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Discrepancies between self-reported hearing difficulty and hearing loss diagnosed by audiometry: prevalence and associated factors in a national survey

Ji Eun Choi, Il Joon Moon, Sun-Young Baek, Seon Woo Kim, Yang-Sun Cho

ABSTRACT

Objective To evaluate discrepancies prevalent between self-reported hearing difficulty (SHD) and audiometrically measured hearing loss (AHL) and factors associated with such discrepancies.

Design Nationwide cross-sectional survey.

Setting Data from 2010 to 2012 Korea National Health and Nutrition Examination Survey conducted by the Korea Centers for Disease Control and Prevention.

Participants We included 14 345 participants aged ≥19 years who had normal tympanic membranes (mean age of 49 years).

Measures Self-reported hearing was assessed by asking participants whether they had difficulty in hearing. AHL was defined as >25 dB of mean hearing thresholds measured at 0.5, 1, 2 and 4 kHz in better ear. Underestimated hearing impairment (HI) was defined as having AHL without SHD. Likewise, overestimated HI was defined as having SHD without AHL. Prevalence of underestimated and overestimated HIs was determined. Univariable and multivariable analyses were performed to examine factors associated with such discrepancies compared with concordant HL.

Results Among 14 345 participants, 1876 (13.1%) had underestimated HI while 733 (5.1%) had overestimated HI. Multivariable models revealed that participants who had discrepancies between SHD and AHL were less likely to have older age (OR: 0.979, 95% CI: 0.967 to 0.991) for the underestimated HI, OR: 0.905, 95% CI: 0.890 to 0.921 for the overestimated HI) and tinnitus (OR: 0.425, 95% CI: 0.344 to 0.525) for the underestimated HI and OR 0.523, 95% CI: 0.391 to 0.699 for the overestimated HI) compared with those who had concordant HI. Exposure to occupational noise (OR: 0.566, 95% CI: 0.423 to 0.758) was associated with underestimated HI, and medical history of hypertension (OR: 1.501, 95% CI: 1.061 to 2.123) and depression (OR: 1.771, 95% CI: 1.041 to 3.016) was associated with overestimated HI.

Conclusion Age, tinnitus, occupational noise exposure, hypertension and depression should be incorporated into evaluation of hearing loss in clinical practice.

Strengths and limitations of this study

- This study was based on a nationwide large-scale cross-sectional survey.
- We analysed only participants who had normal tympanic membranes to exclude participants who have undergone a previous hearing evaluation.
- We used definition of hearing loss as mean hearing threshold of >25 dB HL measured at 0.5, 1, 2 and 4 kHz in the better ear in accordance with the WHO definition (World Health Organization 2014).
- Multivariable logistic analysis was performed using both auditory and non-auditory factors including personal, socioeconomic, psychological and health-related factors.
- Because the survey did not assess the history of hearing evaluation for each participant, this might have influenced discrepancy between self-reported hearing and audiometry.

INTRODUCTION

Hearing is usually assessed in the clinic by using pure-tone audiometry to measure the smallest detectable level of pure tone at several frequencies, typically in the range of 0.5–8 kHz. Sometimes, the use of self-reported hearing measurements is attractive in occupational health screening programmes or a large-scale epidemiologic survey due to the costs and time constraints of audiometric measurements. However, discrepancies between self-reported hearing and pure-tone thresholds have been reported in multiple studies. Therefore, it is necessary to understand prevalence of this discrepancy and various factors affecting the accuracy of self-reported hearing when using as a surrogate measurement of audiometry.

Previous studies have reported that accuracy of self-reported hearing difficulty (SHD) is associated with auditory factors (eg,
degree of hearing loss, frequencies of hearing loss and middle ear infection)\textsuperscript{5-7,9,10,12,13} as well as demographic factors.\textsuperscript{3,5,7,14,15} However, these studies have mainly focused on elderly populations\textsuperscript{3,8,11,14} or SHD with normal audiogram.\textsuperscript{17} Few studies have focused on the non-auditory factors (socioeconomic factors, psychological factors, healthcare utilisation or other personal information) that might influence the self-reported hearing assessment in a large population of various ages. Although a study has recently reported discrepancy between self-reported hearing and audiometry,\textsuperscript{5} this study included participants with abnormal tympanic membrane (TM) findings such as perforation, cholesteatoma or effusion. Because individuals who have abnormal TM are more likely to have undergone a previous hearing evaluation, this might have influenced self-reported hearing and also discrepancy from audiometry.

The primary aim of this study was to evaluate the prevalence of discrepancy between SHD and audiometrically measured hearing loss (AHL) in terms of overestimation or underestimation in a population with normal TMs based on national survey data. We also comprehensively investigated whether non-auditory metrics such as socioeconomic factors, psychological factors, medical history, healthcare utilisation and other personal information could affect the accuracy of SHD and types of discrepancy.

**METHODS**

**Data source**

This study used data from the fifth Korea National Health and Nutrition Examination Survey (KNHANES). The KNHANES is a nationwide cross-sectional survey conducted annually by the Korea Centers for Disease Control and Prevention (KCDC) to investigate health and nutritional status of a representative Korean population.\textsuperscript{16} Every year, about 10 000 individuals in 3840 households are selected from a panel to represent the population through a multistage clustered and stratified random sampling method based on National Census Data. A total of 576 survey areas were drawn from the population and housing census by considering the proportion of each subgroup. The participation rate of selected households was about 80%. The survey manuals and microdata of KNHANES are available in public through the official website of KNHANES (http://knhanes.cdc.go.kr).

**Study population**

From 2010 to 2012, a total of 23 621 individuals (8313 in 2010, 7887 in 2011 and 7421 in 2012) agreed to participate in health surveys. Among participants >19 years of age, we included participants who completed hearing questionnaire, audiometric measurement and examination of TMs. As individuals with abnormal TM are more likely to have correct information on their hearing status from the prior hearing tests, we excluded participants with abnormal TM, and whose information on outcome variables was missing.

**Hearing questionnaire and audiometric measurement**

Participants were first asked about their perceived HD. In detail, participants were asked to rate their difficulty in hearing with a survey question: ‘Which sentence best describes your hearing status (while not using hearing aids)?’, and to choose an answer for the question: (1) ‘Don’t feel difficulty at all,’ (2) ‘A little bit difficult’, (3) ‘Very difficult’ and (4) ‘Can’t hear at all’. SHD was indicated when the response was (2), (3) or (4).

Pure tone air-conduction threshold was measured in a double-walled sound booth (CD-600, Sontek, Paju, South Korea) using an audiometer (SA-203, Entomed AB, Malmö, Sweden). A TDH39P Phone type headphone (10 Ohm) was used. Calibration of the audiometer was carried out annually according to the user’s manual. The ambient noise level measured inside the booth under maximal noisy conditions in the survey unit met the ISO 8253–1 standard. Otolaryngologists who had been trained to operate the audiometer provided instructions to participants and obtained audiometric data. Air conduction thresholds were measured at 0.5, 1, 2, 3, 4 and 6 kHz in accordance with the American National Standards Institute standard.\textsuperscript{17}

Hearing loss (HL) in this study was defined as the mean air conduction hearing thresholds >25 dB HL at 0.5, 1, 2 and 4 kHz in the better ear. Discrepancy between self-reported hearing and audiometry was classified in terms of underestimated and overestimated hearing impairment (HI). Underestimation of HI was defined as having AHL without SHD. Likewise, overestimation of HI was defined as having SHD without AHL. Concordant HI was defined as having both AHL and SHD.

**Otolologic examination and questionnaires**

An ear examination was conducted with a 4 mm 0°-angled rigid endoscope attached to a Charge-Coupled Device camera by trained otolaryngologists. Endoscopic examination was performed to identify abnormal TM findings such as perforation, cholesteatoma (including retraction pocket) and otitis media with effusion (including the presence of a ventilation tube). Trained otolaryngologists categorised both TMs into the following three groups: normal, abnormal and could not examine. Only participants with normal TMs on both sides were included in this study.

