Basic Study on the Mechanism of Earphone Hearing Loss - Further Experiment Obtaining Ear Age and Real Age -

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ABSTRACT

In our laboratory, data on ear age are collected as a part of basic research on earphone hearing loss. The subjects listen to pure tones from 1 kHz to 21 kHz in 1 kHz increments, and their ear age are estimated based on whether or not they can be heard. In the present paper, the correlation between the real age and the ear age for 554 subjects at different locations is integrated. Then, a certain correlation was found between the real age and the ear age. Overall, the ear age increased with the real age, and there was a large variation in the ear age among young subjects under 30 years of age. In addition, the number of teenage subjects who have the ear ages of thirties was overwhelmingly large. There were also many subjects in their 20s with ear ages in their 30s, and it may be that young people around Shinjuku and Kamakura in Japan are likely to have deafness.

Keywords: Mean, Variance, Standard deviation, Correlation diagram, Pure tone.

1. INTRODUCTION

In our laboratory, basic research has been conducting with the aim of elucidating the mechanism of earphone deafness and proposing a quantitative evaluation method for deafness. Earphone deafness, one of the sensorineural hearing loss, occurs when the hair cells of the inner ear are destroyed by sound energy. The authors are trying to find out how to predict the progress of deafness and how to prevent it by organizing this fracture phenomenon based on the knowledge of the conventional fracture mechanics for metallic material [5,6].

As a part of the studies, the authors have set up several opportunities to collect ear age data at some places. The present paper integrates a part of the past findings on the real age and the ear age collected so far. Detailed analysis and discussions are left to another report.

2. PREVIOUS RESEARCH

First Investigation
Our laboratory started investigating earphone deafness in 2010 in response to the WHO warning [1,2]. The first survey had been started with questionnaire sheet on which subjects were asked to describe the earphone usage time and ear condition in addition to their real age and gender. Then, it became clear that many of the subjects whose cumu valuelative time of earphone use reached 10,000 hours had poor ear condition [3]. However, the survey method with the questionnaire-type sheet cannot quantitatively evaluate the causal relationship of deafness.

Hypothesis and Second Investigation
There were some subjects who did not have deafness after listening to earphones for 10,000 hours, so the authors made two hypotheses. First, some subjects have strong enough ears that they would not destroy no matter how much sound energy they receive. Second, even if the earphones are used for a cumulative total of 10,000 hours or more, the sound through the earphone which has too low energy cannot destroy the ear. In order to investigate the hypotheses, occupations, the annoyance of the work environment and home environment, the types of earphones and headphones, the content of sound information, etc. were added to the survey items to the extent possible. Here, questions that are overly detailed will not be answered in return. Trial and error has continued to determine what kind of questions should be asked according to the subject so that the information obtained from the answers can be maximized. Currently, 7229 subjects have given the responses, where there are some data in which information is partially missing.

Third Investigation with Hearing Test
In order to quantitatively evaluate the condition of the ear, a survey of ear age has started. The simplest survey method is a hearing test, that is, a method in which subjects listen to sounds of various frequencies and answer whether or not they can hear them. The pure sound of every 1 kHz frequency from 1 kHz to

21 kHz was initially employed, and the method is still continued to be used. Whether it is necessary to chop more finely is under debate. 554 subjects have responded to the survey up to now. Here, 17 subjects did not completely answer all the various questions about real age AR, ear age AE, and earphone use.

3. RESULTS TO BE INTEGRATED

Overview

The present paper integrates the results of 537 subjects so far regarding the correlation between the real age AR and the ear age AE. The data consists of data collected in Shinjuku in Tokyo Pref., data collected in Kamakura in Kanagawa Pref. next to Tokyo, and the other. The data collected in 2019 in Shinjuku and the data collected in 2019 and 2020 in Kamakura are shown below and then integrated.

Data Collected in 2019 in Shinjuku

At the open laboratory corner at the university festival of Kogakuin University held in 2019 in Shinjuku campus, many visitors agreed to become the subjects. Fig. 1 shows the ear age and the real age of the subjects in a scatter diagram. Each dot indicates the subject's real age AR and ear age AE. The horizontal axis is the real age AR, the vertical axis is the ear age AE, and the thin black dashed line in the graph indicates that they match. Marks colored red and blue means women and men, respectively. And solid marks and open marks are for the subjects with earphones and without earphones, respectively. In addition, each solid line is an approximate straight line of data like as the means position for women and men who use earphones, and the broken line is that for women and men who do not use earphones.

