A consideration of an evaluation index for high-level low-frequency noise by taking into account the effect of human body vibration

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At high sound pressure levels, actual body vibrations (noise-induced vibrations) are induced by low-frequency noise. The purpose of this trial study was to show that considering the effects of noise-induced vibration is effective in evaluating high-level low-frequency noise. Using the A-weighted sound pressure level and the W_k-weighted vibration acceleration level of noise-induced vibration measured on the chest as independent variables, empirical evaluation indices (HLLF1, HLLF2 and HLLF3) for evaluating the unpleasantness caused by high-level low-frequency noise were estimated. The HLLF indices were found to be able to evaluate the unpleasantness caused by high-level low-frequency noise better than the A-weighted pressure level. In addition, the slopes of tentative frequency-weighting characteristics corresponding to the HLLF indices were estimated to be gentler than that of the A-weighting characteristic within 25-50 Hz, which was consistent with many previous results that indicated that noise content at lower frequencies should be given more importance when evaluating low-frequency noise Although there are several areas where the HLLF index needs to be improved before it is put in practical use, the results of this study suggest that high-level low-frequency noise could be more effectively evaluated by taking into account the effect of human body vibration.

1. INTRODUCTION

In working environments, various machines such as air compressors, exhaust fans and large engines generate low-frequency noise at frequencies below 100 Hz [1-3]. The sound pressure levels of these low-frequency noises are sometimes quite high, and occasionally exceed 100 dB(SPL). Low-frequency noise often causes unpleasantness or annoyance [1, 4-6]. However, it is well known that the A-weighted sound pressure level (SPL_A), which is usually used as an evaluation index for noise, underestimates the unpleasantness or annoyance caused by low-frequency noise or noise with a strong low-frequency content [7-9]. It is desirable to establish a suitable evaluation index for low-frequency noise

In 1995 the G-weighting characteristic was standardized [10]. However, the applicability of the G-weighted sound pressure level is limited because the G-weighting characteristic is designed only for evaluating infrasound within a narrow frequency range (1 to 20 Hz) [10]. Some previous studies have suggested that the B-weighting characteristic may be more suitable for evaluating low-frequency noise than the A-weighting characteristic [7, 8]. At present, however, the B-weighted sound pressure level (SPL_B) is not being employed in practical use. Schomer [11] and Schomer et al. [12] have proposed loudness-level weighting. The essential idea of their research is to use the human equal-loudness level contours [13] as dynamic frequency-weighting characteristics. It is expected that the loudness of low-frequency noise is more appropriately evaluated by the loudness level (LL) than by the SPL_A. However, there is a possibility that other factors in addition to the loudness of a noise may contribute to the psychological effects caused by low-frequency noise. Inukai et al. found that human responses to low-frequency noise were primarily contributed by three factors: sound pressure, vibration and loudness [14]. They proposed the LF-weighting characteristic, which takes into account not only the effects of loudness but also the effects of vibratory and oppressive sensations [15]. Like the SPL_B, however, the LF-weighted sound pressure level (SPL_{LF}) is not currently being employed in practice.

When a person is exposed to high-level low-frequency noise, bodily vibrations are induced [16-18]. Although the levels of this vibration (noise-induced vibration) are not especially high, our previous studies have suggested the possibility that noise-induced vibration primarily contributes to vibratory sensation and, through the vibratory sensation or together with other factors, secondarily contributes to the unpleasantness or annoyance experienced by persons exposed to high-level low-frequency noise [19, 20]. Noise-induced vibration may be a useful basis for an evaluation index for low-frequency noise at high sound pressure levels.

The purpose of the present trial study was to show that considering the effects of noise-induced vibration is effective in evaluating high-level low-frequency noise, and to investigate a suitable evaluation index for such noise by taking into account not only the effects of loudness but also those of noise-induced vibration.

2. METHODS

2.1. OUTLINE OF EXPERIMENTS

Experimental data obtained in three previous independent experiments (Experiment 1, Experiment 2 and Experiment 3), was re-analyzed. The methods and procedures used in these three experiments are outlined below. For further details, please refer to References 19-20.

Six male subjects (20-27 yr, mean = 24.3, SD = 2.1) with normal hearing abilities participated in Experiment 1 [20]. Seven types of stationary low-frequency noises were used as noise stimuli (Table I). Two of the stimuli were pure tones, with frequencies of 25 and 50 Hz and a sound pressure level of 100 dB(SPL). The other five stimuli were complex noises, each composed of two pure tones. For the complex noise stimuli, the sound pressure level of one of the two tonal components was set at 100 dB(SPL), while that of the other tonal component was either 90, 95 or 100 dB (S PL).

The experiment was carried out in a soundproof test chamber (3.16 m (W) x 2.85 m (L) x 2.80 m (H)) equipped with twelve loudspeakers (TL-1801, Pioneer,

Table I The low-frequency noise stimuli used in Experiments 1 and 2. The 25-Hz tone was used in Experiment 1, and the 31.5-Hz tone was used in Experiment 2.