Participants were asked about their tinnitus experiences using the following question: ‘During the past year, did you ever hear a sound (buzzing, hissing, ringing, humming, roaring, machinery noise) originating in your ear?’. Examiners were instructed to record either ‘yes’ or ‘no’. If a participant reported that they heard an odd or unusual noise at any time in past years, examiners recorded ‘yes’. Participants were also asked about their experience with occupational noise exposure. They were instructed to record either ‘yes’ or ‘no’ for the question...
‘Have you ever worked more than 3 months in the place where you have to speak loudly to communicate with others because of noisy sound?’

**Outcome variables**

Age, sex, smoking status, alcohol consumption, marital status, waist circumference (cm) and body mass index (kg/m²) of each participant were collected and categorised as personal factors in this study. Smoking status was divided into three groups: never smoked, past smoker and current smoker. The participants were asked to self-report to question ‘Do you smoke now?’ If the participant smoked in the past but did not smoke now, it was classified as a past smoker. Alcohol consumption was divided into two groups according to their drinking frequency during the last year: non-drinker and drinker. The question was ‘How often do you drink alcohol in the last year?’ The participants who had never drunk at all during the last year were classified as non-drinker, while others were classified as drinker.

A non-drinker was defined as a participant who had never drunk during the last year. Marital status was divided into two groups through the questionnaire: ever married and never married. The marital status question was ‘Have you been married?’ Ever married included participants married at the time of survey, separated, widowed or divorced.

To evaluate socioeconomic factors, monthly income, education level and employment status were assessed. Participants answered an open-ended question on income: ‘What is your average monthly income including salaries, property income, pension, government subsidies and allowance?’ Monthly income indicates equalised monthly household income and was calculated by dividing total family income by the square root of the number of household members. Monthly income was classified into quartiles to determine monthly income level: lower, lower middle, upper middle and upper. With regard to educational level, the participants were asked the level at which their education was completed, which was classified into four educational categories: completion of elementary school, middle school, high school and post-secondary school. Education level was re-divided into two groups: less than high school and high school or more. Employment status was divided into employed and unemployed groups. The participants answered either ‘yes’ or ‘no’ to the question ‘Have you ever worked more than 1 hour for the last week for income, or worked as unpaid family worker for over 18 hours? (The temporary leave status is also included if you have worked.)’

Quality of life was measured using Euro Qol-5D (EQ-5D) consisting of a health-status descriptive system (EQ-5D) and a visual analogue scale (EQ-VAS). EQ-5D is a standard tool used to measure patient’s health status in the following five dimensions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Each dimension has three grades of severity: no problem (score of 1), moderate problem (score of 2) or serious problem (score of 3). EQ-5D index is calculated from EQ-5D score by applying a formula that assigns weights to each grade in each dimension. This formula differs among nations because it is based on the value of EQ-5D of the population. KNHANES algorithm was used to calculate the EQ-5D index in the present study. The EQ-5D index ranged from 1 (best health) to 0 (equivalent to death) or −0.171 (worse than death). Next, participants described their own health status using a VAS ranging from 0 (worst imaginable health) to 100 (best imaginable health) presented as EQ-VAS.

To evaluate psychological factors, self-reported health status and body shape perception were assessed. Self-reported health status was categorised into three answers: good, fair and poor. The question was ‘What do you usually think about your health?’ Participants were asked to report their body shape perception as ‘too thin’, ‘just right’ or ‘too fat’. The question was ‘What do you think of your body weight status?’. Self-reported stress and depression levels were also assessed. Participants were asked about their stress level using the following question ‘How much do you feel stress in ordinary life?’ They were instructed to report one of the following responses to the question: ‘extremely stressed’, ‘quite stressed’, ‘a little bit stressed’ and ‘not stressed at all’. The responses were re-categorised into ‘low level (not stressed at all or a little bit stressed)’ or ‘high level (extremely or quite stressed)’. To assess the self-perceived level of depression, participants answered either ‘yes’ or ‘no’ to the question ‘Have you felt sorrow or despair that has affected your daily life for more than 2 weeks continuously during the past year?’

To evaluate health-related factors, physical activity, the use of medical service and current disease were assessed. The intensity of the physical activity was categorised as vigorous, moderate and light. Examples of vigorous intensity physical activities were soccer, basketball, aerobics, running, fast cycling and fast swimming. Moderate physical activities included cycling at a regular pace, swimming at a regular pace, slow swimming, noncompetitive volleyball and doubles tennis. Walking slowly or at a moderate pace for the use of public transportation were included in the light physical activity. We used the guidelines suggested by Noh et al. to divide the participants into exercising and non-exercising groups based on the number of days and hours in which they took part in physical activity. The intensity of the physical activity was based on the physical activity recommendations of the Centers for Disease Control and Prevention and the American College of Sports Medicine. These activities were categorised as follows: those who perform vigorous-intensity activity for a minimum of 20 min at least 3 days each week; those who perform moderate-intensity physical activity for a minimum of 30 min at least 5 days each week and those who perform light-intensity activity for a minimum of 30 min for at least 5 days weekly. Individuals who did not exercise regularly were placed into the non-exercising group. Medical services evaluated restriction of medical service, health screening and medical history.
The participants were asked to answer either ‘yes’ or ‘no’ about the restricted use of medical service. The question was ‘Have you ever been unable to go to the clinic (except for dentistry) during the past year?’. To assess the health screening status, the participants answered either ‘yes’ or ‘no’ to the question ‘Have you ever had a health checkup for health during the last two years?’ Participants were also asked about their current disease diagnosed by a medical doctor. They answered either ‘yes’ or ‘no’ to questions about current disease. Among the various disease lists, histories of hearing-related diseases such as obesity, hypertension, myocardial infarction, angina, asthma, depression, renal failure and diabetes mellitus were selected as variables.22 23

According to the standard protocol, systolic blood pressure (BP) and diastolic BP were measured by trained nurses using a mercury sphygmomanometer (Baumanometer Desk model; Baum, Amherst, New York, USA) on the right arm of the subject while sitting after taking at least 5 min of rest. BP was measured three times and the second and third measurements were averaged. Blood and urine samples were collected in the morning after fasting for at least 8 hours. Fasting blood samples and spot urine samples were processed, refrigerated immediately, and transported in cold storage to a central laboratory (Neodin Medical Institute, Seoul, Korea). All samples were analysed within 24 hours after transportation. Total cholesterol, high-density lipoprotein (HDL) cholesterol, triglyceride, haemoglobin, haematocrit, blood urea nitrogen and serum creatinine levels were measured with a Hitachi Automatic Analyzer 7600 (Hitachi, Tokyo, Japan). Urine protein and glucose levels were measured using a dipstick in a spot urine sample.

Statistical analysis
All statistical analyses were performed by taking account of weights from a complex sampling design according to the guideline for analysis of KNHANES data. The KCDC has published guideline for analysis through the official website of KNHANES (http://knhanes.cdc.go.kr). The survey design created a sample weight assigned to each sample individual through the following three steps so that the total sample would represent the population (on average) for 2010–2012 period: calculating the base weight of the inverse of the final probability an individual being selected, adjusting for non-response and post-stratification adjustment to match previous census population control totals. Weights in 2010, 2011, 2012 surveys were combined, and the average weight (sum of weight for each year/3) was calculated. Statistical analyses were performed using SAS V9.4 (SAS Institute).

Logistic regression or linear regression was used to evaluate factors associated with discrepancies between SHL and AHL. Variables found to have possible association in univariable analysis (p<0.20) were entered into the multivariable analysis model. Serological data were not entered into the multivariable analysis model due to a significant number of missing data. In this study, the population group was classified into three categories: participants who had overestimated HI, underestimated HI and concordant HI. To evaluate factors associated with underestimated HI, we compared participants with underestimated HI and concordant HI. We also compared participants with overestimated HI and concordant HI to evaluate factors associated with overestimated HI. The p values were obtained two-sided. Bonferroni’s correction was applied to the p value and the corresponding CI due to multiple testing. Statistical significance was considered when adjusted p value was less than 0.05.

Patient and public involvement
Participants and the public were neither involved in designing the study or developing the research questions, nor were they involved in analysing or interpreting the findings. There are no plans for the study results to be disseminated directly to participants.

RESULTS
Basic characteristics of study population
A total of 25 094 Korean citizens participated in the KNHANES from 2010 to 2012. Of them, 16727 participants aged ≥19 years completed the hearing questionnaire and audiometric measurement. After excluding participants with abnormal TM and missing data, a total of 14345 participants were ultimately eligible for this study. The mean ±SD age of the study population was 49.2±16.1 years (ranged from 19 to 97). The study population consisted of 42.5% males and 57.5% females.

