correlation coefficient = 0.328 in the 16×10 distribution of data).

The MCV and SCV values of the operators were significantly lower than those of the reference group (2, 5), as shown in table 3. The prevalence of SCV abnormalities was higher than that of the abnormal MCV values. The difference between the forearm and palmar SCV values of the median nerve of each subject was significantly greater for the operators than for the referents. Table 4 shows the correlation coefficients for the relationship between peripheral circulatory functions at a room temperature of $23 (\pm 1) ^\circ\text{C}$ and the MCV and SCV of the median nerve over which skin temperature was about $32 ^\circ\text{C}$ in a warm room [$27 (\pm 1) ^\circ\text{C}$]. The coefficient of correlation between the palmar SCV values of the median nerve and the peripheral circulatory functions was the highest.

Table 2. Means and confidence limits (CL) of the increasing rate of low-frequency electromyographic components for the factors which showed significance in the analysis of variance.

Factors	Level 1		Level 2	
	Mean (%)	CL	Mean (%)	CL
<i>Forearm flexor muscle</i>				
Vibration amplitude of vibrator	21.2	10.9	47.6	23.7*
Gripping strength	13.6	8.6	55.3	24.2**
Handle diameter	19.7	8.5	49.2	24.9**
<i>Forearm extensor muscle</i>				
Vibration exposure time	12.0	7.9	22.4	7.3*
Vibration amplitude of vibrator	11.7	7.0	22.8	8.1**
Gripping strength	9.9	5.6	24.5	8.8**
<i>Shoulder trapezius muscle</i>				
Vibration amplitude in the scapula	16.1	8.5	34.9	25.3**
Gripping strength	14.3	7.4	29.0	21.2**

* $p < 0.05$, ** $p < 0.01$.

Table 3. Nerve conduction velocities of the median nerve of the vibrating tool operators and the referents without vibrating tool operation.

Nerve conduction velocity ^a	Operators (N = 171)		Referents (N = 30)	
	Mean	SD	Mean	SD
MCVe-w (m/s)	57.44	4.98**	60.77	4.42
SCVe-w (m/s)	61.84	6.15*	64.58	3.97
SCVw-f (m/s)	52.88	6.28**	58.23	3.60
(SCVe-w) - (SCVw-f) (m/s)	8.96	6.92*	6.35	4.55

^a MCV = motor nerve conduction velocity, SCV = sensory nerve conduction velocity, e-w = between elbow and wrist, w-f = between wrist and finger.

* $p < 0.05$, ** $p < 0.01$.

Table 4. Relation between the nerve conduction velocities of the median nerve and the peripheral functions of 171 vibrating tool operators. (MCVe-w = motor nerve conduction velocity between the elbow and wrist, SCVe-w = sensory nerve conduction velocity between the elbow and wrist, SCVw-f = sensory nerve conduction velocity between the wrist and finger, r = partial correlation coefficient for controlled age and total number of operating hours).

Function test	MCVe-w	SCVe-w	SCVw-f
Finger skin temperature at a room temperature of 23 °C	$r = 0.061$	$r = 0.017$	$r = 0.302^*$
Recovery activity of the finger skin temperature after cold provocation	$r = 0.082$	$r = 0.033$	$r = 0.298^*$
Nail compression test	$r = -0.069$	$r = -0.042$	$r = -0.234^*$

* $p < 0.01$.

Discussion

Vibration is easily transmitted from a handle to an arm and shoulder in different combinations of magnitude, frequency, and direction of the vibration applied to the hand. Increasing the vibration amplitude in the arm enhances the low-frequency components of electromyograms of the arm (1, 7). Increasing the gripping force itself augments the low-frequency components of the electromyogram and results in muscle fatigue (7). The nerve conduction velocities are slowed in the palm and arm, especially in the more distal part of the arm. The SCV between the wrist and finger correlated with such peripheral circulatory disturbances as con-

tinuously low finger skin temperature in daily life and slow recovery after a reduction in hand temperature. Therefore peripheral nerves seem to be affected directly by applied and transmitted vibration and also indirectly by peripheral circulatory disturbance.

We conclude that peripheral nerve responses, including muscle responses, may not only be influenced by vibration applied to the hand, but also by vibration transmitted to the arm.

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