	Combinations and sound pressure levels (dB(SPL))	
	25- (or 31.5-) Hz	**50-Hz**
Pure tones	100	-
	-	100
Complex noises	100	100
	100	95
	100	90
	95	100
	90	100

Japan). The subject in a standing position was exposed to the seven types of noise stimuli in random order. During exposure to each noise stimulus (1 min), noise-induced vibrations perpendicular to the body surface were detected at the right anterior chest (2 cm above the right nipple) and the left anterior chest (2 cm above the left nipple). Two small (3.56 mm x 6.85 mm x 3.56 mm) and lightweight (0.5 g) accelerometers (EGA-125-10D, Entran Devices, USA), detected noise-induced vibrations at the right and left chest simultaneously. After the FFT analysis, the spectral components at 25 and 50 Hz of the detected noise-induced vibration were transformed to vibration acceleration levels (VALs) defined as

$$\mathrm{VAL} = 20 \times \log_{10}(a_{meas} / a_{ref}) \text{ [dB]},$$

where a_{meas} was a measured acceleration (m/s^2 (r.m.s.)) and a_{ref} was the reference acceleration equal to 10^{-6} m/s^2. For the complex noise stimuli, we then calculated the total vibration acceleration level (VAL_{total}) defined as the power summation of two VALs (the 25-Hz component and the 50-Hz component).

During a one-minute rest period assigned after each noise exposure, the subject rated the unpleasantness perceived during the preceding exposure as 1, 2, 3, 4 or 5 based on whether the unpleasantness was 'not sensed', 'slightly sensed', 'mildly sensed', 'strongly sensed' or 'very strongly sensed', respectively. Unpleasantness was defined as a totally unpleasant feeling, including a feeling of discomfort, a feeling of annoyance, and the wish that the noise stimulus would diminish. Throughout the measurements, the subjects wore no hearing protection so that they could be exposed to the low-frequency noise stimuli under normal hearing conditions.

In Experiment 2 [20], six male subjects with normal hearing abilities (19-25 yr, mean = 22.8, SD - 2.1) participated. Seven types of low-frequency noise stimuli were used in which the 25-Hz tone of Experiment 1 was replaced with a 31.5-Hz tone (Table I). All other experimental methods were the same as those in Experiment 1.

Nine male subjects (21-24 yr, mean = 22.6, SD = 1.0) with normal hearing abilities participated in Experiment 3 [19]. The noise stimuli used in this experiment included fifteen types of stationary low-frequency pure tones (Table II). The frequencies of these stimuli were 20, 25, 31.5, 40 and 50 Hz, and their sound pressure levels were 100, 105 and 110 dB(SPL). In this experiment, subjective unpleasantness was rated as 1, 2 or 3 based on whether the unpleasantness was 'not sensed', 'mildly sensed' or 'strongly sensed', respectively. The VAL_{total} was not calculated because the noise stimuli were pure tones. All of the other experimental methods were the same as those in Experiment 1.

The protocols of the three experiments were approved in advance by the Research Ethics Committee of the National Institute of Industrial Health, Japan (now known as the National Institute of Occupational Safety and Health, Japan).

2.2 ESTIMATION OF EVALUATION INDICES

In order to estimate an empirical evaluation index for high-level low-frequency noise by taking into account both the effects of loudness and those of noise-induced vibration, we performed a multiple regression analysis on the

Table II The low-frequency noise stimuli used in Experiment 3.

	Frequencies (Hz)	Sound pressure levels (dB(SPL))
Pure tones	20, 25, 31.5. 40. 50	100,105,110

experimental data obtained in Experiment 1. In this analysis, we adopted the mean rating score (RS) of unpleasantness as a dependent variable, and adopted the SPL_A as an independent variable representing the contribution to the unpleasantness made by the loudness. As an independent variable representing the contribution made by noise-induced vibration, we did not use the raw VAL_{total} but the $VAL,_{k,total}$, which was defined as the VAL_{total} to which the W_k-weighting characteristic was applied. This was because a physical stimulus such as vibration was, in general, frequency-dependently related to psychological responses such as unpleasantness. The W_k-weighting characteristic is a frequency-weighting characteristic standardized for evaluating the discomfort of a person exposed to a whole-body vibration [21]. As described below in the discussion section, our previous results have suggested that applying the W_k-weighting characteristic to noise-induced vibration is provisionally valid [19, 20]. We adopted the mean $VAL_{k,total}$, which was the averaged value of two mean $VAL_{k,total}$, values measured at the right and left chest, as an independent variable representing the contribution made by noise-induced vibration, because no clear difference was observed between these two values [17, 18]. This multiple regression analysis was performed on the condition that the regression coefficients for the SPL_A and the $VAL_{k,total}$ were calculated to be positive.

The evaluation index estimated on the basis of the experimental data of Experiment 1 will be referred to temporarily as the HLLF1 index in the rest of this paper. By the same method, the HLLF2 index and the HLLF3 index were estimated on the basis of the experimental data from Experiment 2 and Experiment 3, respectively. In estimating these HLLF indices on the basis of the experimental data obtained for pure tonal stimuli, we used the VAL_k rather than the $VAL_{k,total}$.

2.3. ESTIMATION OF FREQUENCY-WEIGHTING CHARACTERISTICS CORRESPONDING TO THE HLLF INDICES

For practical use, it is preferable that a frequency-weighting characteristic corresponding to an evaluation index is available. In a previous study using low-frequency pure tones as noise stimuli, the equal-acceleration level contour was considered to be a contour connecting the sound pressure levels at which equal VALs of noise-induced vibrations were induced, and roughly estimated the contour in the 25- to 50-Hz range [22]. Using the notation of the present study, the equal-acceleration level contours estimated at the chest can be expressed approximately as

$$SPL = - 50 \times \log_{10}(f) + VAL + 90,$$

where f is the frequency [Hz] and SPL is the non-weighted sound pressure level [dB(SPL)] of a low-frequency noise stimulus. Using this expression, the frequency-weighting characteristics corresponding to the HLLF1, HLLF2 and HLLF3 indices were tentatively estimated. For simplicity, in this estimation, only low-frequency pure tones were considered.

