FREQUENCY WEIGHTING OF HAND-TRANSMITTED VIBRATION FOR EVALUATING COMFORT

Setsuo Maeda[1], Serap G. Geridonmez[2], Kazuhisa Miyashita[3], and Kazuma Ishimatsu[4]
[1]Department of Applied Sociology, Kinki University, 3-4-1 Kowakae, Higashiosaka 577-8502, Japan
[2] Department of Engineering Sciences, Middle East Technical University, Ankara 06531, Turkey
[3]Department of Hygiene, School of Medicine, Wakayama Medical University, 811-1, Wakayama, 641-8509, Japan
[4] National Institute of Occupational Safety and Health, 6-21-1 Nagao Tama-ku Kawasaki, 214-8585, Japan

1. INTRODUCTION

The purpose of this research is to establish a suitable frequency-weighting curve for comfort evaluation with regard to hand-arm vibration using the category judgment method (Guilford, 1954). Many frequency-weighting curves based on biodynamic responses or on epidemiological data for hand-arm vibration exposure have been proposed by many researchers, as shown in Figure 1. It is not clear which frequency-weighting curve is best for establishing relationships between frequency-weighted r.m.s. acceleration and hand-arm vibration comfort. Therefore a psychological experiment has been performed to investigate the effectiveness of the frequency weightings in Figure 1 to predict comfort.

2. APPARATUS AND METHOD

2.1. Apparatus

A shaker with a power amplifier (VA-ST-03, IMV Corp.) and signal processing unit (F2 SPU, IMV Corp.) were used in the experiments. All vibration stimuli were generated on the handle, and the frequency-weighted r.m.s. vibration acceleration was feedback controlled by the F2 SPU controller and computer.

2.2. Method

A series of 15 vibration stimuli (three times for five levels of vibration stimuli, respectively), each of which was randomly ordered, were applied in the X_h axis to the right hand of each subject, who was seated in a relaxed posture. All vibration stimuli had a duration of five seconds with a two-second pause between them. The vibration load was applied in the direction of the X_h axis with a predetermined stimulus program input into the vibrator, and then applied to the subject grasping the vibrating handle. The grasping force was about 2-3 N. The diameter of handle was 0.03 m and the length was 0.12 m. The subjects were issued verbal responses to each vibration stimulus, selecting from five evaluation categories using the designated numeric value (1 to 5) for each category (Maeda and Shibata, 2008).

The subjects were exposed to vertical vibrations before being asked to choose a numerical category to indicate their best perceived level of comfort during each stimulus. The creation of this assessment scale, including the afore-mentioned categories, enabled not only the clarification of the relationship between the vibration stimuli and the degree of comfort but also the connection between the r.m.s. acceleration frequency-weighted according to Figure 1 and the corresponding comfort categories.

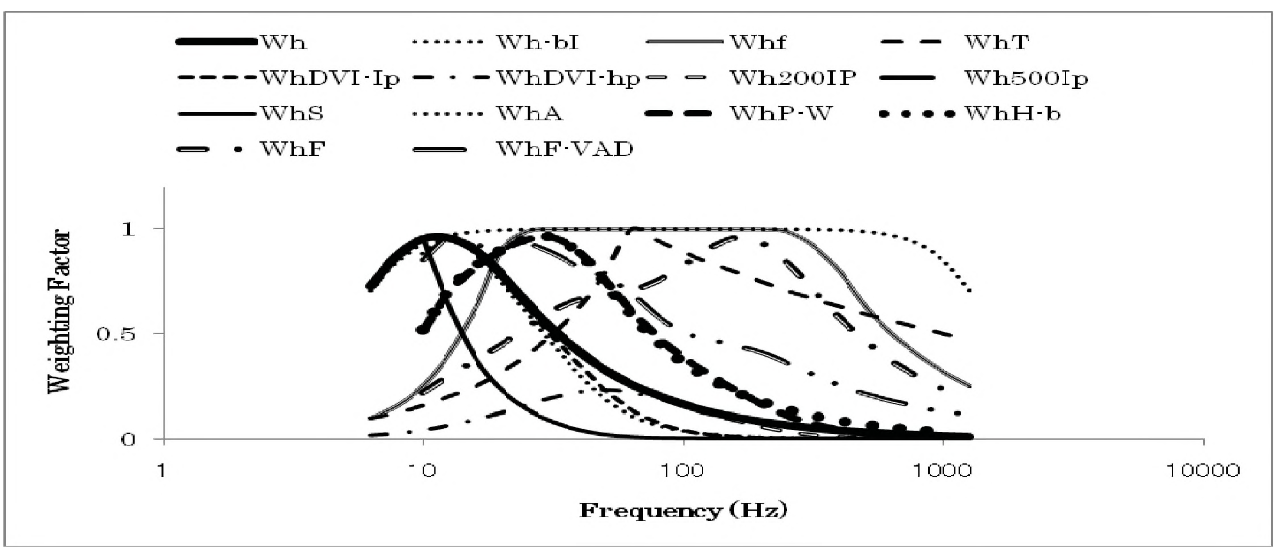

Figure 1. Comparison of frequency weighting curves (for explanations see Table 1).

