

Peripheral circulatory and nervous response to various frequencies of local vibration exposure

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NOHARA S, OKAMOTO K, OKADA A. Peripheral circulatory and nervous response to various frequencies of local vibration exposure. *Scand J Work Environ Health* 12 (1986) 382–384. The influence of local vibration exposure on peripheral circulatory and nervous functions was studied in order that the vibration frequency which has the greatest effect on the body could be determined. The response to various vibration frequencies (30, 60, 120, 240, 480 and 960 Hz) under constant acceleration (50 m/s^2) was examined in humans. The hands of five healthy men were exposed for 1 h to local vibration at various frequencies. The skin temperature did not change significantly at any frequency. The finger blood flow decreased after vibration exposure (60 and 480 Hz, $p < 0.05$; 30 and 120 Hz, $p < 0.10$). In addition the peripheral nerve conduction velocity became slightly slower after the vibration exposure (30 and 120 Hz, $p < 0.10$). The physiological responses to local vibration depended on the vibration frequency. The peripheral nervous system was affected by low frequencies, whereas the peripheral circulatory system was influenced not only by low frequencies, but also by high frequencies. The results obtained with humans were consistent with those obtained with animals.

Key terms: electrolysis, hydrogen gas clearance method, local blood flow, peripheral nerve conduction velocity, skin temperature, vibration.

It is a matter of great importance to clarify the physiological relationship between vibration hazards and vibration intensity or frequency. Especially the latter is an interesting exposure variable because vibration hazards consist of a variety of disorders and vibration frequency is very related to their onset (9). Accordingly, this study was performed to examine physiological responses to various frequencies in local vibration exposure. The responses of peripheral circulatory and nervous functions in healthy men's hands to local vibration of various frequencies under constant acceleration were examined. The responses of these functions were observed from the skin temperature, local blood flow, and peripheral nerve conduction velocity.

Material and methods

The subjects were five healthy men, 25–31 years of age. They had no experience with vibrating tools or with riding a motorbike, and they were nonsmokers. The apparatus for providing vibration exposure was composed of an electromagnetic shaker (Emic 513-A, shaking power 75 g; vibrating frequency range 5–5 000 Hz) coupled to an amplifier (Tachikawa TA-100), a function oscillator (Trio AG202), a vibration meter (Emic 505-D), and the acrylic vibration exposure device with the column handle (diameter 40 mm) fixed on the vibrating plate of the shaker. The vibration level

of the handle was measured by the vibration meter and the pick up of the acceleration type fitted to the handle.

The subjects sat down and clasped the vibrating handle with their left hand under a constant grasping power. Their hands were exposed to sinusoidal and vertical vibration of various frequencies (30, 60, 120, 240, 480, and 960 Hz) under a constant acceleration of 50 m/s^2 for 1 h. For contrast, the effects of only gripping without vibration for 1 h were also examined. The grasping power was checked with a strain gauge. Each experiment was performed at 1-d intervals and at a frequency selected at random. The experimental room was kept at $23 (\pm 1)^\circ\text{C}$ temperature.

The skin temperature was measured on the palmar side of the distal phalanx of the left middle finger by a digital thermometer (Takara D111). The finger blood flow was measured on the right side of the middle phalanx of the left middle finger by the hydrogen gas clearance method (2) using electrolysis (blood flow meter, Biomedical Science Co) (6, 10). The motor nerve conduction velocity (MNCV) of the ulnar and median nerves was calculated from induced electromyograms of the abductor muscle of the little finger or the abductor muscle of the thumb during electric stimuli to the elbow joint or the wrist joint (7). These measurements were performed before and immediately after 1 h of exposure.