3. RESULTS

3.1. HLLF INDICES

On the basis of the experimental data in Experiment 1, we obtained the multiple regression equation

$$RS = 0.045 \times SPL_A + 0.062 \times VAL_{k,total} - 5.0.$$

We temporarily defined the HLLF1 index as the right side of the above equation. That is,

$$HLLF1 = 0,045 \times SPL_A + 0.062 \times VAL_{k,total} —5.0.$$

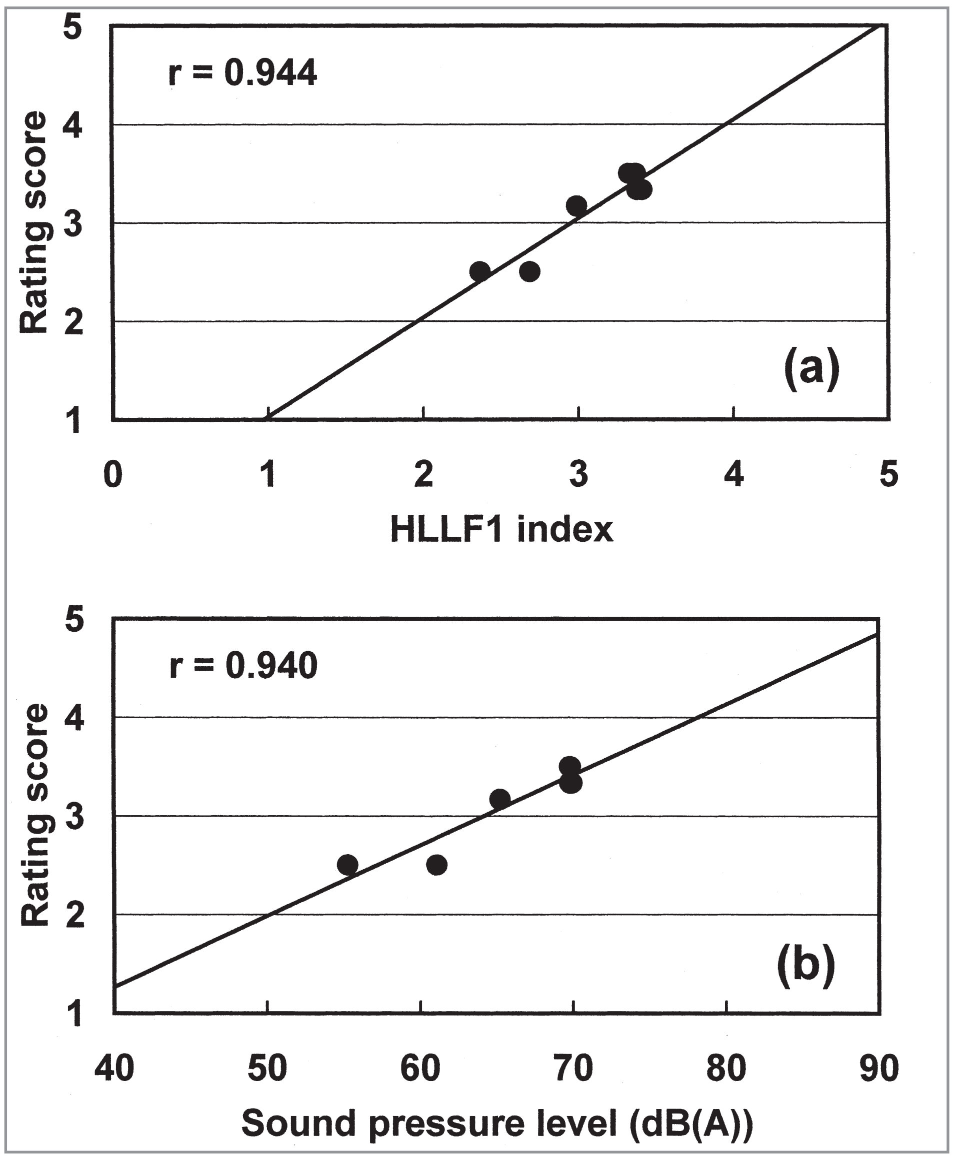

Fig. 1 *The correlation between the mean rating scores of unpleasantness and: (a) the HLLF1 index values; and (b) the A-weighted sound pressure levels. This figure shows the correlation obtained In Experiment 1.*

In Fig. 1, the mean rating scores of unpleasantness in Experiment 1 are correlated with the HLLF1 index values (Fig. 1 (a)) and with the SPLA values (Fig. 1 (b)). The correlation coefficient calculated for the HLLF1 Index was 0.944 ($p<0.01$), which was larger than that calculated for the SPL_A, which was 0.940 ($p<0.01$).

