

Study on Measurement Method of Auditory Acuity using Hearing Threshold of Extended High Frequency

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Abstract: Our society has already entered aging society. By 2026, the elderly population is expected to enter the super-aged society of more than 20%. Hearing impairment is a very dangerous disease that lowers the quality of life in aging society. Auditory acuity should be well managed in normal circumstances, as it is rarely recovered once it is damaged. However, it is very difficult to confirm the degree of auditory acuity in daily life. Therefore, the self measurement method of auditory acuity is very necessary. In this study, we propose an auditory acuity measurement method using the hearing threshold of the extended high frequency which is very different from auditory acuity. It is a way to tell three levels of sound in the band above 12,000 Hz and count the number of sounds heard. The experiment was conducted on 10 people who normally communicate with the proposed method. As a result of the experiment, nine people heard sounds close to the predicted expectations for each age group. However, in one case the number was <10. In addition, nine people who listened to the predicted expectation showed the difference in the number of sounds heard according to auditory acuity. As a result of this experiment, we confirmed that the proposed method using the extended high frequency is effective as a self measurement method to measure auditory acuity by itself.

Key words:Hearing impairment, auditory acuity, aging society, extended high frequency, hearing threshold, self measurement method

INTRODUCTION

The hearing impairment is the most representative disease of the aging society. According to the Ministry of Health and Welfare, the population of old people aged 65 and over will reach 13.2% in 2020 and the population of old people will enter the super-aged society of 20% or more in 2026. Hearing impairment is a common disease that affects more than one in two elderly people over the age of 60. It is expected that the acceleration of aging will lead to millions of hearing impairment patients. Moreover, modern people are exposed to various noise environments. It is no exaggeration to say that it is always exposed to noise such as automobile noise on the road as well as noise from factories and industrial sites. Also with the development and popularization of various smart devices, it is easy to see people listening to music or watching TV with earphones, regardless of the time and place of the street or subway. This environment makes auditory acuity loss easy. In addition to industrial noise and loud earphones, daily life noise also causes noise

deafness (Sim, 2015; Kim and Bae, 2009). Therefore, in order to prevent hearing impairment from the aging of the auditory acuity due to aging and surrounding noise, it is necessary to care about the auditory acuity condition of the person. However, even if the auditory acuity is bad, if the degree is not serious, it can understand the other person's words. It is difficult to doubt the hearing impairment unless the auditory acuity deteriorates greatly. In addition, even if auditory acuity deteriorates, it is very difficult to recognize because there is no pain and it is often difficult to know the symptom without going to otorhinolaryngology. Because of this characteristic of auditory acuity, the hearing impairment is diagnosed only when the hearing impairment is advanced. However, since, auditory acuity is almost impossible to recover once it is damaged, it is necessary to have an easy self-measurement method to check the degree of auditory acuity.

In this study, we propose a method that can easily measure auditory acuity by using characteristics of hearing threshold for extended high frequency.

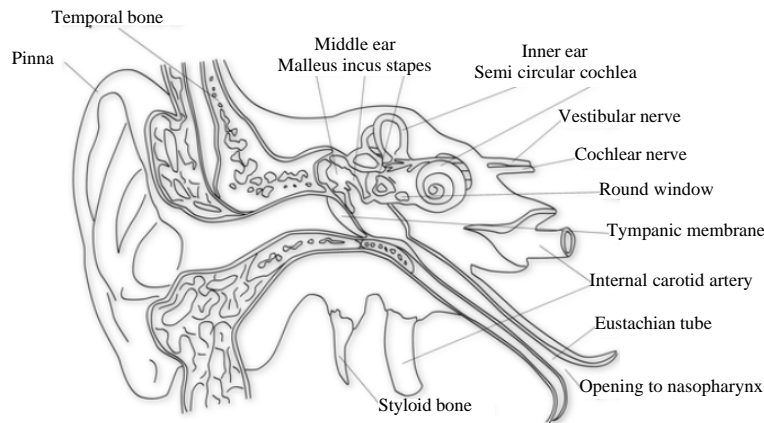


Fig. 1: Auditory system (Lee *et al.*, 2011)

The basic theory of auditory acuity

Auditory system: The auditory system for listening to sounds in our bodies is called ear. The ear is divided into an external ear, a middle ear and an inner ear. The external ear is a section from the ear conch to the tympanic membrane. It plays a role of collecting sounds and transmitting the tympanic membrane to the middle ear. The middle ear plays the role of amplifying the sound transmitted by the vibration of the tympanic membrane using an auditory ossicle composed of three bones and transmitting it to the inner ear. The inner ear is composed of cochlea, vestibule and semicircular canal. Cochlea analyzes the vibration transmitted from the middle ear and transmits it to the brain. The auditory cell and auditory nerve in the front part of the cochlea recognize the high frequencies and recognize the low frequencies as they go backward. Especially, as aging progresses, cognitive ability of auditory cell and auditory nerve in front of cochlea that recognize high frequency is known to decrease rapidly (Lee *et al.*, 2011; Lee, 2004). Figure 1 shows the auditory system.

