

Transmission of hand-arm vibration to the head

by Hisataka Sakakibara, MD,¹ Taka'aki Kondo, MD,¹ Masaru Miyao, MD,¹ Shin'ya Yamada, MD,¹ Takeo Nakagawa, MD,² Fumio Kobayashi, MD,³ Yuichiro Ono, MD⁴

SAKAKIBARA H, KONDO T, MIYAO M, YAMADA S, NAKAGAWA T, KOBAYASHI F, ONO Y. Transmission of hand-arm vibration to the head. *Scand J Work Environ Health* 12 (1986) 359–361. A "tooth impression" was devised to measure head vibration. The vertical head vibration of four subjects was measured with the tooth impression during exposure of the hand to vertical sinusoidal vibration at acceleration levels of 3.15, 10.0, and 31.5 m/s² root mean square in the range of 8–200 Hz. While in a standing position, the subjects pulled the vibrating handle upward at a force of 5 kg with the elbow joint stretched during the tests. The measurement was repeated twice. The difference between the two measurements was within 3 dB, a level which suggests that this method has good reproducibility. The vibration transmitted to the head was the greatest in the range of 12.5–16 Hz, and the attenuation was about 20 dB. Head vibration decreased by approximately 15 dB per octave at frequencies above 20 Hz as the frequency increased. When the excitation level was increased by 10 dB, the head vibration increased by about 8 dB.

Key terms: attenuation, head vibration, measuring method, vibration transmission.

It is important to understand the transmission of hand-arm vibration to the human body so that its effects can be estimated. There is, however, some difficulty in measuring vibration in the human body because of the resiliency of the skin and muscles (11). Hence various methods have been devised to fix accelerometers on the body rigidly. In some studies accelerometers have been attached directly to the bone (11).

A "tooth impression" was devised to measure head vibration. It is closely set in the incisors. Head vibration is measured by small accelerometers fixed to the tooth impression. A previous study (6) revealed that the method has high reproducibility. In the present study the vibration transmitted to the head was measured with the use of a tooth impression during exposure of the hand to vibration.

Subjects and methods

Four subjects (aged 21 to 31 years) were tested.

Sinusoidal vibration was produced by an Akashi ASE12 electrodynamic vibrator. The acceleration of the vibrator was recorded by an accelerometer (Rion, VM-17) attached to the handle of the vibrator. The acceleration of the head was measured by an accelerometer (Imv, VP-4132, 5 × 5 × 11.5 mm, 1 g weight) on a tooth impression set in the upper central incisors.

A tooth impression, to be fitted to the upper incisors of each subject, was made from resin prior to the tests. The size of the tooth impression was about 20 mm long by 15 mm wide by 12 mm thick, and the weight was about 2 g. The surfaces were flat except for the top and the sides, where the shape of the incisors was imprinted.

The force of pulling the handle of the vibrator was measured by strain gauges attached to the handle. The output voltage of the strain gauges was recorded with an output indicator (Watanabe, DS-1L). The subjects kept the pulling force constant during the tests by watching the indicator.

While in a standing position the subjects pulled the handle upward at a constant force of 5 kg with the elbow joint stretched during the tests. The right hand was exposed to vertical sinusoidal vibration at acceleration levels of 3.15 m/s² root mean square (rms), 10.0 m/s² rms, and 31.5 m/s² rms in the range of 8–500 Hz at intervals of the one-third octave band. Vertical head vibration was measured under these conditions. The measurement of each subject was repeated twice (figure 1).

Head acceleration was recorded by a portable cassette recorder (Teac, R-70). The data were analyzed by a one-third octave-band analyzer (Rion, SA-59A). Because of the capacity of the vibrator and the measuring apparatus, the analysis was limited to the range of 8–80 Hz at the excitation level of 3.15 m/s² rms, of 25–125 Hz at the level of 10.0 m/s² rms, and of 40–200 Hz at the level of 31.5 m/s² rms.

Results

The two measurements of each subject under the same conditions were nearly equal, and the difference

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Figure 1. Method for measuring head vibration with a tooth impression.

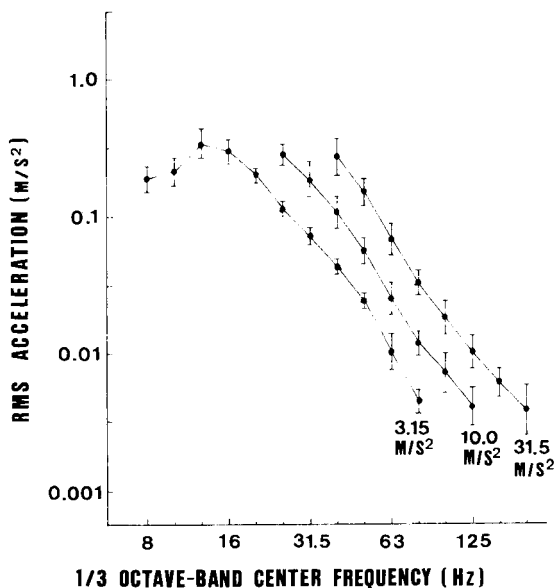


Figure 2. Vertical vibration (mean $\pm$ SD) transmitted to the head of the subjects during exposure of the hand to vertical sinusoidal vibration at the acceleration of 3.15, 10.0, and 31.5 m/s² root mean square (RMS). (M/S² = meters per square second)

between them was within 3 dB. There were some differences in the results among the subjects, but the patterns were approximately similar. The vibration transmitted to the head was the greatest at frequencies from 12.5 to 16 Hz, and above 20 Hz it decreased as the frequency increased.