The HLLF2 index and HLLF3 index were estimated as

$$HLLF2 = 0.001 \text{ x } SPL_A + 0.11 \text{ x } VAL_{k,total} — 6.3$$

and

$$HLLF3 = 0.001 \text{ x } SPL_A + 0.063 \text{ x } VAL_{k,total} — 3.4,$$

respectively. The mean rating scores of unpleasantness in Experiment 2 were found to correlate more closely with the HLLF2 index than with the SPL_A. Similarly, the mean rating scores of unpleasantness in Experiment 3 were in closer correlation with the HLLF3 index than with the SPL_A. The correlation coefficients for these correlations are listed in Table III

Table III The correlation coefficients calculated for the correlation between the rating of unpleasantness and eight evaluation indices.

Evaluation indices	**Correlation coefficients**		
	Exp. 1	Exp. 2	Exp. 3
HLLF 1	0.944^{**}	0.860^{*}	0.766^{**}
HLLF2	0.932^{**}	0.869^{*}	0.834^{**}
HLLF3	0.933^{**}	0.869^{*}	0.834^{**}
SPL	0.356	0.627	0.789^{**}
SPL_A	0.940^{**}	0.848^{*}	0.665^{**}
SPL_B	0.953^{**}	0.844^{*}	0.766^{**}
SPL_{LF}	0.948^{**}	0.843^{*}	0.704^{**}
LL	0.950^{**}	0.784^{*}	0.678^{**}

HLLF1, HLLF2 and HLLF3: evaluation indices defined in this paper.

SPL: non-weighted sound pressure level.

SPL_A: A-weighted sound pressure level.

SPL_B: B-weighted sound pressure level.

SPL_{LF}: LF-weighted sound pressure level.

LL: loudness level.

$^{**}p<0.01$, $^{*}p<0.05$.

3.2 EFFECTIVENESS OF THE HLLF INDICES

The better evaluative ability of the HLLF1 index shown in Fig. 1 was trivial because the HLLF1 index was estimated using the SPL_A and an additional variable, the $VAL_{k,total}$. In order to verify the effectiveness of the HLLF1 index for evaluating unpleasantness, we applied the definition of the HLLF1 index to the experimental data of the other two experiments (Experiments 2 and 3), and then examined whether the HLLF1 index was able to effectively evaluate the unpleasantness rated in those experiments.

In Fig. 2, the mean ratings of unpleasantness in Experiment 2 are correlated with the HLLF1 index values (Fig. 2 (a)) and with the SPL_A values (Fig. 2 (b)). The correlation coefficient calculated for the HLLF1 index (0.860, $p<0.05$) was larger than that calculated for the SPL_A (0.848, $p<0.05$). Figure 3 (a) shows the correlation between the mean ratings of unpleasantness and the HLLF1 index values, while Fig. 3 (b) shows the correlation between the mean ratings of unpleasantness and the SPL_A values. The correlation coefficient calculated for the HLLF1 index (0.766, $p<0.01$) was clearly larger than that calculated for the SPL_A (0.665, $p<0.01$). The better evaluative abilities of the HLLF1 indices shown in Figs. 2 and 3 were not trivial because these HLLF 1 indices were defined according to the result of the multiple regression analysis in Experiment 1 that was carried out independently of Experiments 2 and 3. The results shown in Figs. 2 and 3 supported the effectiveness of the HLLF1 index in evaluating the unpleasantness caused by high-level low-frequency noise. In addition, these results indicated that the HLLF1 index could be consistently used to evaluate not only the unpleasantness caused by complex low-frequency noises but also that caused by low-frequency pure tones.

The effectiveness of the evaluations by the HLLF2 index and the HLLF3 index were also examined using the method described above. It was found that both of these evaluation indices had evaluative abilities similar to that of the HLLF1 index (Table III)