From this scatter plot, the difference between women and men and the difference between the use and non-use of earphones are not shown as significant differences. On the other hand, with the border around the age of 40, it can be seen that the older subjects have ear ages equivalent to their real ages, and the younger subjects have considerably damaged ears. Furthermore, the ear ages of young subjects vary widely. While the accuracy of the audiogram used in estimating ear age is currently under discussion, it can be said that the fact that there is such a variation confirms that some young people have noticeably hurt their ears. By the way, it is about 50 years old that the ear age AE and the real age AR match.

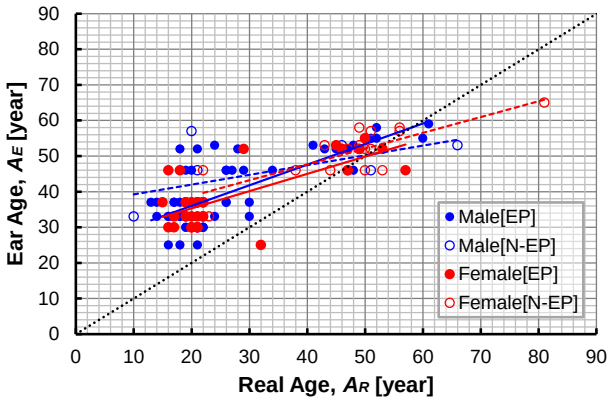

Fig. 1: Result of the Survey in 2019 in Shinjuku.

Data Collected in 2019 and 2020 in Kamakura

In the previous paper [3], the detailed description of the data collected in 2019 in Kamakura was given. And the same survey was conducted in 2020 at the same location. Furthermore, a similar survey is scheduled to be conducted in 2021 this year. Some of the subjects who came to the 2019 survey also participated in the 2020 survey. Most of them, nicely, had improved their ear ages. The detail about this would like to be presented later. The same investigation is in schedule to be implemented in 2021.

Fig. 2 shows a scatter plot. For subjects participating in both 2019 and 2020, data for both years are included in Fig. 2. This is because their 2 plots were taken in different situations and could be regarded as different data while they are for the same subject. In this scatter plot, the gender difference is clearly shown to some extent. On the other hand, there was no clear difference between the presence and absence of earphones. There are several possible reasons why the difference due to the presence or absence of earphones and the difference between women and men did not clearly appear, such as the fact that the information about what was being listened to through an earphone was not included. It would be a future issue.

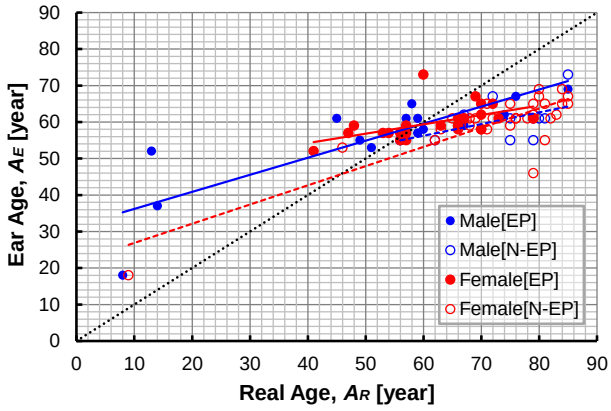

Fig. 2: Result of the Survey in 2019 and 2020 in Kamakura.

4. DATA INTEGRATION

Difference of Survey Conditions

The survey results in Shinjuku shown in Fig. 1 and those in Kamakura shown in Fig. 2 were obtained by estimating the ear age with the same sound source and audiogram [4]. On the other hand, the size of the survey site and the speakers used to reproduce the test sounds were different. While the volume is selected for each venue so that it is not bothersome and difficult to hear, it is not possible to carry out the survey at exactly the same volume each time, and the distance from the speaker to the subject also varies from venue to venue. However, it is generally said that a healthy person can hear the sound of the pitch that should be heard unless the volume is too low. Therefore, the characteristics of the sound which reaches the subject are treated as if there is no significant difference.