The experiments were conducted using random signals for the stimuli over a frequency range of 1-1000 Hz, similar to the ISO 5349-1 standard evaluation range.

In addition, in order to clarify the individual characteristics of the different spectra, varying degrees of high and low frequency components were used. The stimuli consisted of three kinds of signals, designated: stimulus F, with a flat PSD from 1 to 1000 Hz; stimulus H, with a PSD that became 20 dB higher at 1000 Hz than at 1 Hz, and; stimulus L, with a PSD 20 dB lower at 1000 Hz than at 1 Hz. The signals were modified using the W_h frequency weighting of ISO 5349-1:2001, and the frequency-weighted r.m.s. accelerations were adjusted to be equal. In addition, the magnitudes of the signals were varied over a range of five steps to make 15 kinds of stimuli with accelerations of 0.28, 0.56, 1.12, 2.48 and 4.48 m/s^2 r.m.s. These stimuli were selected from the specific vibration magnitudes of hand-held vibration tools. Each one of these signals was used three times, comprising a total of 45 stimulus applied in random order, each for a duration of five seconds with a two-second pause between stimuli. Each subject in the experiment experienced all stimuli. This meant that each subject was exposed to a total of 225 seconds of vibration, which even when the exposure time is considered, is in the acceptable range for the ISO 5439-1:2001.

2.3. Subjects

The experiments were performed with twelve healthy subjects, six males and six females, with mean ages of 23.2 and 24.5 years, respectively. All of the subjects were non-smokers. None of the subjects had been exposed to high magnitudes or long periods of hand-arm vibration occupationally or in their leisure time activities. The experiments were approved by the Research Ethics Committee of the Japan National Institute of Occupational Safety and Health. All the subjects underwent an explanation of the test procedure and gave their written informed consent to participate in the study.

3. RESULTS

The category judgment method can establish the relationship between the frequency-weighted r.m.s. acceleration according to the frequency weighting curves shown in Figure 1 and the corresponding categories representing each degree of comfort for hand-arm vibration. In order to clarify the effectiveness of the frequency-weighting curve for evaluating the hand-arm vibration comfort, the effectiveness was quantified in terms of the square root of the sum of the squared differences between the least square line of the category judgment results and the experimental data (i.e., r.m.s. errors), as shown in Table 1 (Maeda and Griffin, 1994).

Table 1. Effectiveness (the r.m.s. errors) obtained from the frequency-weighting curves as shown in Figure 1.

Frequency-Weighting Curve	R.M.S. Error
Wh (ISO 5349-1)	1.963
Wh-bl (band-limiting component of Wh)	6.167
Whf (Finger vibration power absorption)	5.441
WhT (Epideiological data)	5.775
WhVDI-lp (Wh with 24dB/Oct low-pass filter at 50 Hz)	2.680
WhVDI-hp (Wh with 24dB/Oct high-pass filter at 50 Hz)	2.925
Wh200lP (VDI 2057 200 Hz)	2.245
Wh500lp (VDI 2057 500 Hz)	2.017
WhS (Biodynamic Response of Shoulder)	3.599
WhA (Biodynamic Response of Arm)	2.729
WhP-W (Biodynamic Response of Palm and Wrist)	1.966
WhH-b (Biodynamic Response of Hand back)	1.945
WhF (Biodynamic Response of Finger)	5.426
WhF-VAD (Finger of Vibration Absorption Density)	2.979

4. DISCUSSION

From the results for r.m.s. errors in Table 1, the most suitable frequency-weighting curves for evaluating hand-arm vibration comfort are WhH-b, Wh, and WhP-W. From Figure 1, the shapes of the weighting curves WhH-b, Wh, and WhP-W are almost same. But, the weighting factors are a little greater than the ISO 5349-1:2001 weighting factors. Although the frequency-weighting curves Wh-bl, Whf, and WhT are suitable for evaluating the hand-arm vibration syndrome, the r.m.s. errors of these frequency- weighting curves are large. Therefore, these weighting curves are not suitable for evaluating hand-transmitted vibration comfort. From this experiment, it is clear that the frequency-weighting curve of the current standard, ISO 5349-1:2001, is suitable for evaluating hand-transmitted vibration comfort.

REFERENCES

Guilford, J. (1954) *Psychometric methods* (McGraw-Hill, New York).

ISO 5349-1 (2001). (International Organization for Standardization, Geneva).

Maeda, S., and Griffin, M. J. (1994). "A comparison of vibrotactil thresholds on the finger obtained with different equipment," Ergonomics, **37**, No.8, 1391-1406.

Maeda, S., and Shibata, N. (2008). "Subjective Scaling of Hand-Arm Vibration," Ind. Health, **46**, 118-124.