Prevalence of discrepancies between self-reported hearing and audiometry
Of the 14345 participants with normal TMs, 3001 (20.9%) participants had AHL and 1858 (13.0%) had SHD. Table 1 shows the percentage and prevalence of discrepancies between self-reported hearing and audiometry. Of the 3001 participants with AHL, 62.5% (n=1876) reported no SHD. On the other hand, 733 (39.5%) of 1858 participants with SHD had no AHL (mean audiometric thresholds ≤25 dB HL in the better ear). That is, the prevalence of underestimated and overestimated HI was 62.5% and 39.5%, respectively. The prevalence of discrepancies between self-reported hearing and audiometry was 18.2% (n=2.609).

Factors associated with underestimated hearing impairment
A total of 3001 participants who had bilateral HL (mean hearing thresholds >25 dB HL at 0.5, 1, 2 and 4 kHz) were analysed to evaluate factors associated with underestimated HI using linear and logistic regression analyses. Results are shown in table 2. In univariable analyses, age, alcohol consumption, education, employment status, quality of life, self-reported health status, depressive mood, restricted use of medical service, hospital visit, history of myocardial infarction, angina, asthma, tinnitus, occupational noise exposure, diastolic BP and
blood urea nitrogen were significantly associated with underestimated HI. In multivariable analysis, participants who underestimated HI showed significantly decreased age (OR: 0.979, 95% CI: 0.967 to 0.991) compared with those who had both AHL and SHD. Also, participants who underestimated HI were less likely to have tinnitus (OR: 0.425, 95% CI: 0.344 to 0.525) or exposure to occupational noise (OR: 0.566, 95% CI: 0.423 to 0.758) compared with those who showed concordant HI.

**Associated factors with overestimated hearing impairment**

A total of 1858 participants who had SHD were analysed to investigate factors associated with overestimated HI. Results of univariable and multivariable analyses are shown in [table 3](#). In univariable analysis, age, sex, smoking, alcohol consumption, waist circumference, monthly income, marital status, education level and employment status were significantly associated with overestimated HI compared with those who had both SHD and AHL. For quality of life factors, EQ-5D subscales such as physical activity about mobility, self-care, and usual activity, EQ-5D index and EQ-VAS were significantly associated with overestimated HI. For psychologic factors, self-reported health status, body shape perception and amount of stress in life were significantly associated with overestimation of HI. Overestimation of HI was also significantly associated with vigorous and moderate physical activity, hospital visit and history of hypertension, angina, depression, diabetes mellitus and tinnitus. Systolic BP, HDL cholesterol, blood urea nitrogen and serum creatinine levels were also significantly associated with overestimated HI. In multivariable analysis, participants who overestimated HI showed significantly decreased age (OR: 0.905, 95% CI: 0.890 to 0.921) compared with those who had concordant HI. Participants who overestimated HI were more likely to have hypertension (OR: 1.501, 95% CI: 1.061 to 2.123) and depression (OR: 1.772, 95% CI: 1.041 to 3.016) but less likely to report tinnitus (OR 0.523, 95% CI: 0.391 to 0.699) compared with those who had both SHD and AHL.

**DISCUSSION**

This cross-sectional survey of Korean population aged ≥19 years found that 18.2% of participants had a discrepancy between their SHD and AHL. Most (71.9%) of these participants had AHL but no SHD (underestimated HI) while the rest (28.1%) had SHD but no AHL (overestimated HI, [table 1](#)). The accuracy of hearing assessments in the present study (81.8%) was higher than that reported in elderly population of USA (71.8%), but similar to that reported in the general population of Australia (82%). Previously, Kim et al categorised the self-reported hearing into three categories (no difficulty, a little difficulty and much difficulty) and classified the mean pure-tone threshold of the better ear into three groups (<25 dB, ≥25 dB and <40 dB, and ≥40 dB). When the participants of previous study were reclassified as in our study, the accuracy of hearing assessments was slightly higher (83.2%) than our result. In addition, our result showed that 5.1% (733 of 14 325) of participants reported overestimated HI and 13.1% (1876 of 14 325) reported underestimated HI. However, reclassified results in Kim et al showed that 6.3% (1237 of 19 642) of participants reported overestimated HI and 10.5% (2059 of 19 642) of participants reported underestimated HI. Although present study and Kim et al analysed using same dataset, participants with abnormal TMs were excluded in our study, but included in Kim et al. Thus, differences in prevalence can be explained by the fact that individuals who have abnormal TM are more likely to report SHD and are more likely to have undergone a previous hearing evaluation.

Our results showed that both non-auditory factors (demographic factors and medical histories) and auditory factors (tinnitus and occupational noise exposure) were associated with discrepancy between self-reported hearing and audiometry in multivariable analysis. For demographic factors, participants who underestimated or overestimated their HI were significantly younger compared with participants who had concordant HI ([tables 2 and 3](#)). It is well known that audiometric HL dramatically increases with increasing age. SHD is also increased with age as difficulty of speech understanding in adverse listening conditions increases due to decreased synaptic loss, working memory capacity or impaired temporal processing. Our reference group was defined as participants who had both SHD and AHL (concordant HI), so it is highly likely that older participants will have both SHD and AHL. Therefore, it is not surprising that younger participants were less likely to have SHD among participants with audiometric HL ([table 2](#)) and had fewer.

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**Table 1** Percentage and prevalence rates of discrepancy between self-reported hearing and audiometry

| Audiometry | Hearing difficulty | No difficulty | Total |
|------------|--------------------|---------------|-------|
| Normal     | 733 (C)            | 10611 (D)     | 11344 (C+D) |
| Total      | 1858 (A+C)         | 12 487 (B+D)  | 14 345 (A+B+C+D) |

Percentage of discrepancy (%)=18.2% [(B+C) / (A+C)], Underestimation of hearing impairment=62.5% [B / (A+B)], Overestimation of hearing impairment=39.5% [C / (A+C)].

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Choi JE, et al. BMJ Open 2019;9:e022440. doi:10.1136/bmjopen-2018-022440
Table 2  Univariable and multivariable analyses of factors associated with underestimated hearing impairment