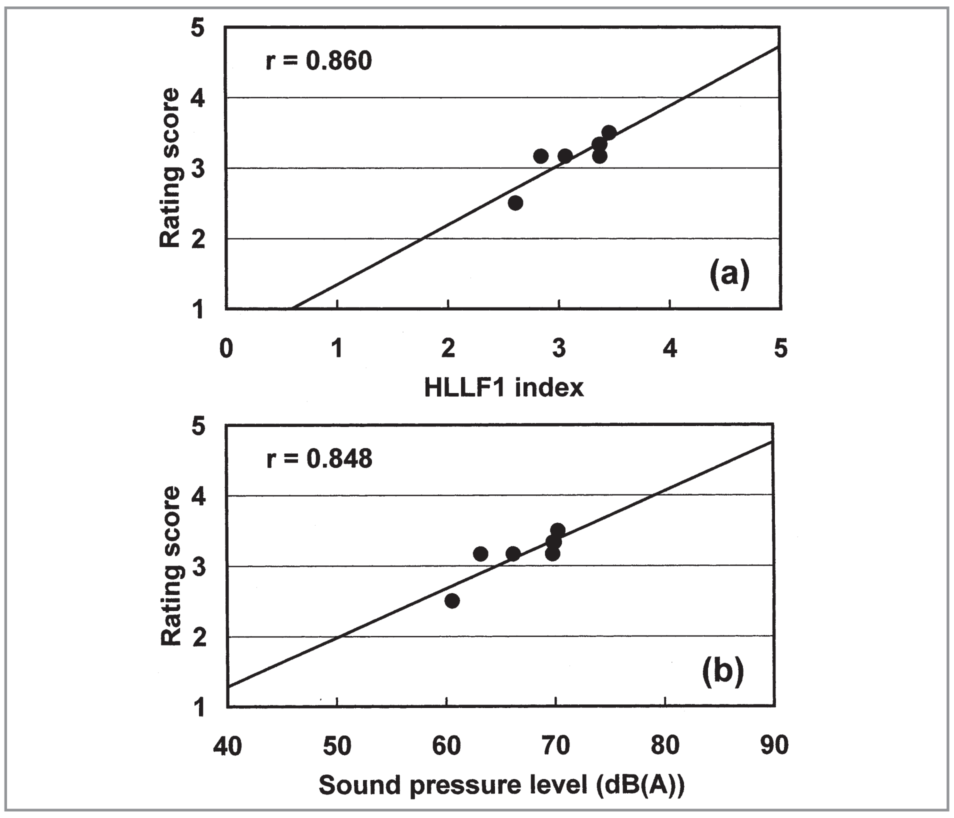

Fig. 2 *The correlation between the mean rating scores of unpleasantness and: (a) the HLLF1 Index values and (b) the A-weighted sound pressure levels. This figure shows the correlation obtained in Experiment 2*

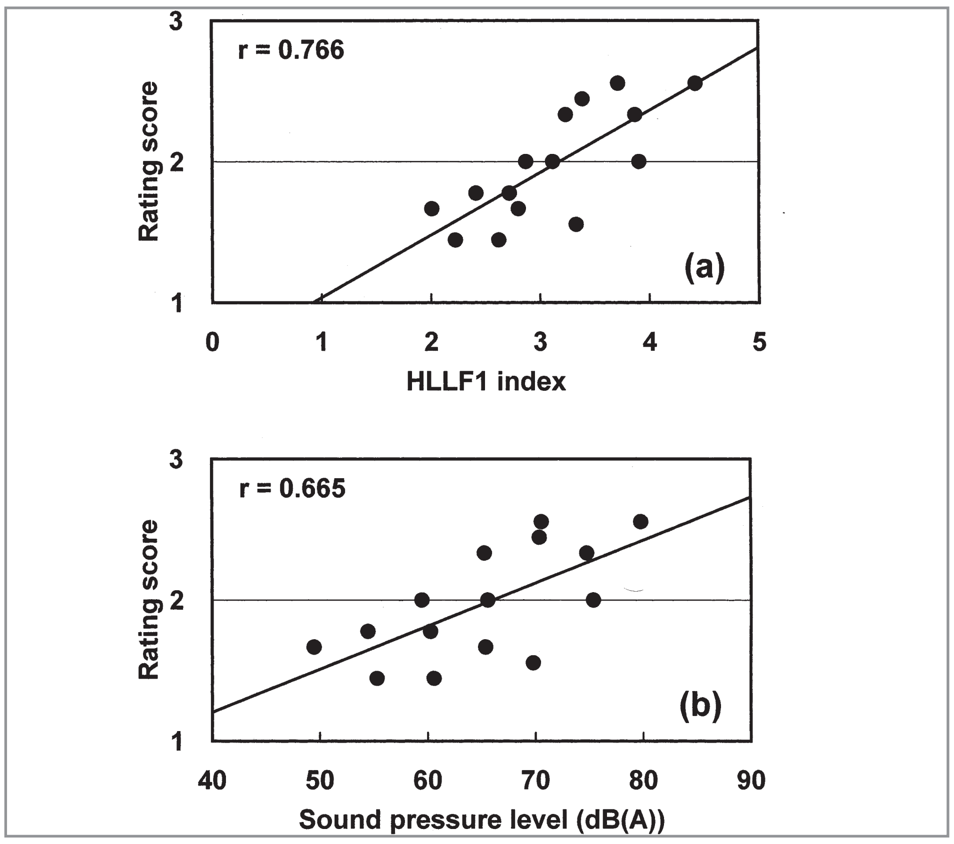

Fig. 3 *The correlation between the mean rating scores of unpleasantness and: (a) the HLLF1 index values; and (b) the A-weighted sound pressure levels. This figure shows the correlation obtained in Experiment 3.*

For comparison, we examined the correlations between the mean ratings of the unpleasantness in the three experiments and certain other evaluation indices, namely the non-weighted sound pressure level (SPL), the SPL_B, the SPL_{LF} and the LL. The SPL_{LF} values were calculated following the definition given by Inukai et al. [15], and LLs were calculated in accordance with the recent version of ISO 226 [13]. Table III summarizes the correlation coefficients calculated for these evaluation indices together with the correlation coefficients for the three HLLF indices and the SPL_A. The three shaded cells in Table III correspond to the trivially close correlations between the HLLF index and the rating of unpleasantness. In all three experiments, it was found that the three HLLF indices could evaluate the rating of unpleasantness comparably with or more effectively than the SPL_A. In addition, in Experiments 2 and 3, all of the three HLLF indices (the HLLF1, HLLF2 and HLLF3 indices) were included among the best four evaluation indices for unpleasantness. In Experiment 1, the evaluative abilities of all of the evaluation indices examined, except the SPL, were found to be comparable with each other.