Hearing impairment: The auditory acuity is very good for the childhood before the auditory cell ages. However, as age increases, the auditory cell aging causes hearing impairment. This phenomenon is called presbycusis. In addition to presbycusis, there are various hearing impairments caused by disease and noise deafness caused by exposure to noise. Depending on the location of the auditory system where the hearing impairment occurs, it can be broadly divided into conductive hearing impairment and sensorineural hearing impairment. A conductive hearing impairment occurs when a sound wave is not transmitted normally due to disturbances such as external ear, tympanic membrane or middle ear. A sensorineural hearing impairment occurs when an abnormality occurs in the cochlear function to detect

sound or in an auditory nerve abnormality. Presbycusis and noise deafness correspond to sensorineural hearing impairment due to aging and abnormalities of auditory cells. Presbycusis and noise deafness corresponding to sensorineural hearing impairment are the hearing impairment types with the highest prevalence. Therefore, it can be said that management effort is the most necessary type (Sim, 2015; Kim and Bae, 2009).

The damage caused by hearing impairment can be difficult to communicate, adversely affect daily life and interpersonal relationships and can lead to psychiatric illnesses such as depression due to poor self-esteem. In particular, research has shown that the hearing impairment reduces the cognitive function and the odds of developing dementia are two times higher than that of normal people. Since, auditory acuity is almost impossible to recover if it is damaged, proper management is necessary from the time when auditory acuity is good, so that, it does not get into hearing impairment.

Extended high frequency and hearing threshold

Extended High Frequency (EHF): was first reported by Galton in 1870 and refers to a frequency band that can be recognized by a person in excess of the normal frequency (250-8000 Hz) which is usually perceived as an auditory sense. After about 100 years, it was reported by Sataloff *et al.* That harmful effects of noise exposure on EHF as well as conventional frequencies (250-8,000 Hz) were reported (Kim *et al.*, 2008).

The audio frequency of a person is generally known as 20-20,000 Hz and there are individual differences depending on the person. However, as the auditory acuity of a person weakens, the audible frequency changes. Teenagers can usually hear up to 18,000 Hz while 20 sec and 30 sec can hear up to 17,000 Hz, 40 sec to 14,000 Hz and 50 sec with auditory acuity that is very weak can hear up to 12,000 Hz. Also, the weaker the auditory acuity, the

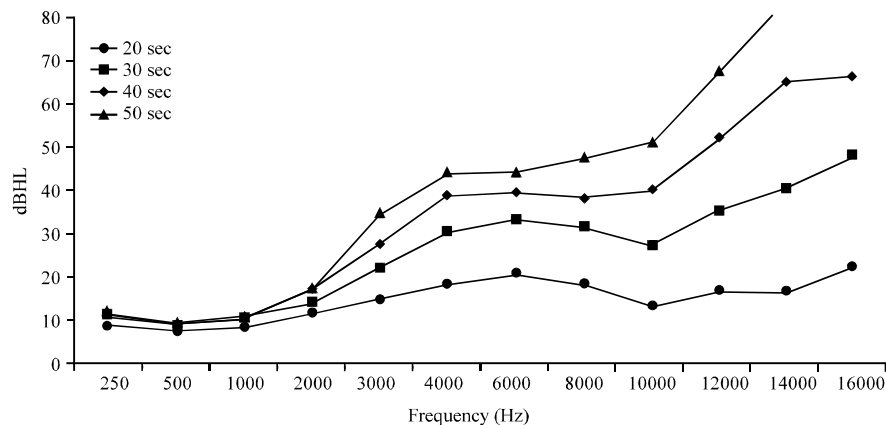


Fig. 2: Average hearing threshold by age group (Kim *et al.*, 2008)

higher the hearing threshold at higher frequencies. In the band of 250–8,000 Hz, there is a slight difference in hearing threshold even though auditory acuity is different. On the other hand, the difference of the hearing threshold is very large in the EHF region exceeding 8,000 Hz (Kim *et al.*, 2008). Therefore, in the case of the EHF domain, if the auditory acuity is bad for a while the frequency range that can not be heard easily becomes very large. Therefore, it can be said that discrimination power for auditory acuity is very large. Figure 2 shows the age groups average hearing threshold.