| Variables                        | Total population with AHL | Underestimated HI* | Univariable analysis | Multivariable analysis |
|----------------------------------|---------------------------|--------------------|----------------------|------------------------|
|                                  | Weighted frequency | Mean† or % | Weighted frequency | Prevalence (%)‡ | OR  | 95% CI | P value | OR  | 95% CI | P value |
| **Personal factor**              |                           |                |                     |                  |     |        |        |     |        |        |
| Age (years)                      | 4 660 594                | 62.0†         | 3 023 386           | 64.9           | 0.977| 0.968 to 0.986 | <0.0001| 0.979| 0.967 to 0.991 | 0.001 |
| Sex                              |                           |                |                     |                  |     |        |        |     |        |        |
| Male                             | 2 594 824                | 55.7          | 1 702 933           | 65.6           | 1.078| 0.897 to 1.295 | 0.425  |     |        |        |
| Female                           | 2 065 770                | 44.3          | 1 320 453           | 63.9           | Referent |         |        |     |        |        |
| **Smoke**                        |                           |                |                     |                  |     |        |        |     |        |        |
| Never                            | 2 165 731                | 46.5          | 1 385 246           | 64.0           | Referent |         |        |     |        |        |
| Past smoker§                     | 1 369 414                | 29.4          | 883 557             | 64.5           | 1.025| 0.804 to 1.306 | 1.000  |     |        |        |
| Current smoker§                  | 1 125 449                | 24.1          | 754 583             | 67.0           | 1.146| 0.850 to 1.546 | 1.227  |     |        |        |
| **Drinking alcohol in past year**|                           |                |                     |                  |     |        |        |     |        |        |
| Non-drinker                      | 1 666 794                | 35.8          | 1 012 283           | 60.7           | Referent |         |        |     |        |        |
| Drinker                          | 2 993 800                | 64.2          | 2 011 103           | 67.2           | 1.323| 1.102 to 1.589 | 0.003  | 1.025| 0.831 to 1.266 | 0.814 |
| **Marital status**               |                           |                |                     |                  |     |        |        |     |        |        |
| Ever married                     | 4 518 752                | 97.0          | 2 917 820           | 64.6           | 0.626| 0.289 to 1.360 | 0.236  |     |        |        |
| Never married                    | 14 184 3                 | 3.0           | 105 566             | 74.4           | Referent |         |        |     |        |        |
| **Socioeconomic factors**        |                           |                |                     |                  |     |        |        |     |        |        |
| **Income**                       |                           |                |                     |                  |     |        |        |     |        |        |
| Lower                            | 1 579 965                | 33.9          | 964 575             | 61.1           | Referent |         |        |     |        |        |
| Lower middle§                    | 1 296 182                | 27.8          | 833 271             | 64.3           | 1.148| 0.853 to 1.547 | 0.800  | 0.806| 0.585 to 1.111 | 0.324 |
| Upper middle§                    | 934 922                  | 20.1          | 641 226             | 68.6           | 1.393| 0.994 to 1.952 | 0.057  | 0.949| 0.659 to 1.366 | 1.000 |
| Upper§                           | 849 526                  | 18.2          | 584 315             | 68.8           | 1.406| 0.999 to 1.978 | 0.052  | 0.963| 0.651 to 1.427 | 1.000 |
| **Education**                    |                           |                |                     |                  |     |        |        |     |        |        |
| Less than high school            | 2 883 779                | 61.9          | 1 789 349           | 62.0           | Referent |         |        |     |        |        |
| High school or more              | 1 776 815                | 38.1          | 1 234 038           | 69.5           | 1.391| 1.134 to 1.704 | 0.002  | 1.087| 0.853 to 1.386 | 0.498 |
| **Employment status**            |                           |                |                     |                  |     |        |        |     |        |        |
| Employed                         | 2 566 437                | 55.1          | 1 730 554           | 67.4           | 1.283| 1.066 to 1.545 | 0.009  | 0.966| 0.777 to 1.202 | 0.757 |
| Unemployed                       | 2 094 158                | 44.9          | 1 292 832           | 61.7           | Referent |         |        |     |        |        |
| **Quality of life**              |                           |                |                     |                  |     |        |        |     |        |        |
| Variables | Total population with AHL | Underestimated HI* | Univariable analysis | Multivariable analysis |
|-----------|--------------------------|-------------------|---------------------|------------------------|
| EQ-5D (%) | Weighted frequency | Weighted frequency | Prevalence (%)† | OR  | 95% CI | P value | OR  | 95% CI | P value |
| Physical activity (mobility) | | | | | | | | | |
| Normal | 3310530 | 71.0 | 2252247 | 68.0 | Referent | | | | |
| Limited | 1350065 | 29.0 | 771140 | 57.1 | 0.626 | 0.516 to 0.759 | <0.0001 | | |
| Physical activity (self-care) | | | | | | | | | |
| Normal | 4249662 | 91.2 | 2790703 | 65.7 | Referent | | | | |
| Limited | 410932 | 8.8 | 232683 | 56.6 | 0.682 | 0.509 to 0.915 | 0.011 | | |
| Physical activity (usual activities) | | | | | | | | | |
| Normal | 3832356 | 82.2 | 2562274 | 66.9 | Referent | | | | |
| Limited | 828238 | 17.8 | 461112 | 55.7 | 0.623 | 0.497 to 0.780 | <0.0001 | | |
| Physical activity (pain/discomfort) | | | | | | | | | |
| Normal | 3243388 | 69.6 | 2167417 | 66.8 | Referent | | | | |
| Limited | 1417206 | 30.4 | 855969 | 60.4 | 0.757 | 0.622 to 0.922 | 0.006 | | |
| Physical activity (anxiety/depression) | | | | | | | | | |
| Normal | 4020865 | 86.3 | 2651467 | 65.9 | Referent | | | | |
| Limited | 639729 | 13.7 | 371919 | 58.1 | 0.717 | 0.554 to 0.929 | 0.012 | | |
| EQ-5D index (%) | | | | | | | | | |
| Index<0.75 | 560616 | 12.0 | 316793 | 56.5 | Referent | | | | |
| 0.75≤index < 1.00§ | 1479603 | 31.7 | 885908 | 59.9 | 1.148 | 0.841 to 1.568 | 0.638 | 0.841 | 0.584 to 1.210 | 0.573 | |
| Index=1.00§ | 2620375 | 56.2 | 1820686 | 69.5 | 1.752 | 1.275 to 2.408 | <0.0001 | 0.930 | 0.606 to 1.426 | 1.000 | |
| EQ-VAS (0 to 100) | 4660594 | 62.0† | 3023386 | 64.9 | 1.008 | 1.003 to 1.012 | 0.001 | | |
| Psychological factors | | | | | | | | | |
| Perceived health status | | | | | | | | | |
| Good§ | 1279057 | 27.4 | 922424 | 72.1 | 1.311 | 1.007 to 1.707 | 0.043 | 1.255 | 0.958 to 1.643 | 0.120 | |
| Average | 2077480 | 44.6 | 1378474 | 66.4 | Referent | | | | |
| Bad§ | 1304058 | 28.0 | 722488 | 55.4 | 0.630 | 0.492 to 0.806 | <0.0001 | 0.79 | 0.588 to 1.061 | 0.148 | |
| Body shape perception | | | | | | | | | |
| Too thin§ | 981355 | 21.1 | 617482 | 62.9 | 0.914 | 0.697 to 1.707 | 0.456 | | |
| Just right | 2055525 | 44.1 | 1336044 | 65.0 | Referent | | | | |
| Too fat§ | 1623715 | 34.8 | 1069861 | 65.9 | 1.040 | 0.814 to 1.330 | 0.719 | | |
### Table 2  Continued

| Variables                                      | Total population with AHL | Underestimated HI* | Univariable analysis | Multivariable analysis |
|------------------------------------------------|---------------------------|--------------------|----------------------|------------------------|
|                                                 | Weighted frequency or % | Weighted frequency | Prevalence (%)‡ | OR | 95% CI | P value | OR | 95% CI | P value |
| Stress level                                   |                           |                    |                     |               |        |         |       |        |         |
| Low                                            | 3 556 134 | 76.3 | 2 350 397 | 66.1 | Referent |               |        |        |         |
| High                                           | 1 104 460 | 23.7 | 672 990 | 60.9 | 0.800 | 0.629 to 1.018 | 0.070 | 1.000 | 0.762 to 1.313 | 0.998 |
| Depressive mood lasting for 2 weeks            |                           |                    |                     |               |        |         |       |        |         |
| No                                             | 3 881 578 | 83.3 | 2 579 702 | 66.5 | Referent |               |        |        |         |
| Yes                                            | 779 016 | 16.7 | 443 684 | 57.0 | 0.668 | 0.513 to 0.868 | 0.003 | 0.795 | 0.576 to 1.097 | 0.162 |
| Health-related factors                         |                           |                    |                     |               |        |         |       |        |         |
| Vigorous physical activity practice            |                           |                    |                     |               |        |         |       |        |         |
| Non-exercising                                 | 4 150 544 | 89.1 | 2 680 694 | 64.6 | Referent |               |        |        |         |
| Exercising                                     | 510 050  | 10.9 | 342 693 | 67.2 | 1.123 | 0.822 to 1.534 | 0.467 |        |         |
| Moderate physical activity practice            |                           |                    |                     |               |        |         |       |        |         |
| Non-exercising                                 | 4 306 908 | 92.4 | 2 791 890 | 64.8 | Referent |               |        |        |         |
| Exercising                                     | 353 687 | 7.6 | 231 496 | 65.5 | 1.028 | 0.733 to 1.442 | 0.873 |        |         |
| Light physical activity practice               |                           |                    |                     |               |        |         |       |        |         |
| Non-exercising                                 | 2 957 617 | 63.5 | 1 912 833 | 64.7 | Referent |               |        |        |         |
| Exercising                                     | 1 702 977 | 36.5 | 1 110 554 | 65.2 | 1.024 | 0.841 to 1.247 | 0.814 |        |         |
| Restricted use of medical services             |                           |                    |                     |               |        |         |       |        |         |
| Yes                                            | 864 993 | 18.6 | 492 523 | 56.9 | 0.661 | 0.516 to 0.847 | 0.001 | 0.802 | 0.608 to 1.059 | 0.120 |
| No                                             | 3 795 601 | 81.4 | 2 530 863 | 66.7 | Referent |               |        |        |         |
| Health screening                               |                           |                    |                     |               |        |         |       |        |         |
| Yes                                            | 2 954 154 | 63.4 | 1 912 266 | 64.7 | 0.983 | 0.804 to 1.202 | 0.870 |        |         |
| No                                             | 1 706 441 | 36.6 | 1 111 120 | 65.1 | Referent |               |        |        |         |
| Hospital visit in past 2 weeks                 |                           |                    |                     |               |        |         |       |        |         |
| Yes                                            | 1 922 260 | 41.2 | 1 156 350 | 60.2 | 0.705 | 0.583 to 0.851 | 0.0003 | 0.896 | 0.727 to 1.104 | 0.301 |
| No                                             | 2 738 335 | 58.8 | 1 867 037 | 68.2 | Referent |               |        |        |         |
| Hospitalisation in past year                  |                           |                    |                     |               |        |         |       |        |         |
| Yes                                            | 572 508 | 12.3 | 360 689 | 63.0 | 0.912 | 0.700 to 1.188 | 0.492 |        |         |
| No                                             | 4 088 086 | 87.7 | 2 662 698 | 65.1 | Referent |               |        |        |         |
| Obesity occurrence                             |                           |                    |                     |               |        |         |       |        |         |
| Underweight§                                   | 159 020 | 3.4 | 97 392 | 61.2 | 0.894 | 0.491 to 1.628 | 1.000 |        |         |