3.3. FREQUENCY-WEIGHTING CHARACTERISTICS CORRESPONDING TO THE HLLF INDICES

Using the equal-acceleration level contours estimated at the chest [22], the HLLF1 index could be rewritten as

$$\begin{aligned} \text{HLLF1} &= 0.045 \times [\text{SPL} + C_A(f)] + 0.062 \times [\text{SPL} + 50 \times \log_{10}(f) - 90 + C_k(f)] - 5.0 \\ &= 0.107 \times [\text{SPL} + 0.42 \times C_A(f) + 0.58 \times C_k(f) + 29 \times \log_{10}(f)] - 10.6 \end{aligned}$$

where $C_A(f)$ and $C_k(f)$ represent the correction functions for the A- and W_k-weighting characteristics as $C_A(f)$ and $C_k(f)$, respectively. By regarding the correction terms for the SPL in brackets as a frequency-weighting function, we temporarily defined the tentative HLLF1-weighting characteristic as

$$C_{HLLF1}(f) = 0.42 \times C_A(f) + 0.58 \times C_k(f) + 29 \times \log_{10}(f).$$

By the same method, the tentative HLLF2- and HLLF3-weighting characteristics were estimated as

$$C_{HLLF2}(f) = 0.0091 \times C_A(f) + 1.0 \times C_k(f) + 50 \times \log_{10}(f)$$

and

$$C_{HLLF3}(f) = 0.016 \times C_A(f) + 0.98 \times C_k(f) + 50 \times \log_{10}(f),$$ respectively.

Figure 4 compares these three tentative HLLF-weighting characteristics, which were defined only in the 25- to 50-Hz range, with the A-, B- and LF-weighting characteristics. In Fig. 4, to facilitate comparison of the slopes within the 25-50 Hz range, all corrections of the six frequency-weighting characteristics were depicted by setting the corrections at 50 Hz to be equal to that of the A-weighting characteristic. The slopes of the three tentative HLLF-weighting characteristics were found to be clearly gentler than that of the A-weighting characteristic and similar to that of the B- or LF-weighting characteristics. The LF-weighting characteristic was established by taking into account not only the effects of loudness but also the effects of vibratory and oppressive sensations [15]. In addition, it is reasonable to consider that noise-induced vibration is related to vibratory sensation [23]. Therefore, it was considered plausible that the slopes of the tentatlve HLLF-weighting characteristics were similar to the slope of the LF-weighting characteristic.

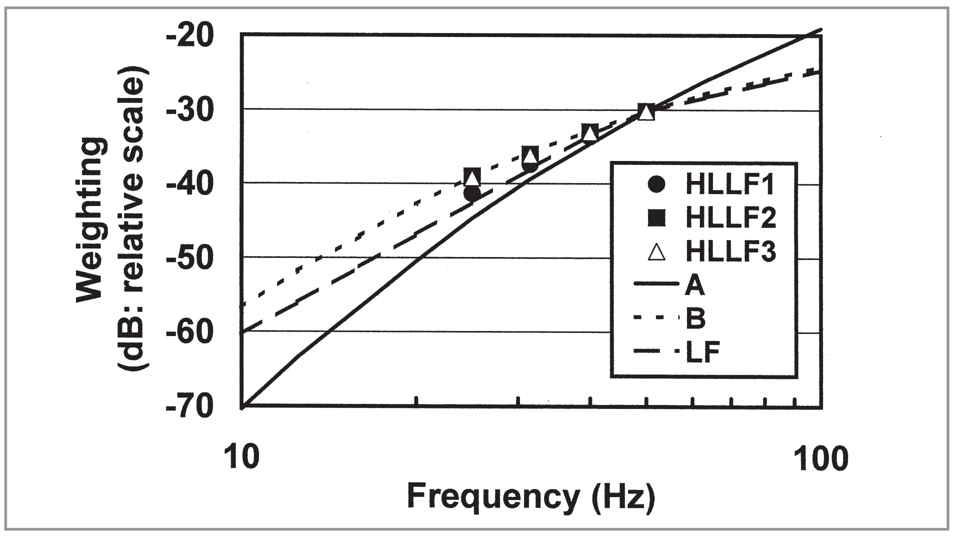

Fig. 4 *Comparison of six frequency-weighting characteristics: the tentative HLLF1-, HLLF2- and HLLF3-weighting characteristics estimated in this study, and the A-, B- and LF-weighting characteristics.*

4. DISCUSSION

The induction of a vibratory sensation is a remarkable feature specific to low-frequency noise, and many previous studies have reported that subjects perceive vibration when exposed to low-frequency noise stimuli [23-25]. The vibration is expected to be more strongly perceived at higher sound pressure levels, while our previous study has suggested that noise-induced vibration is related to the perception of the vibration [23]. Because the loudness of low-frequency noise also increases at higher sound pressure levels, it seems reasonable to speculate that high-level low-frequency noise could be more effectively evaluated by taking into account both the effects of loudness and those of noise-induced vibration. The three evaluation indices estimated in the present study (the HLLF1, HLLF2 and HLLF3 indices) were able to evaluate the unpleasantness caused by high-level low-frequency noise more effectively than was the SPL_A (TableIII). This result is consistent with the above speculation and supports the validity of considering the effects of noise-induced vibration in evaluating high-level low-frequency noise.