Results

The effects of local vibration exposure at various frequencies under constant acceleration are shown in figures 1–4. For skin temperature, no statistically

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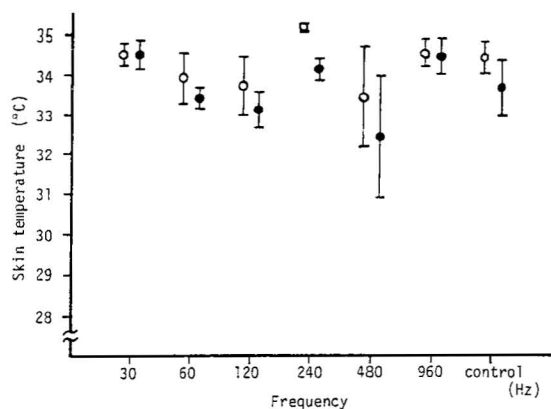


Figure 1. Effect of various frequencies on skin temperature of hands exposed for 1 h to local vibration under a constant acceleration (50 m/s^2). Each circle with its vertical line represents the mean and the standard error of the mean of five men. (○ = before vibration exposure, ● = after vibration exposure)

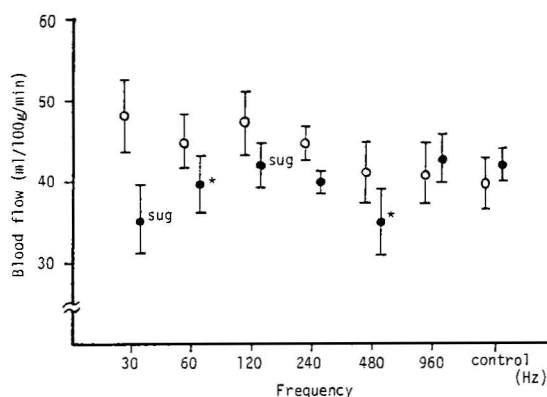


Figure 2. Effect of various frequencies on blood flow of hands exposed for 1 h to local vibration under a constant acceleration (50 m/s^2). Each circle with its vertical line represents the mean and standard error of the mean of five men [* $p < 0.05$, sug $p < 0.10$ (the paired t-test)]. (○ = before vibration exposure, ● = after vibration exposure, $\text{ml}/100 \text{ g}/\text{min} = \text{ml} \cdot 100 \text{ g}^{-1} \cdot \text{min}^{-1}$)

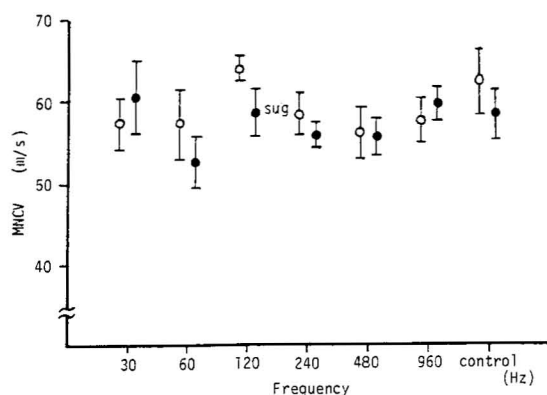


Figure 3. Effect of various frequencies on the peripheral motor nerve conduction velocity (MNCV) of the ulnar nerve of hands exposed for 1 h to local vibration under a constant acceleration (50 m/s^2). Each circle with its vertical line represents the mean and standard error of the mean of five men [sug $p < 0.10$ (the paired t-test)]. (○ = before vibration exposure, ● = after vibration exposure)

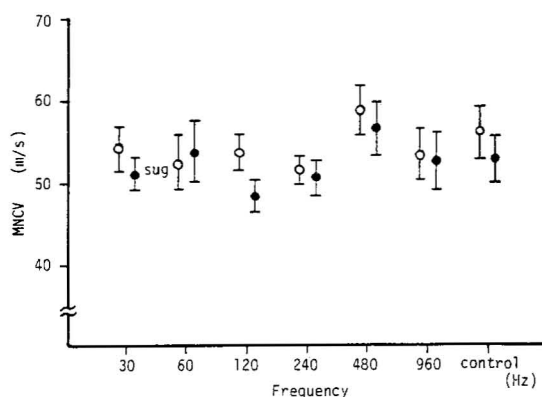


Figure 4. Effect of various frequencies on the peripheral motor nerve conduction velocity (MNCV) of the median nerve of hands exposed for 1 h to local vibration under a constant acceleration (50 m/s^2). Each circle with its vertical line represents the mean and standard error of the mean of five men [sug $p < 0.10$ (the paired t-test)]. (○ = before vibration exposure, ● = after vibration exposure)

significant difference was found for any frequency level or for the control experiment (figure 1).