Continued
| Variables                     | Total population with AHL | Underestimated HI* | Univariable analysis | Multivariable analysis |
|-------------------------------|---------------------------|--------------------|----------------------|-----------------------|
|                               | Weighted frequency | Mean† or % | Weighted frequency | Prevalence (%)‡ | OR      | 95% CI       | P value | OR      | 95% CI       | P value |
| Normal                        | 2881216         | 61.8       | 1840506         | 63.9             | Referent |                      |         |          |                      |         |
| Overweight§                   | 1620358         | 34.8       | 1085489         | 67.0             | 1.148    | 0.918 to 1.435 | 0.335   |          |                      |         |
| Medical history               |                           |                   |                     |                  |          |                      |         |          |                      |         |
| Hypertension                  | 1684501         | 36.1       | 1066151         | 63.3             | 0.898    | 0.742 to 1.086 | 0.266   |          |                      |         |
| Yes                           | 2976094         | 63.9       | 1957235         | 65.8             | Referent |                      |         |          |                      |         |
| No                            | 4589773         | 98.5       | 2988935         | 65.1             |          |                      |         |          |                      |         |
| Myocardial infarction         | 70821          | 1.5        | 34451           | 48.6             | 0.507    | 0.258 to 0.999 | **0.050** | 0.538    | 0.242 to 1.198 | 0.129   |
| Yes                           | 4410522         | 96.4       | 2933694         | 65.3             | Referent |                      |         |          |                      |         |
| No                            | 4468019         | 95.9       | 2921748         | 65.4             |          |                      |         |          |                      |         |
| Angina                        | 169542          | 3.6        | 89693           | 52.9             | 0.596    | 0.381 to 0.900 | **0.024** | 0.803    | 0.500 to 1.288 | 0.363   |
| Yes                           | 4491052         | 96.4       | 2933694         | 65.3             | Referent |                      |         |          |                      |         |
| No                            | 4458555         | 95.7       | 2892616         | 64.9             | Referent |                      |         |          |                      |         |
| Asthma                        | 192575          | 4.1        | 101638          | 52.8             | 0.591    | 0.389 to 0.899 | **0.014** | 0.765    | 0.498 to 1.175 | 0.221   |
| Yes                           | 4618526         | 99.1       | 3003479         | 65.0             | Referent |                      |         |          |                      |         |
| No                            | 4001727         | 85.9       | 2626635         | 65.6             | Referent |                      |         |          |                      |         |
| Depression                    | 202039          | 4.3        | 130770          | 64.7             | 0.993    | 0.663 to 1.487 | 0.974   |          |                      |         |
| Yes                           | 4458555         | 95.7       | 2892616         | 64.9             | Referent |                      |         |          |                      |         |
| No                            | 42069           | 0.9        | 19908           | 47.3             | 0.483    | 0.184 to 1.268 | 0.139   | 0.707    | 0.255 to 1.956 | 0.503   |
| Renal failure                 | 42069           | 0.9        | 19908           | 47.3             | 0.483    | 0.184 to 1.268 | 0.139   | 0.707    | 0.255 to 1.956 | 0.503   |
| Yes                           | 4618526         | 99.1       | 3003479         | 65.0             | Referent |                      |         |          |                      |         |
| No                            | 4001727         | 85.9       | 2626635         | 65.6             | Referent |                      |         |          |                      |         |
| Diabetes mellitus             | 658868          | 14.1       | 396751          | 60.2             | 0.792    | 0.618 to 1.202 | 0.067   | 0.974    | 0.740 to 1.281 | 0.849   |
| Yes                           | 4001727         | 85.9       | 2626635         | 65.6             | Referent |                      |         |          |                      |         |
| No                            | 3040249         | 65.2       | 2205518         | 72.5             | Referent |                      |         |          |                      |         |
| Auditory factors              |                           |                   |                     |                  |          |                      |         |          |                      |         |
| Tinnitus                      | 1620345         | 34.8       | 817869          | 50.5             | 0.386    | 0.316 to 0.472 | **<0.0001** | 0.425    | 0.344 to 0.525 | **<0.0001** |
| Yes                           | 800620          | 17.2       | 459993          | 57.5             | 0.683    | 0.520 to 0.897 | **0.006** | 0.566    | 0.423 to 0.758 | **<0.0001** |
| No                            | 3040249         | 65.2       | 2205518         | 72.5             | Referent |                      |         |          |                      |         |
| Occupational noise exposure   |                           |                   |                     |                  |          |                      |         |          |                      |         |
Table 2 Continued

| Variables | Total population with AHL | Underestimated HI* | Univariable analysis | Multivariable analysis |
|-----------|---------------------------|--------------------|----------------------|------------------------|
|           | Weighted frequency | Mean† or % | Weighted frequency | Prevalence (%)‡ | OR 95% CI | P value | OR 95% CI | P value |
| No        | 3859974 | 82.8 | 2563394 | 66.4 | Referent |

**Laboratory measures**

|                          | Weighted frequency | Mean† or % | Weighted frequency | Prevalence (%)‡ | OR 95% CI | P value | OR 95% CI | P value |
|--------------------------|--------------------|------------|--------------------|-----------------|-----------|---------|-----------|---------|
| Systolic BP (mm Hg)      | 4660594            | 126.4†     | 3023386            | 64.9            | 1.001     | 0.996 to 1.007 | 0.573 |
| Diastolic BP (mm Hg)     | 4660594            | 77.0†      | 3023386            | 64.9            | 1.015     | 1.006 to 1.024 | **0.002** |
| Total cholesterol (mg/dL)| 4394622            | 191.7†     | 2859596            | 65.1            | 1.001     | 0.998 to 1.003 | 0.683 |
| HDL cholesterol (mg/dL)  | 4394622            | 50.3†      | 2859596            | 65.1            | 1.005     | 0.998 to 1.013 | 0.158 |
| Serum TG (mg/dL)         | 4394622            | 148.7†     | 2859596            | 65.1            | 1.000     | 1.000 to 1.001 | 0.411 |
| Haemoglobin (g/dL)       | 4369845            | 14.1†      | 2848403            | 65.2            | 1.029     | 0.968 to 1.093 | 0.360 |
| Haematocrit (%)          | 4369845            | 41.9†      | 2848403            | 65.2            | 1.008     | 0.986 to 1.032 | 0.471 |
| BUN (mg/dL)              | 4394622            | 15.5†      | 2859596            | 65.1            | 0.978     | 0.958 to 0.998 | **0.033** |
| Serum creatinine (mg/dL) | 4394622            | 0.9†       | 2859596            | 65.1            | 1.095     | 0.725 to 1.655 | 0.665 |