MATERIALS AND METHODS

Proposed measurement method of auditory acuity

General measurement method of auditory acuity:

General measurement methods of auditory acuity include; Pure tone audiometry, immittance audiometry, speech audiometry and infants audiometry. Pure tone audiometry is a test that measures the strength of a sound by generating a pure tone corresponding to each frequency. Immittance audiometry is an audiometry that measures the reflected energy as a part of the sound is reflected when it encounters a new medium. Speech audiometry measures the hearing threshold and understanding of speech. Infants audiometry is an early detection of hearing impairment through auditory acuity screening within 6 months of age. However, this general measurement method of auditory acuity is test method that can measure auditory acuity only if it goes to otolaryngology. It can be said that it is not suitable for individual to manage auditory acuity (Kim and Bae, 2018; Kim *et al.*, 2018).

Measurement method of auditory acuity using EHF hearing threshold: Pure tone audiometry which is the most commonly used of the general measurement method

of auditory acuity, tests auditory acuity by judging whether a pure tone of 250–8,000 Hz is heard or not. However, in the case of 4,000 Hz or less, people can hear very little sound very well. In addition, the auditory acuity decreases but the hearing threshold changes relatively little. Therefore, pure tone audiometry needs to measure whether the level is varied by each frequency in addition to playing pure tone according to frequency. For this reason, pure tone audiometry has to be measured in otolaryngology and it is very difficult to measure by the hearer itself. On the other hand, in the EHF region, a specific frequency band is not audible at all as the auditory acuity decreases. The auditory characteristic for this EHF region makes highly discriminating measurements possible for small differences in auditory acuity. Figure 3 is a graph of the value of the audible threshold according to age groups. The value of the audible threshold for each age group was estimated by applying the following three methods. Three methods is the generally known value of the audible threshold, the dBHL value according to the age groups average hearing threshold in Fig. 2 converted to dB SPL, audio frequency according to age.

Figure 3 shows that in the low frequency region, the change of value of the audible threshold according to the change of auditory acuity is very small. On the other hand in the high frequency region, the change of value of the audible threshold according to the change of auditory acuity is very large. Therefore, it is easy to distinguish auditory acuity.

In this study, based on the results shown in Fig. 3, nine sounds belonging to the EHF region of 12,000–20,000 Hz which is expected to be most easily discriminated from the auditory acuity are sequentially presented at three levels, so that, auditory acuity can be easily measured we propose a method. The reason why

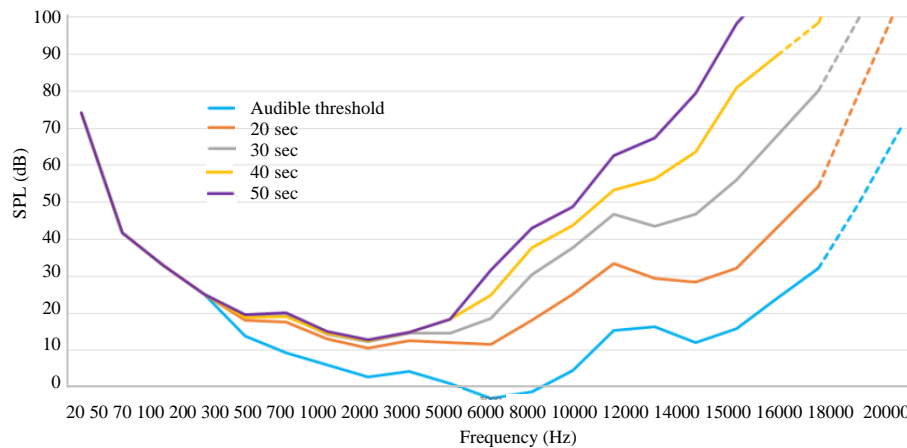


Fig. 3: Estimation of value of the audible threshold for each age group

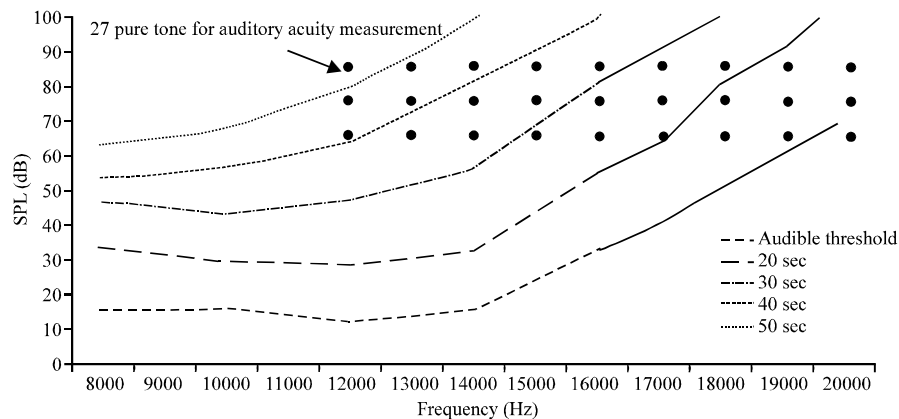


Fig. 4: Proposed measurement model of auditory acuity

the EHF used for the measurement is set to 12,000 Hz or more is that the hearing threshold rises with increasing frequency for all bands at a frequency of 12,000 Hz or more, so that, the discrimination power can be further increased. Figure 4 shows the proposed measurement model of auditory acuity.