The vibration transmitted to the head of the subjects and the attenuation between the excitation vibration (handle of vibrator) and the head vibration are shown in figure 2 and table 1. The head vibration was the greatest in the range of 12.5–16 Hz, and the attenuation was about 20 dB. In the range of 20–125 Hz at every excitation level the vibration transmitted to the head decreased at the rate of approximately 15 dB per octave.

When the excitation level was increased by 10 dB, the vibration transmitted to the head increased about 8 dB at every frequency.

Discussion

A method for measuring head vibration using a tooth impression was examined in an earlier study (6). The results showed that the method has good reproducibility. In the present experiments the difference between two measurements was also within 3 dB, which was similar to the results of the prior study.

The difference between measurements on the forehead and those on the tooth impression was investigated in earlier studies (6, 8). These studies indicated that measurement on the forehead was influenced by the fixing condition of the accelerometers, and the measurement level on the forehead was higher than that on a tooth impression at frequencies below 25 Hz. The results were reversed at frequencies above 80 Hz. The difference may be due to the soft tissue or the position of the accelerometers on the head. The influence of the soft tissue is smaller in measurements on a tooth impression than on the forehead. The influence of the position of the head has been indicated to be due to the difference in angular head movement, such as nodding (4, 10) and/or anatomical structure. Eliminating the influence is difficult. But the obvious effects of the head movement should be taken into account. It can be concluded that measuring head vibration with a tooth impression is more accurate because there is little influence from the soft tissue.

Various methods of measuring head vibration have been devised. "Bite-bar" by Griffin (4), "dental bite" by Sandover (10), and "Beiß — platte" by Szameitat & Dupius (12) are similar to our "tooth impression" approach. Griffin reported that the bite-bar method is a highly acceptable and repeatable technique. The difference between their method and the present one is in the way these devices are fixed. For fixation, the former devices must be bit in the mouth, but the latter is closely set in the upper central incisors. Thus, the present method would appear to be superior.

Table 1. Attenuation between the vibrating handle and the head.

One-third octave-band center frequency (Hz)	Attenuation (dB)					
	At excitation of 3.15 m/s ²		At excitation of 10.0 m/s ²		At excitation of 31.5 m/s ²	
	Mean	SD	Mean	SD	Mean	SD
8	24.6	1.8	.	.	.	.
10	23.5	2.1	.	.	.	.
12.5	19.5	1.9	.	.	.	.
16	20.5	1.7	.	.	.	.
20	23.9	1.1	.	.	.	.
25	28.8	1.2	30.9	1.5	.	.
31.5	32.8	1.3	34.8	2.3	.	.
40	37.3	1.0	39.4	2.3	41.4	2.6
50	42.4	1.2	44.9	1.9	46.5	1.9
63	49.8	2.6	52.0	2.4	53.3	2.3
80	57.1	1.7	58.5	1.7	59.6	1.8
100	.	.	62.9	2.8	64.8	2.5
125	.	.	67.8	2.8	69.8	2.4
160	.	.	.	.	74.4	2.1
200	.	.	.	.	78.4	3.7

Denisov (2) examined head vibration under similar conditions in the range of 8–125 Hz at octave intervals. His results were similar to the present ones in the range of 16–125 Hz except at 8 Hz. Von Bekésy (1) has reported that the attenuation was about 40 dB at the frequency of 50 Hz. In the present experiment it was 42 dB at an excitation level of 3.14 m/s² rms. These results were nearly the same except for the low frequency in spite of some difference in the experimental conditions of these studies. For instance, the manner of attaching the accelerometers, the location of the accelerometers, the gripping force, and the excitation level.

The present experiment showed that the vibration transmitted to the head was the greatest at 12.5 to 16 Hz. Iwata et al (5) and Dupuis et al (3) have indicated a resonance at 10–16 Hz in the wrist and elbow. These findings suggest that the vibration measured in the wrist of our subjects may have been transmitted to the head without any deformation of the frequency distribution, since the subjects kept their elbow joint stretched.

Pyykkö et al (9) have reported that the attenuation recorded in the elbow was almost the same regardless of the excitation level. In the present study head vibration was increased by about 8 dB when the excitation level was increased by 10 dB. The difference may be attributed to the position of measurement, in the elbow or in the head, and the measuring method. More investigations would be required on this point.

The attenuation between the excitation vibration and the head vibration was about 20 to 25 dB at frequencies below 20 Hz. Under the present experimental conditions head vibration can be estimated to be approximately 1.0 to 3.15 m/s² when the hand is exposed to vibration levels of 31.5 m/s². Thus head vibration might affect the human body. These effects should be further investigated.

The vibration transmission to the body is influenced by the grip strength on the vibrator handles (2, 9),

postures (4, 7, 9), and other factors. The grip strength and posture vary greatly in the use of vibrating tools. The vibration transmitted to the head would also vary widely. The authors are, therefore, planning to examine head vibration under field conditions.

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