主論文の要旨

Improvement of balance in young adults by a sound component at 100 Hz in music

（音楽の 100Hz の音成分による若年成人のバランスの改善）

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【Background】

Personal listening devices (PLDs) have become increasingly popular, especially among young adults. A previous study showed that about 80% of young people use PLDs in their daily life. Many epidemiological studies have shown associations of exposure to sound levels (dB) from a PLD with noise-induced hearing loss. Balance is a fundamental function in daily life, which is associated with an increased incidence of falls in adults. Previous human studies showed that exposure to noise of high intensities affected balance in humans. Music output from a PLD consists of sound components with various frequencies (Hz). However, there is no information about the frequency-dependent effect of sound components in music from a PLD on balance in young people.

【Methods】

This study was performed for 110 Japanese subjects with an average age of 20.4 ± 1.0 years. None of the subjects had a history of ear disease and none of the subjects were suffering from illness at the time of the investigation. A self-reporting questionnaire was used to collect basic information. Postural stability was measured by using a posturography system. Posturography parameters including track lengths and surface areas of the center of pressure were measured for analyses. Hearing examinations at frequencies of 1, 4, 8 and 12 kHz were performed with duplicated measurements by pure tone audiometry (PTA). A sound level meter was used to perform triplicate measurements of sound levels of components at 100, 1000 and 4000 Hz in music output from their PLDs and in the background.

All participants were divided into (low and high exposure groups) based on cut-off values of sound component levels at each frequency using receiver operating characteristic (ROC) curves. The Mann-Whitney *U* test and Kruskal-Wallis *H* test were used for nonparametric data to determine a significant difference between two groups and among three groups, respectively. Finally, we performed multivariate analysis using a logistic regression model adjusted with sex, BMI, smoking status and alcohol consumption. All statistical analyses were conducted using SPSS v24.0 (IBM Corp., Armonk, NY).

【Results】

The subjects included 52 females and 58 males with an average BMI of 21.4 ± 3.3 kg/m^2 (Table 1). The values of track length and surface area with eyes open and with eyes closed in males were significantly higher than those with eyes open and with eyes closed in females ($p < 0.05$) (Fig. 1A). Smokers had significantly larger surface areas with both eyes open and eyes closed than those of eyes open and eyes closed in non-smokers ($p < 0.05$) (Fig. 1C). There was no significant difference in any of the scores of posturography among different BMI and alcohol consumption groups (Fig. 1B, D).

Sound levels at 100, 1000 and 4000 Hz output from a PLD were 48.4 ± 4.0, 34.2 ± 10.3 and 40.4 ± 12.7 dB, respectively (Table 2). The results showed that surface areas with eyes open and eyes closed in the high exposure group at 100 Hz were significantly smaller than those with eyes open and eyes closed in the low exposure group (Fig. 2A). Track length with eyes closed in the high exposure group at 100 Hz was also less than that in the low exposure group ($p = 0.038$) (Fig. 2A). Comparisons between two groups categorized at 1000 and 4000 Hz showed that there were no significant differences between the low and high exposure groups (Fig. 2B, C).

We next determined the effects of sound component levels at 100 Hz, 1000 Hz and 4000 Hz on posturography scores in the logistic regression models adjusted for sex, BMI, smoking and alcohol consumption as confounding factors (Table 3). There was a significant association with a track length of eyes open with sound levels at 100 Hz [high exposure group vs. low exposure group: odds ratio (OR) = 0.39, 95% confidence interval (CI) = 0.16–0.95, $p = 0.039$]. Furthermore, the high exposure group at 100 Hz had smaller surface areas with both eyes open (OR = 0.26, 95% CI = 0.10–0.64, $p = 0.004$) and eyes closed (OR = 0.21, 95% CI = 0.08–0.53, $p < 0.001$) than those in the low exposure group (Table 3). However, we did not find any relationships between the scores of posturography and sound levels at 1000 or 4000 Hz (all $p > 0.05$) (Table 3).

【Discussion】

In this study, the group with high exposure at 100 Hz showed smaller values of track length and surface area in posturography, suggesting better balance than in the group with low exposure at 100 Hz. Furthermore, in the logistic regression models adjusted for confounders, the group with high exposure (≥46.6 dB) at 100 Hz showed significant ORs with less than 1.00. Thus, the results of this study showed a significant association of better balance with high exposure at 100 Hz compared to low exposure at 100 Hz.

Our results partially correspond to results of a previous study showing that stimulation by white noise at 55 dB significantly improved balance in patients with imbalance, although there was no mention in that report about which frequency was effective for balance. Sounds with frequencies below 100 Hz are defined as low frequency sound (LFS). Previous studies have shown that earphones connected to a PLD output sound with a frequency range of LFS. Thus, this pilot study showed for the first time that mild exposure to LFS included in music output from a PLD was associated with better balance in young adults.

On the other hand, there was no significant difference between hearing levels in the low and high exposure at 100, 1000 and 4000 Hz in this study (Fig. S1). All of the subjects were young and had exposure to sound components with levels below 85 dB at 100, 1000 and 4000 Hz. Our previous study showed that acute exposure to low frequency noise 5

times at 100 Hz, 95 dB for 12 hours each time did not cause hearing loss in mice. Thus, this study showed that the sound component with a frequency of at least 100 Hz in music from a PLD is associated with better balance, but not hearing loss, in young adults.

【Conclusion】

Thus, our human study showed an association of the sound component at 100 Hz with more than 46.6 dB output from a PLD with better balance in young adults. Further studies are needed to determine the mechanism and the effects of stimulation of the sound component at 100 Hz on balance in humans.