Comparison of These Results

In both Figs. 1 and 2, the real age of 50 to 60 years means a certain boundary age, and older subjects have a lower ear age

than the real age and the ear age of younger subjects is inferior to the real age. In particular, it can be seen that the ear ages of the subjects aged 10 to 20 years are remarkably high.

Both Fig. 1 and 2 shows that the ear age of female subjects is slightly younger than that of male, but neither result suggests a significant gender difference. As a medical finding, it is empirically said that women are less likely to suffer from deafness due to the effects of female hormones. To explain it in terms of fracture mechanics, it can be said that male hair cells are prone to brittleness because there are few female hormones, which helps the material to become ductile, in the male body.

Only the results shown in Fig. 2 suggested that the use of earphones tended to promote deafness. Here, it can be seen that the earphone usage rate of young people is remarkably high. In this survey, subjects were asked to answer their favorite music genre. A more detailed analysis of what the subjects listen to with earphones will give us a clearer picture of the effects of earphone use on ear age.

Integration of These Results

By superimposing the data of Figs. 1 and 2, the correlation discrete diagram of the ear age AE and the real age AR of 537 persons shown in Fig. 3 was obtained. The effects of gender differences and the use of earphones are still unclear. On the other hand, there was a clear tendency for young people to be deaf. More subjects will be needed to see a clear gender difference. There may be differences in the difficulty of hearing loss between ethnic groups. In order to confirm the effect of the presence or absence of earphone use, information such as how hard each subject is to have deafness, how long he / she has used an earphone, what he / she has listened to on the earphone, etc. should be properly considered and discussed, which will be done for another paper in future.

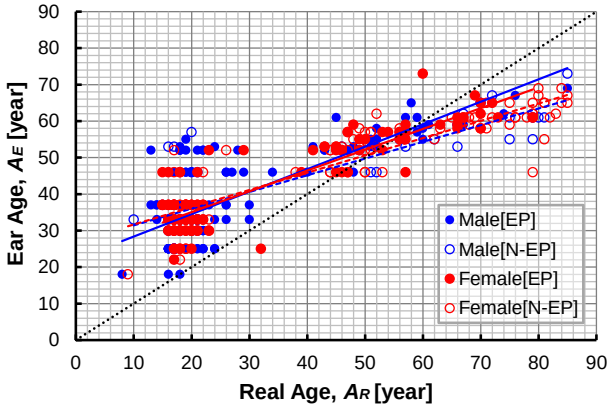

Fig. 3: Result of all the Survey shown in Figs. 1 and 2.

5. DISCUSSIONS

Mean and Variability

Fig. 4 shows the mean value and the variance value of the ear age for each real age. For each real age, the gray bar indicates the mean value of the ear ages of all the subjects, and the black circle mark and the black broken line connecting them indicate the variance value of that. In order to compare how much the degree of variance is relatively to the mean, standard deviation, which is defined as the square root of the variance and has the same unit as the mean, is usually discussed instead of the variance. However, in the present case, the standard deviation on the elderly side is considerably smaller than the mean, so variance was intentionally used to make the graph display easier to see.

The mean value rises at an almost constant rate with the real age. The solid lines and broken lines shown in Figs. 2, 3 and 4 can be considered as averages like mean straight lines which would be obtained with the number of subjects as a weight on the mean value of each age.

On the other hand, the variance of young subjects under 30 years old is remarkably large. It is possible that young people are more likely to hear deafening sounds. It may also be said that young people are more likely to have deafness. There are three peaks of variance at 24, 54 and 60 years old. It is considered that the variability become larger since the number of subjects of these ages was smaller than that of other ages.