Some previous studies have pointed out that the SPL_B [7, 8], LL [11, 12] and SP_{LF} [15] are more suitable for evaluating low-frequency noise than the SPL_A. These evaluation indices have a common feature in that they evaluate noise content at lower frequencies more significantly than the SPL_A. Thus, for the effective evaluation of low-frequency noise, it seems essential to give more importance to the noise content at lower frequencies. In the present study, the slopes of the tentative frequency-weighting characteristics corresponding to the three HLLF indices were estimated to be similar to those of the B- or LF-weighting characteristics (Fig. 4). These results suggest the possibility that considering the effects of noise-induced vibration could lead to an evaluation method that gives more importance to the noise content at lower frequencies. The gentle slopes of the tentative HLLF-weighting characteristics estimated in the present study also support the idea that high-level low-frequency noise could be evaluated more effectively by taking into account the effects of noise-induced vibration.

However, several points regarding the HLLF index remain to be discussed, and several improvements should be made. First, although we hypothesized in this study that the W_k-

weighting characteristic was useful for relating noise-induced vibration to subjective unpleasantness, its applicability has not yet been determined conclusively. In our previous study using low-frequency pure tones [19], we estimated the slope of a tentative frequency-weighting that related the VAL of noise-induced vibration measured at the chest to subjective unpleasantness. The slope was estimated to be -8.5 dB/oct. in the 20-50 Hz range, which was close to the slope (approximately -6 dB/oct. in the 20-50 Hz range) of the W_k-weighting characteristic [21]. In another previous study [20], we showed that this tentative frequency-weighting estimated for pure tones was consistently applicable to noise-induced vibrations caused by complex low-frequency noises. These previous results have suggested that the application of W_k-weighting to noise-induced vibration is provisionally valid. In the future, more detailed investigations of a frequency-weighting characteristic that is suitable for relating noise-induced vibration to subjective unpleasantness should be performed.

Second, the validity of the use of the SPL_A as an independent variable representing the contribution of the loudness of low-frequency noise must be discussed. One alternative approach is to replace the SPL_A with the LL, the adoption of which is expected to allow for a more accurate evaluation of the loudness of high-level low-frequency noise [11, 12]. As we have already reported in another paper [26], however, this replacement did not remarkably improve the correlation coefficient between the rating of unpleasantness and the HLLF index. Thus, with regard to the experimental data treated in this paper, the SPL_A can be regarded as a suitable variable for representing the effect of the loudness of high-level low-frequency noise.

Another important point to be discussed is the effective ranges of both the sound pressure levels and frequencies within which the effects of noise-induced vibration should be taken into account. According to Yamada et al. [24], the threshold levels of the body sensation (i.e., the sensation of low-frequency noise through the perception of vibrations in the body) for normal-hearing persons are 10-30 dB(SPL) higher than their hearing threshold levels at frequencies below 63 Hz. This finding indicates that at sufficiently low sound pressure levels, it is controversial to consider the effects of noise-induced vibration. In addition, our previous results have indicated that at sufficiently low frequencies and sufficiently lower sound pressure levels, the VALs of noise-induced vibrations are expected to be lower than those of the vibrations inherent in the human body [17, 18]. In such a situation, the HLLF index cannot be properly defined. At sufficiently high frequencies, on the other hand, the VALs of noise-induced vibrations are expected to become lower due to the mechanical characteristics of the body tissue. It is meaningless to consider the effects of noise-induced vibration at such high frequencies. The HLLF index in the present study was estimated on the basis of the experimental data within a limited range of sound pressure levels and frequencies. To employ the HLLF index for practical use, its applicable range of sound pressure levels and frequencies has to be investigated and clarified.

In contrast to the HLLF indices, the SPL_{LF} and SPL_B are defined in a much wider frequency range, and their characteristics are independent of the sound pressure level. Figure 4 indicates that subjective unpleasantness caused by high-level low-frequency noise can be evaluated almost equally by the SPL_{LF} and the HLLF1 index. The SPL_B and other HLLF indices (HLLF2 and HLLF3) can also evaluate the unpleasantness equally. Therefore, the SPL_{LF} and the SPL_B can be used as alternatives to the HLLF evaluation indices. To the best of the authors' knowledge, however, the effectiveness of the SPL_{LF} and the SPL_B in evaluating high-level low.frequency noise has not been widely investigated. It would be valuable to investigate the usefulness of the SPL_{LF} and SPL_B using various experimental data.

5. CONCLUSIONS

Taking into account not only the effect of the loudness of the noise but also the effect of noise-induced vibration, we estimated an evaluation index for high-level low-frequency noise. The HLLF indices that we estimated were found to be consistently valid when applied to the experimental data obtained in three independent experiments, suggesting that subjective unpleasantness caused by high-level low-frequency noise could be more effectively evaluated by taking into account not only the contribution of loudness, but also that of noise-induced vibration. Before these HLLF indices can be put into practical use, however, several aspects need to be improved. On the other hand, the SPL_{LF} and the SPL_B were found to lead to an evaluation method similar to those in which the HLLF indices were employed. It would be valuable to widely investigate the effectiveness of SPL_{LF} and SPL_B in evaluating high-level low-frequency noise.

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NOISE OR FREE SPEECH?

Free speech does not protect a woman from being prosecuted for disorderly conduct after she continued to shout at police officers who warned her to stop, the Indiana Court of Appeals ruled. Latoya Blackman of Indianapolis began shouting "This is unconstitutional" and various obscenities at the officers as they arrested her brother on drug charges in front of their home in May 2005, according to court records. Officers told her to stop yelling and leave the scene, but she instead yelled even louder and a crowd began to gather. The officers warned her she would be arrested if she did not leave and handcuffed her when she failed to comply. She was later convicted of disorderly conduct. Blackman's defense attorney argued that the noise she caused wasn't unreasonable given the circumstances and that her shouts were protected speech under Indiana's Constitution. The three-judge panel disagreed Tuesday. "The facts before us plainly indicate that Blackman made unreasonable noise and continued to do so after being repeatedly asked to stop," Judge Carl Darden wrote in the 3-0 decision.