**Urine protein**

|                          | Weighted frequency | Mean† or % | Weighted frequency | Prevalence (%)‡ | OR 95% CI | P value | OR 95% CI | P value |
|--------------------------|--------------------|------------|--------------------|-----------------|-----------|---------|-----------|---------|
| Negative                 | 3913238            | 89.1       | 2519106            | 64.4            | Referent |
| Positive                 | 477957             | 10.9       | 315207             | 65.9            | 1.072     | 0.774 to 1.484 | 0.675 |

**Urine glucose**

|                          | Weighted frequency | Mean† or % | Weighted frequency | Prevalence (%)‡ | OR 95% CI | P value | OR 95% CI | P value |
|--------------------------|--------------------|------------|--------------------|-----------------|-----------|---------|-----------|---------|
| Negative                 | 4199401            | 95.6       | 2708365            | 64.5            | Referent |
| Positive                 | 191793             | 4.4        | 125948             | 65.7            | 1.053     | 0.652 to 1.699 | 0.833 |

Bold type indicates significant differences (p<0.05).
*Underestimated HI was defined as having AHL without SHD.
†Continuous variables are denoted by the mean.
‡Prevalence of underestimated HI in total population with AHL.
§Probability values and 95% CIs for ORs were corrected using Bonferroni’s method for cases with multiple testing.
AHL, audiometrically measured hearing loss; BP, blood pressure; BUN, blood urea nitrogen; EQ-5D, Euro Qol-5D; HDL, high-density lipoprotein; HI, hearing impairment; SHD, self-reported hearing difficulty; TG, triglycerides.
Table 3  Univariable and multivariable analyses of factors associated with overestimated hearing impairment

| Variables | Total population with SHD | Overestimated HI* | Univariable analysis | Multivariable analysis |
|-----------|---------------------------|-------------------|----------------------|------------------------|
|           | Weighted frequency or %   | Weighted frequency | Prevalence (%)†‡     | OR 95% CI P value      | OR 95% CI P value      |
| Personal factors |                       |                   |                      |                        |                        |
| Age (years) | 3089060 56.3†          | 1451852 47.0      | 0.915 0.904 to 0.927 | <0.0001 0.905 0.890 to 0.921 | <0.0001 |
| Sex |                       |                   |                      |                        |                        |
| Male | 1574262 51.0          | 682372 43.3      | 0.741 0.576 to 0.954 | 0.020 0.660 0.424 to 1.029 | 0.067 |
| Female | 1514797 49.0        | 769480 50.8      | Referent             |                        |                        |
| Smoke |                       |                   |                      |                        |                        |
| Never | 1568370 50.8          | 787885 50.2      | Referent             |                        |                        |
| Past smoker§ | 799930 25.9      | 314073 39.3    | 0.640 0.458 to 0.895 | 0.006 0.866 0.520 to 1.445 | 1.000 |
| Current smoker§ | 720760 23.3   | 349894 48.5    | 0.935 0.640 to 1.365 | 1.000 0.597 0.351 to 1.017 | 0.061 |
| Drinking alcohol in past year |       |                   |                      |                        |                        |
| Non-drinker | 998495 32.3        | 343984 34.5    | Referent             |                        |                        |
| Drinker | 2090565 67.7         | 1107867 53.0    | 2.145 1.650 to 2.788 | <0.0001 1.150 0.784 to 1.687 | 0.475 |
| Marital status |               |                   |                      |                        |                        |
| Ever married | 2792856 90.4      | 1191925 42.7    | 0.104 0.048 to 0.223 | <0.0001 1.276 0.511 to 3.184 | 0.601 |
| Never married | 296204 9.6         | 259927 87.8     | Referent             |                        |                        |
| Waist circumference (cm) | 3089060 83.2†       | 1451852 47.0    | 0.977 0.964 to 0.991 | 0.001 0.988 0.964 to 1.014 | 0.363 |
| Body mass index (kg/m²) | 3089060 24.0†       | 1451852 47.0    | 1.018 0.979 to 1.059 | 0.375 0.857 to 2.514 | 0.266 |
| Socioeconomic factors |           |                   |                      |                        |                        |
| Income |                       |                   |                      |                        |                        |
| Lower | 847736 27.4           | 232347 27.4      | Referent             |                        |                        |
| Lower middle§ | 862386 27.9       | 399476 46.3     | 2.286 1.481 to 3.526 | <0.0001 0.957 0.577 to 1.584 | 1.000 |
| Upper middle§ | 681338 22.1       | 387641 56.9     | 3.496 2.187 to 5.588 | <0.0001 1.244 0.739 to 2.093 | 0.951 |
| Upper§ | 697599 22.6           | 432388 62.0      | 4.318 2.833 to 6.582 | <0.0001 1.468 0.857 to 2.514 | 0.266 |
| Education |                       |                   |                      |                        |                        |
| Less than high school | 1610010 52.1      | 515579 32.0     | Referent             |                        |                        |
| High school or more | 1479050 47.9     | 936273 63.3     | 3.661 2.858 to 4.690 | <0.0001 1.166 0.792 to 1.716 | 0.436 |
| Employment status |                   |                   |                      |                        |                        |
| Employed | 1738450 56.3         | 902568 51.9     | 1.575 1.224 to 2.027 | 0.0004 0.912 0.625 to 1.330 | 0.631 |
| Unemployed | 1350609 43.7        | 549284 40.7     | Referent             |                        |                        |
| Quality of life |               |                   |                      |                        |                        |

Continued
| Variables                              | Total population with SHD | Overestimated HI* | Univariable analysis | Multivariable analysis |
|----------------------------------------|---------------------------|-------------------|----------------------|------------------------|
|                                        | Weighted frequency | Mean† or % | Weighted frequency | Prevalence (%)‡ | OR 95% CI | P value | OR 95% CI | P value |
| EQ-5D (%)                              |                           |                  |                      |                    |          |         |          |         |
| Physical activity (mobility)           |                           |                  |                      |                    |          |         |          |         |
| Normal                                 | 2262057                   | 73.2             | 1203774             | 53.2               | Referent  | 0.377   | 0.291 to 0.488 | <0.0001 |
| Limited                                | 827002                    | 26.8             | 248078              | 30.0               |          | 0.0001  |
| Physical activity (self-care)          |                           |                  |                      |                    |          |         |          |         |
| Normal                                 | 2855547                   | 92.4             | 1396588             | 48.9               | Referent  | 0.324   | 0.200 to 0.524 | <0.0001 |
| Limited                                | 233513                    | 7.6              | 55264               | 23.7               |          | 0.987   | 0.563 to 1.730 | 0.373   |
| Physical activity (usual activities)   |                           |                  |                      |                    |          |         |          |         |
| Normal                                 | 2566840                   | 83.1             | 1296758             | 50.5               | Referent  | 0.041   | 0.306 to 0.560 | <0.0001 |
| Limited                                | 522220                    | 16.9             | 155094              | 29.7               |          | 0.783   |          |         |
| Physical activity (pain/discomfort)    |                           |                  |                      |                    |          |         |          |         |
| Normal                                 | 2084203                   | 67.5             | 1008232             | 48.4               | Referent  | 0.844   | 0.667 to 1.067 | 0.156   |
| Limited                                | 1004857                   | 32.5             | 443620              | 44.1               |          | 0.783   |          |         |
| Physical activity (anxiety/depression) |                           |                  |                      |                    |          |         |          |         |
| Normal                                 | 2575106                   | 83.4             | 1205708             | 46.8               | Referent  | 1.044   | 0.769 to 1.418 | 0.783   |
| Limited                                | 513954                    | 16.6             | 246144              | 47.9               |          | 0.783   |          |         |
| EQ-5D index (%)                        |                           |                  |                      |                    |          |         |          |         |
| Index<0.75                             | 352500                    | 11.4             | 108676              | 30.8               | Referent  | 1.000   |          |          |
| 0.75≤index < 1.00§                     | 1112495                   | 36.0             | 518799              | 46.6               | Referent  | 0.987   | 0.563 to 1.730 | 0.003   |
| Index=1.00§                            | 1624065                   | 52.6             | 824376              | 50.8               | Referent  | 0.705   | 0.389 to 1.275 | 0.373   |
| EQ-VAS (0 to 100)                      | 3089060                   | 69.1†            | 1451852             | 47.0               | Referent  | 0.001   |          |          |
| Psychological factors                  |                           |                  |                      |                    |          |         |          |         |
| Perceived health status                |                           |                  |                      |                    |          |         |          |         |
| Good§                                  | 759297                    | 24.6             | 402665              | 53.0               | 1.164    | 0.798 to 1.697 | 0.736   | 1.342 | 0.893 to 2.017 | 0.212   |
| Fair                                   | 1377238                   | 44.6             | 678232              | 49.2               | Referent  | 0.004   | 0.957   | 0.640 to 1.431 | 1.000   |
| Poor§                                  | 952524                    | 30.8             | 370955              | 38.9               | 0.657    | 0.484 to 0.892 | 0.035   | 1.031 | 0.608 to 1.746 | 1.000   |
| Body shape perception                  |                           |                  |                      |                    |          |         |          |         |
| Too thin§                              | 549060                    | 17.8             | 185188              | 33.7               | 0.641    | 0.422 to 0.973 | 0.035   | 1.031 | 0.608 to 1.746 | 1.000   |
| Just right                             | 1290616                   | 41.8             | 571135              | 44.3               | Referent  | 0.002   | 1.312 | 0.874 to 1.968 | 0.269   |
| Too fat§                               | 1249383                   | 40.4             | 695530              | 55.7               | 1.582    | 1.158 to 2.162 | 0.002   | 1.312 | 0.874 to 1.968 | 0.269   |