The blood flow after the vibration exposure was statistically significantly less than that before vibration exposure at 60 and 480 Hz ($p < 0.05$). In addition, tendencies for the blood flow to decrease were found at 30 and 120 Hz ($p < 0.10$). There was no significant change at any other frequency or in the control study (figure 2).

The ulnar nerve conduction velocity after vibration exposure showed a tendency to be slower than that before vibration exposure at the frequency level of 120 Hz ($p < 0.10$). No statistically significant difference was shown at other frequencies or in the control exposure (figure 3). The median nerve conduction velocity after the vibration exposure tended to decrease

in relation to that before the exposure at 30 Hz ($p < 0.10$). It showed no significant change at the other frequency levels or in the control study (figure 4).

Discussion

It is very important to clarify the role played by vibration intensity or vibration frequency in the pathogenesis of vibration hazards. Therefore, there is need to expose humans to local vibration and observe the responses experimentally as this study did.

The published works on circulatory disorders of occupational origin clearly demonstrate that vibration is a factor common to all outbreaks. Gerbis and others (3) found that tools in the shoe trade were responsible

for vibration of 280 to 600 Hz and that these levels produced Raynaud's phenomenon very rapidly. Hunter et al (4) reported that the white finger syndrome occurred the most frequently among workers who were using tools with a vibration frequency of 33–50 Hz. Agate & Druett (1) recorded the vibration spectra of a number of different tools and concluded that the most harmful vibration lies in the range of 40 to 125 Hz. And Hyvärinen and his group (5) found that 125 Hz was the most effective in producing vasospasms in their experimental study. On the other hand, there are few reports on peripheral nervous disturbances and bone and joint changes in relation to vibration frequency. It is said that these symptoms occur not only at low frequencies of 11–30 Hz, but also at 160 Hz or above (1). After all, these results do not coincide with one another on the most effective frequency for either function. And the most effective frequency was analogized in comparisons of the vibration characteristics of the tool with clinical impressions in most of these reports. In the present study, certain physiological responses to local vibration exposure were observed experimentally. The physiological responses to local vibration depended on the vibration frequency. The peripheral nerve function was affected by low frequencies, whereas the peripheral circulatory function was influenced not only by low frequencies, but also by high frequencies.

Ljung et al (8) observed the influence of longitudinal sine-wave oscillation on contractile activity of isolated preparations of rat portal vein and concluded that the frequency of 200 Hz was effective. The results suggested that the effect was most likely due to a direct action on the contractile elements of the oscillations.

The blood flow changes in our study may be assumed to depend upon a direct action, as has already been mentioned, or may reflect vasoconstriction mediated by the pacinian corpuscles.

References

1. Agate JN, Druett HA. A study of portable vibrating tools in relation to the clinical effect which they produce. *Br J Ind Med* 4 (1947) 141–163.
2. Aukland K, Bower BF, Berliner RW. Measurement of local blood flow with hydrogen gas. *Circ Res* 14 (1964) 164–187.
3. Gerbis H, Gross A, Meyer-Brdnitz KF, Robinson J. Die Verhütung von Gesundheitsschädigungen durch Anklöpnachinen. Berlin. Cited in: Teleky L. Occupation and health supplement. International Labour Organisation, Geneva 1938.
4. Hunter D, McLaughlin AIG, Perry KMA. Clinical effects on the use of pneumatic tools. *Br J Ind Med* 2 (1945) 10–16.
5. Hyvärinen J, Pyykkö I, Sundberg S. Vibration frequencies and amplitudes in the aetiology of traumatic vasospastic disease. *Lancet* 1 (1973) 791–794.
6. Kosshu K, Kamiyama K, Oka N, Endo S, Takaku A, Saito T. Measurement of regional blood flow using hydrogen generated by electrolysis. *Stroke* 13 (1982) 483–487.
7. Lenman JAR, Ritchie AE. Clinical electromyography. Pitman Medical, Kent 1977.
8. Ljung B, Sirvertsson R. Inhibition of vascular smooth muscle contraction by vibration. *Acta Physiol Scand Suppl* 396 (1973) 95.
9. Okada A, Suzuki K. Vibration hazards. Shinohara, Tokyo 1982.
10. Stossek K, Luebbers DW, Cottin N. Determination of local blood flow (microflow) by electrochemically generated hydrogen: Construction and application of measuring probe. *Pfluegers Arch* 348 (1974) 225–238.