STILETTOS, SEX, NOISE, POLICE!

Police in Taiwan are getting growing numbers of complaints about noise, from loud sex to high-heel shoes clicking, but are powerless to do anything about it. The Taipei Times cited a recent incident in which a university professor complained to his apartment building's janitor about near-constant, erratic clicking coming from a new neighbour in the apartment above. The janitor explained the young woman liked to wear high heels all the time, so the professor went to the police. He was told existing noise pollution laws only cover noises made by mechanical means, such as karaoke machines, the newspaper said. That also applied to a woman who complained about the loud moaning and bed-banging sounds she heard at all hours from an apartment next door, where two university students live. Taichung City Environmental Protection Bureau officials told the Times the only solution was to ask the building's management committee to get involved and work out a compromise.

OPENCAST V. HUMAN RIGHTS

Residents of Merthyr Tydfil, Wales, who believe their lives will be devastated if a huge opencast development goes ahead, are planning to use human rights legislation in a last-ditch attempt to halt the scheme. Initial work is due to start next month on the Ffos-y-Fran site on the outskirts of Merthyr Tydfil following a Court of Appeal ruling last autumn. But neighbours of the scheme – which would be the biggest of its kind undertaken in the UK and take 22 years to complete – claim they have been discriminated against because they live in Wales. They argue that stricter planning legislation in Scotland would have ruled out the development there. While the key issues for those in the locality are noise, vibration, dust, the technical argument will centre around Article 14 of the Human Rights Act, which states that people in analogous situations should be treated in the same way. The point is being made that because of the proximity to residences, this scheme would not be permitted under Scottish regulations so an inequity exists for those living under Welsh regulations. However, a counter argument likely to be put forward is that since Welsh and Scottish are no longer under the same polity, Article 14 cannot apply.

HARTLEPOOL HOT LINE

The four-week trial noise hotline has been launched by Hartlepool Borough Council to combat noise problems across town. It comes in the wake of figures which show a sharp rise in complaints last summer. Council officials are urging residents not to put up with excessive late night noise and make sure they contact the new confidential phone number. Culprits could eventually find themselves facing fines of up to £5,000 if they snub the warnings given to them by the hotline team. Environmental health officer Stephanie Bristow said: “A typical example of excessive noise is when someone has maybe not gone out intentionally to have a party, but has ended up bringing people home. People are coming home from the pub and wanting to continue the party – that tends to be what we are getting called out for.” Noise complaints tripled in town last summer from 52 in 2005 to 157 in 2006.

EU ENTERS DEBATE

The debate on lowering carbon dioxide emissions and clean air has overshadowed the issue of road and transport noise with European legislators preparing a host of new laws to curb the noise level in densely populated city areas. “The issue of noise is a growing problem, especially in the cities,” says Dietmar Oeliger of the Berlin-based eco group NABU, pointing out that most of it comes from streets and roads. By mid 2007, a European Union directive takes effect, making it compulsory for urban areas to compile noise maps indicating in which sectors and roads the noise levels are the highest. Initially measurements will be taken in cities with more than 250 000 inhabitants and the main traffic arteries with more than six million vehicles annually. Later, the programme will be extended to areas with populations of 100 000. A year later, action plans must be tabled on how the noise levels can be reduced. Some of the solutions could include special road coatings that cause less noise and sound barriers along roads near homes. However, the plans will not be immediately implemented. Michael Niedermeier, traffic expert with Germany’s ADAC automobile association says the directive has no ceilings and offers no indication of what noise levels must be achieved. But NABU’s Dietmar Oeliger says it is just a matter of time before such regulations with a noise ceiling will be introduced. Car makers have made much technical progress in reducing the noise levels of vehicles but they are still far from silent. The German Federal Environmental Office In Dessau in 2005 conducted a study showing that cars are still as noisy as 25 years ago. “Engine noise has progressively been reduced In line with new legislation but the noise produced from tyres was never included in new directives. In reality, the noise coming from tyres at speeds of over 30-40 km/h is dominating,” says Michael Niedermeier. Engine noise is heard especially when cars stop at traffic lights. Progress made on reducing engine noise Is not as significant Is It could be, according to Gerd Lottsiepen from the German traffic association (VCD). In addition noise fluctuations cause different perceptions of the noise level. “Two cars with each producing a noise level of 71 decibel are perceived as one vehicle producing 74 decibel while four cars with 68 decibel are also heard as one vehicle with 74 decibel,” says Lottsiepen. “Most people do not really perceive the monotonous sound coming from a busy road. What is disturbing is the sudden sound coming from a heavy truck pulling a trailer or a loud motor cycle,” says Michael Niedermeier. According to the VCD’s Gerd Lottsiepen the motorist can do a lot to reduced noise levels. Crucial is whether the engine is revved up or not. Most cars can easily be driven in city areas at a rev count of about 2000 revs per minute, he says. Lottsiepen offers an idea of how big the difference can be: “32 cars driven at 2000 revs are as loud as one car driven at 4000 revs.”