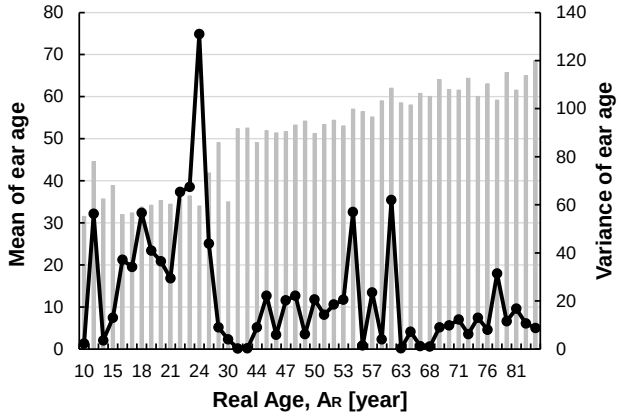

Fig. 4: Mean and variance of ear age of subjects each real age.

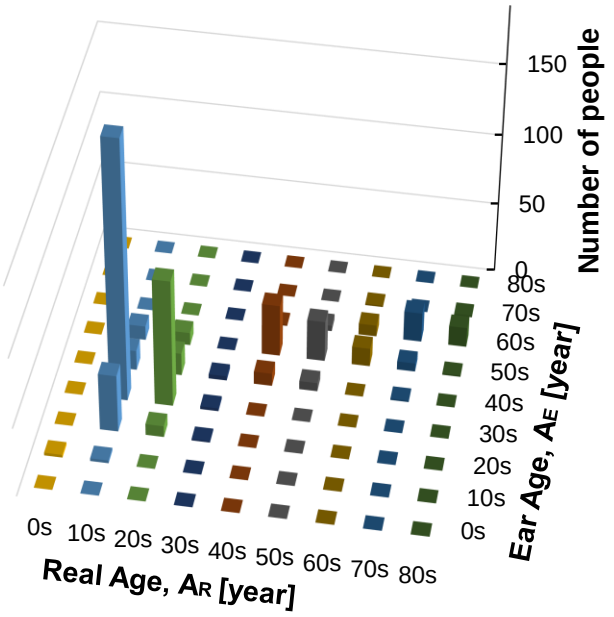

Fig. 5: Distribution of correlation.

However, even so, the peak of variance at the age of 24 is significantly large.

Distribution of correlation

The frequency distribution table, correlation table can be obtained with real age and ear age in 10-year increments. Fig. 5 shows the 3D histogram. Data existing at the boundary of classes, such as 10 years old, are defined to be in the upper class. That is, the 20-30 class includes data of subject who is 20, 21,･･･ , 28, 29 years old. The peaks of ear ages are 30s for 10s and 20s aged subjects, 50s for 30sm 40s and 50s aged subjects, and 60s for 70s and 80s aged subjects.

Future Plan

The results of other ear age surveys will be added to the integrated data, and the ear age survey will be continued in the future. In particular, the number of the subjects aged about 25 and 40 would be collected in the future, since there are few subjects. In addition, detailed quantitative evaluation will be examined in the future, taking into consideration the earphone usage time and what the subject is listening to with the earphones.

6. CONCLUSIONS

As the result, the correlation discrete diagram of the ear age AE and the real age AR of 537 persons was obtained. The following is a list of what was found from this result. Young people around Shinjuku and Kamakura in Japan are likely to have deafness.

1) A certain correlation was found between the real age and the ear age. Overall, the ear age increased with the real age, and there was a large variation in the ear age among young subjects under 30 years of age.

2) The number of teenage subjects who have the ear ages of thirties was overwhelmingly large. The next, there were many subjects in their 20s with ear ages in their 30s.

References

[1] World Health Organization, “New WHO-ITU standard aims to prevent hearing loss among”, 12 Feb. 2019.
[2] World Health Organization, “Addressing the rising prevalence of hearing loss”, Feb. 2018.
[3] H. Hishida, et.al, “Basic Study on the Mechanism of Earphone Hearing Loss: About Correlation between Ear Age and Real Age”, J. SCI, 18-5 (2020) pp.1-6.
[4] H. Hishida, et.al, "Earphone Hearing Loss - Discussion of Accuracy of Ear Age Conversion Method -", ,AK-IMCIC-2021, Paper ID: ZA102EB.
[5] H. Hishida, “Study on Viscoplastic Constitutive Equation and Its Application to Some Engineering Problems”, Doctor thesis, Tokyo University, March 1992.
[6] For an example; K. Dang Van, I. V. Paradopoulos, “High-Cycle Metal Fatigue: From Theory to Applications", Springer, 4 May 2014.