Continued
| Variables               | Total population with SHD | Overestimated HI* | Univariable analysis | Multivariable analysis |
|------------------------|---------------------------|-------------------|----------------------|------------------------|
|                        | Weighted frequency | Mean† or % | Weighted frequency | Prevalence (%)‡ | OR | 95% CI | P value | OR | 95% CI | P value |
| Stress level           |                           |                   |                      |                      |    |       |         |    |       |         |
| Low                    | 2 134 226                | 69.1             | 928 488             | 43.5               | Referent                 |                      |    |       |         |    |       |         |
| High                   | 954 834                  | 30.9             | 523 364             | 54.8               | 1.575 | 1.198 to 2.072 | 0.001 | 0.980 | 0.698 to 1.376 | 0.908 |
| Depressive mood lasting for 2 weeks |                   |                   |                      |                      |    |       |         |    |       |         |
| No                     | 2 455 973                | 79.5             | 1 154 097           | 47.0               | Referent                 |                      |    |       |         |    |       |         |
| Yes                    | 633 087                 | 20.5             | 297 755             | 47.0               | 1.002 | 0.730 to 1.375 | 0.992 |    |       |         |
| Health-related factors |                           |                   |                      |                      |    |       |         |    |       |         |
| Vigorous physical activity practice |                   |                   |                      |                      |    |       |         |    |       |         |
| Non-exercising         | 2 676 411                | 86.6             | 1 206 561           | 45.1               | Referent                 |                      |    |       |         |    |       |         |
| Exercising             | 412 648                 | 13.4             | 245 291             | 59.4               | 1.785 | 1.207 to 2.641 | 0.004 | 1.232 | 0.798 to 1.901 | 0.346 |
| Moderate physical activity practice |                   |                   |                      |                      |    |       |         |    |       |         |
| Non-exercising         | 2 793 226                | 90.4             | 1 278 209           | 45.8               | Referent                 |                      |    |       |         |    |       |         |
| Exercising             | 295 834                 | 9.6              | 173 643             | 58.7               | 1.684 | 1.103 to 2.571 | 0.016 | 1.191 | 0.738 to 1.923 | 0.474 |
| Light physical activity practice |                   |                   |                      |                      |    |       |         |    |       |         |
| Non-exercising         | 1 925 733                | 62.3             | 880 948             | 45.7               | Referent                 |                      |    |       |         |    |       |         |
| Exercising             | 1 163 327               | 37.7             | 570 903             | 49.1               | 1.143 | 0.887 to 1.473 | 0.302 | 1.232 | 0.798 to 1.901 | 0.346 |
| Restricted use of medical services |                   |                   |                      |                      |    |       |         |    |       |         |
| Yes                    | 714 039                 | 23.1             | 341 569             | 47.8               | 1.045 | 0.774 to 1.409 | 0.775 |    |       |         |
| No                     | 2 375 021               | 76.9             | 1 110 283           | 46.7               | Referent                 |                      |    |       |         |    |       |         |
| Health screening in past 2 years |                   |                   |                      |                      |    |       |         |    |       |         |
| Yes                    | 1 904 102                | 61.6             | 862 214             | 45.3               | 0.836 | 0.651 to 1.073 | 0.158 | 1.134 | 0.823 to 1.562 | 0.441 |
| No                     | 1 184 958               | 38.4             | 589 638             | 49.8               | Referent                 |                      |    |       |         |    |       |         |
| Hospital visit in past 2 weeks |                   |                   |                      |                      |    |       |         |    |       |         |
| Yes                    | 1 326 445                | 42.9             | 560 535             | 42.3               | 0.715 | 0.567 to 0.902 | 0.005 | 1.163 | 0.873 to 1.551 | 0.302 |
| No                     | 1 762 615               | 57.1             | 891 317             | 50.6               | Referent                 |                      |    |       |         |    |       |         |
| Hospitalisation in past year |                   |                   |                      |                      |    |       |         |    |       |         |
| Yes                    | 423 019                 | 13.7             | 211 199             | 49.9               | 1.146 | 0.775 to 1.695 | 0.495 |    |       |         |
| No                     | 2 666 041               | 86.3             | 1 240 652           | 46.5               | Referent                 |                      |    |       |         |    |       |         |
| Obesity occurrence    |                           |                   |                      |                      |    |       |         |    |       |         |
| Underweight§          | 112 572                 | 3.6              | 50 943              | 45.3               | 0.955 | 0.467 to 1.957 | 1.000 |    |       |         |

Cont.
**Table 3 Continued**

| Variables | Total population with SHD | Overestimated HI* | Univariable analysis | Multivariable analysis |
|-----------|--------------------------|-------------------|----------------------|------------------------|
|           | Weighted frequency | Mean† or % | Weighted frequency | Prevalence (%)‡ | OR | 95% CI | P value | OR | 95% CI | P value |
| Normal    | 1941254 | 62.8 | 900545 | 46.4 | Referent |
| Overweight§ | 1035234 | 33.5 | 500364 | 48.3 | 1.081 | 0.819 to 1.428 | 1.000 |
| Medical history | | | | | | | |
| Hypertension | | | | | | | |
| Yes       | 937031 | 30.3 | 318681 | 34.0 | 0.463 | 0.361 to 0.595 | **<0.0001** | 1.501 | 1.061 to 2.123 | **0.022** |
| No        | 2152029 | 69.7 | 1133171 | 52.7 | Referent |
| Myocardial infarction | | | | | | | |
| Yes       | 47034 | 1.5 | 10664 | 22.7 | 0.326 | 0.101 to 1.052 | 0.061 | 0.582 | 0.129 to 2.621 | 0.480 |
| No        | 3042026 | 98.5 | 1441188 | 47.4 | Referent |
| Angina    | | | | | | | |
| Yes       | 105569 | 3.4 | 25719 | 24.4 | 0.352 | 0.198 to 0.625 | **0.0004** | 0.848 | 0.422 to 1.705 | 0.643 |
| No        | 2983490 | 96.6 | 1426132 | 47.8 | Referent |
| Asthma    | | | | | | | |
| Yes       | 142099 | 4.6 | 51162 | 36.0 | 0.621 | 0.342 to 1.128 | 0.117 | 0.991 | 0.482 to 2.037 | 0.980 |
| No        | 2946961 | 95.4 | 1400690 | 47.5 | Referent |
| Depression | | | | | | | |
| Yes       | 167870 | 5.4 | 96600 | 57.5 | 1.566 | 1.009 to 2.432 | **0.046** | 1.772 | 1.041 to 3.016 | **0.035** |
| No        | 2921190 | 94.6 | 1355251 | 46.4 | Referent |
| Renal failure | | | | | | | |
| Yes       | 27962 | 0.9 | 5801 | 20.7 | 0.292 | 0.049 to 1.733 | 0.175 | 0.442 | 0.065 to 2.987 | 0.402 |
| No        | 3061098 | 99.1 | 1446051 | 47.2 | Referent |
| Diabetes mellitus | | | | | | | |
| Yes       | 375984 | 12.2 | 113868 | 30.3 | 0.447 | 0.303 to 0.658 | **<0.0001** | 1.140 | 0.725 to 1.792 | 0.569 |
| No        | 2713075 | 87.8 | 1337984 | 49.3 | Referent |
| Auditory factors | | | | | | | |
| Tinnitus | | | | | | | |
| Yes       | 1301805 | 42.1 | 499329 | 38.4 | 0.545 | 0.427 to 0.697 | **<0.0001** | 0.523 | 0.391 to 0.699 | **<0.0001** |
| No        | 1787254 | 57.9 | 952523 | 53.3 | Referent |
| Occupational noise exposure | | | | | | | |
| Yes       | 630805 | 20.4 | 290178 | 46.0 | 0.951 | 0.687 to 1.315 | 0.760 |
Table 3  Continued