In the measurement model of auditory acuity shown in Fig. 4, it is expected that about 26 sounds will be heard in a child with good auditory acuity, 19 in the 20 sec, 12 in the 30 sec, 6 in the 40 sec, In the case of 50 sec, one is expected to be heard. Depending on the age groups, the number of pure tones will vary depending on the individual's auditory acuity.

RESULTS AND DISCUSSION

As shown in Fig. 4, the experiment was performed on 10 persons ranging from 10-40 years of age for the proposed measurement model of auditory acuity. The experiment participant was people who did not have any obstacles in speaking and listening and who had freely

communicated in everyday life and who did not feel abnormal in the auditory sense. For the experiment participant, we adjusted the level to 65, 75 and 85 dB for nine pure tones ranging from 12,000-20,000 Hz to give a total of 27 pure tones. As shown in Fig. 4, the experiment was performed on 10 persons ranging from 10-40 years of age for the proposed measurement model of auditory acuity. The experiment participant was people who did not have any obstacles in speaking and listening and who had freely communicated in everyday life and who did not feel abnormal in the auditory sense. For the experiment participant, we adjusted the level to 65, 75 and 85 dB for nine pure tones ranging from 12,000- 20,000 Hz to give a total of 27 pure tones. Experiments were carried out in a place where it could be frequently encountered such as in a conference room or a lecture room with low noise and took the same place as the usual environment for self-measurement. The equipment used in the experiment was the LG XNote SD-550 and the software used to create and play the sound was Audition CC and Cool Edit Pro 2.1. Table 1 shows the age, gender and auditory acuity of each experiment participant.

Table 1: Results of hearing tests

Experiment participant	Gender	Age	No. of perceived pure tones
A	Woman	11	20
B	Woman	13	20
C	Man	27	8
D	Man	32	14
E	Man	32	11
F	Man	39	9
G	Man	39	11
H	Woman	37	8
I	Man	45	7
J	Woman	46	2

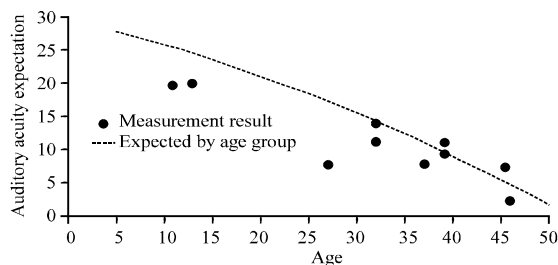


Fig. 5: Distribution according to hearing measurement result

Figure 5 shows the distribution of auditory acuity expectation and actual measurement results by age groups based on the experimental results of Table 1.

Figure 4 shows the number of perceived pure tones that can be heard according to age groups. As shown in Fig. 5, most of the experiment participants showed a difference of about ± 5 compared to the predicted number. However, experiment participant C heard $10 <$ expected expectation. In addition, even in the case of experiment participants of the same age groups, there was a difference of about 4~5, indicating that there was a difference in auditory acuity (Park *et al.*, 2016, 2017).

CONCLUSION

Hearing impairment is a disease that hinders the quality of life. Our society has already entered aging society and is always exposed to noise. Rapidly popularized smart devices are threatening the health of our ears. As our auditory acuity is almost impossible to recover once it is damaged, we are living in the age of 100 and we can say that hearing impairment is a very dangerous disease and requires special preventive efforts. However, our auditory acuity is very difficult to recognize the state of auditory acuity when it is possible to communicate through words. For this reason, despite our auditory acuity has been very bad, we have been neglected and we can get into hearing impairment without our knowledge.

Therefore, it can be said that the auditory acuity is well managed at the audible age. However, until now, auditory acuity measurement method is difficult to

measure before going to otorhinolaryngology and otorhinolaryngology does not go to the state where it understands speech well. Therefore, we proposed a measurement method that can easily measure auditory acuity without going to otorhinolaryngology. The proposed method is based on auditory acuity which uses the sound of EHF band, it is a method of counting the number of sounds in practice by giving a total of 27 sounds in each of three levels of sound over 12,000 Hz.

Most of the experiment participants heard a similar number of predictions for each age group. However, one experiment participant confirmed that the auditory acuity was very low, by listening $10 <$ the expected number. In addition, although, the remaining nine people listened closely to the expected number of expectations in each age group, it was confirmed that there was a difference in auditory acuity among individuals.

RECOMMENDATIONS

The method proposed in this study applies the same measurement method to all age groups but we will try to make it a more efficient measurement method by supplementing the measurement method according to the situation of each age group in the future.

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