| Variables               | Total population with SHD | Overestimated HI* | Univariable analysis | Multivariable analysis |
|-------------------------|---------------------------|-------------------|----------------------|------------------------|
|                         | Weighted frequency | Mean† or % | Weighted frequency | Prevalence (%)‡ | OR   | 95% CI      | P value | OR   | 95% CI      | P value |
| No                      | 2 458 254            | 79.6       | 1 161 674          | 47.3            | Referent             |
| Laboratory measures     |                          |       |                          |                |                   |       |       |       |                   |       |
| Systolic BP (mm Hg)     | 3 089 060            | 122.8†    | 1 451 852           | 47.0            | 0.974              | 0.966 to 0.981 | <0.0001 | 0.996 | 0.984 to 1.008 | 0.469  |
| Diastolic BP (mm Hg)    | 3 089 060            | 76.5†     | 1 451 852           | 47.0            | 1.011              | 0.999 to 1.023 | 0.083   | 1.013 | 0.993 to 1.033 | 0.215  |
| Total cholesterol (mg/dL) | 2 931 858          | 191.5†    | 1 396 832           | 47.6            | 1.001              | 0.997 to 1.004 | 0.723   |       |                   |       |
| HDL cholesterol (mg/dL) | 2 931 858           | 50.7†     | 1 396 832           | 47.6            | 1.013              | 1.003 to 1.023 | 0.011   |       |                   |       |
| Serum TG (mg/dL)        | 2 931 858           | 141.3†    | 1 396 832           | 47.6            | 0.999              | 0.998 to 1.000 | 0.149   |       |                   |       |
| Haemoglobin (g/dL)      | 2 913 750            | 14.1†     | 1 392 308           | 47.8            | 1.038              | 0.953 to 1.132 | 0.392   |       |                   |       |
| Haematocrit (%)         | 2 913 750            | 41.9†     | 1 392 308           | 47.8            | 1.012              | 0.980 to 1.045 | 0.463   |       |                   |       |
| BUN (mg/dL)             | 2 931 858            | 14.9†     | 1 535 026           | 52.4            | 0.904              | 0.873 to 0.936 | <0.0001 | 0.996 | 0.984 to 1.008 | 0.469  |
| Serum creatinine (mg/dL) | 2 931 858          | 0.9†      | 1 535 026           | 52.4            | 0.330              | 0.169 to 0.646 | 0.001   |       |                   |       |
| Urine protein           |                          |       |                          |                |                   |       |       |       |                   |       |
| Negative                | 2 602 155            | 89.2     | 1 208 023           | 46.4            | Referent           |
| Positive                | 314 670              | 10.8     | 151 920             | 48.3            | 1.077              | 0.700 to 1.658 | 0.734   |       |                   |       |
| Urine glucose           |                          |       |                          |                |                   |       |       |       |                   |       |
| Negative                | 2 812 935            | 96.4     | 1 321 898           | 47.0            | Referent           |
| Positive                | 103 890              | 3.6      | 38 045              | 36.6            | 0.652              | 0.342 to 1.243 | 0.193   |       |                   |       |

Bold text indicates significant differences (p<0.05).
*Overestimated HI was defined as having SHD without AHL.
†Continuous variables are denoted by the mean.
‡Prevalence of overestimated HI in total population with SHD.
§Probability values and 95% CIs for OR were corrected using Bonferroni’s method for cases with multiple testing.
AHL, audiometrically measured hearing loss; BP, blood pressure; BUN, blood urea nitrogen; EQ-5D, Euro Qol-5D; HDL, high-density lipoprotein; HI, hearing impairment; SHD, self-reported hearing difficulty; TG, triglycerides.
audiometric HL among participants with SHD (table 3). In contrast to our result, Kamil et al has reported that old age was related to underestimation of HI. The contradictory result between our study and Kamil et al may be due to the fact that younger people who underestimated HI were not included because they examined participants aged 250 years. Among 2609 participants with discrepancy between SHD and AHL in this study, underestimated HI was more prevalent in older participants than overestimated HI, and it might be attributed to a tendency of older population to consider their HL to be ‘normal’ for their age.3

For medical-related factors, participants who overestimated their HI significantly had more hypertension and depression than those who had concordant HI (table 3). Because hypertension is known to increase the risk of cochlea damage possibly through malfunction of the stria vascularis,29 it might be related to early development of preclinical HL in auditory way. Also, hypertension and depression may influence the SHD in non-auditory way. Subjects with hypertension have worse overall health than subjects without hypertension, which in turn has been shown to be associated with an increased likelihood of reporting HD.30 Studies have suggested that personality traits of neuroticism had a more adverse perception of their HD,31 32 and it is widely known as an important factor that influences depression.33 Accordingly, hypertension and depression may lead to an increased perception of HD. Moreover, as the present study is cross-sectional, it cannot be excluded that hypertension and depression is a result of SHD.

For auditory factors, tinnitus and occupational noise exposure were associated with concordant HI (tables 2 and 3). It is possible that these participants had an audiometric assessment for their tinnitus or occupational health screening programme and had known about their hearing status. Participants who had been exposed to occupational noise tended to have less underestimated HI regardless of tinnitus (table 2). As they are more likely to have severe HL than other participants, the severity of HL may affect SHD.9

Although a similar study from same dataset has been recently reported,5 our study has several significant differences in approach. First, we excluded data from participants with abnormal TM who are more likely to have undergone a previous hearing evaluation. Second, we excluded normal hearing population with normal audiometry (<25 dB) and without SHD in the reference group, and confined the concordant HI group to those who showed both SHD and AHL as reference. However, Kim et al has had the concordance group including normal hearing population as reference. Because a large number of normal hearing people (93%) were included in their reference group, their analysis is likely to be biased by factors related to SHD or AHL, rather than focusing on the discrepancy between subjective hearing assessment and audiometry itself. Subgroup analysis for participants with ≥25 dB in Kim et al showed that age, sex, education, occupation and stress were not associated with the discrepancy between subjective hearing assessment and audiometric thresholds. Lastly, this study analysed more variables including smoking status, alcohol consumption, waist circumference, body mass index, monthly income, marital status, quality of life, self-reported health status, body shape perception, noise exposure, physical activity, the use of medical service, current disease and serological data. Therefore, we expected that this study could provide more comprehensive information related to discrepancy between SHD and AHL.

In summary, the prevalence of discrepancy between SHD and AHL was 18.2% in South Korea. Age, medical histories of hypertension and depression, tinnitus and occupational noise exposure were associated with inconsistent results between self-reported and audiometrically measured hearing assessment in multivariable analysis. Understanding the factors related to self-reported hearing will assist clinicians in interpreting subjective reports of hearing and using these data as a surrogate measure of audiometry. These factors need to be considered when determining whether to conduct a hearing test, even if the patients do not report an HI.

Author affiliations
1Department of Otorhinolaryngology-Head and Neck Surgery, Dankook University Hospital, Cheonan, Republic of Korea
2Department of Otorhinolaryngology-Head and Neck Surgery, Samsung Medical Center, Seoul, Republic of Korea
3Biostatistics and Clinical Epidemiology Center, Research Institute for Future Medicine, Samsung Medical Center, Seoul, Republic of Korea

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