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

Ji Eun Choi,¹ Il Joon Moon,² Sun-Young Baek,³ Seon Woo Kim,³ Yang-Sun Cho²

To cite: Choi JE, Moon IJ, Baek S-Y, *et al.* Discrepancies between self-reported hearing difficulty and hearing loss diagnosed by audiometry: prevalence and associated factors in a national survey. *BMJ Open* 2019;9:e022440. doi:10.1136/bmjopen-2018-022440

► Prepublication history for this paper is available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2018-022440>).

JEC and IJM contributed equally.

Received 21 February 2018

Revised 27 February 2019

Accepted 1 March 2019

© Author(s) (or their employer(s)) 2019. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

For numbered affiliations see end of article.

Correspondence to

Professor Yang-Sun Cho; yscho@skku.edu

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.^{1–11} 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)^{5–7 9 10 12 13} as well as demographic factors.^{3 5 7 14 15} However, these studies have mainly focused on elderly populations^{3 8 11 14} or SHD with normal audiogram.^{1 7} 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,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.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.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.

Otologic 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/m^2) 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.^{18 19} 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.²⁰ 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.*²¹ 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 V.9.4 (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, 16 727 participants aged ≥ 19 years completed the hearing questionnaire and audiometric measurement. After excluding participants with abnormal TM and missing data, a total of 14 345 participants were ultimately eligible for this study. The mean $\pm$ 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 14 345 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% ($n=2609$).

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

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

Audiometry	Questionnaire		Total
	Hearing difficulty	No difficulty	
Hearing loss	1125 (A)	1876 (B)	3001 (A+B)
Normal	733 (C)	10 611 (D)	11 344 (C+D)
Total	1858 (A+C)	12 487 (B+D)	14 345 (A+B+C+D)

Percentage of discrepancy (%)=18.2% [(B+C) / (A+B+C+D)].

Underestimation of hearing impairment=62.5% [B / (A+B)].

Overestimation of hearing impairment=39.5% [C / (A+C)].

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%),³ but similar to that reported in the general population of Australia (82%).⁶ Previously, Kim *et al*⁵ 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 study⁵ 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.²³ SHD is also increased with age as difficulty of speech understanding in adverse listening conditions increases²⁴ due to decreased synaptic loss,²⁵ working memory capacity^{26 27} or impaired temporal processing.^{12 28} 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

Table 2 Univariable and multivariable analyses of factors associated with underestimated hearing impairment

Variables	Total population with AHL			Underestimated HI* Prevalence (%)†		Univariable analysis			Multivariable analysis		
	Weighted frequency	Mean† or %	Weighted frequency	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	141 843	3.0	105 566		74.4	Referent					
Waist circumference (cm)	4 660 594	84.0†	3 023 386		64.9	0.998	0.988 to 1.008	0.668			
Body mass index (kg/m ²)	4 660 594	24.0†	3 023 386		64.9	1.012	0.982 to 1.042	0.447			
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											

Continued

Table 2 Continued

Total population with AHL											
Variables	Weighted frequency		Mean† or %	Underestimated HI*		Univariable analysis			Multivariable analysis		
	Weighted frequency			Weighted frequency	Prevalence (%)‡	OR	95%CI	P value	OR	95%CI	P value
EQ-5D (%)											
Physical activity (mobility)											
Normal	3 310 530		71.0	2 252 247	68.0	Referent					
Limited	1 350 065		29.0	771 140	57.1	0.626	0.516 to 0.759	<0.0001			
Physical activity (self-care)											
Normal	4 249 662		91.2	2 790 703	65.7	Referent					
Limited	410 932		8.8	232 683	56.6	0.682	0.509 to 0.915	0.011			
Physical activity (usual activities)											
Normal	3 832 356		82.2	2 562 274	66.9	Referent					
Limited	828 238		17.8	461 112	55.7	0.623	0.497 to 0.780	<0.0001			
Physical activity (pain/discomfort)											
Normal	3 243 388		69.6	2 167 417	66.8	Referent					
Limited	1 417 206		30.4	855 969	60.4	0.757	0.622 to 0.922	0.006			
Physical activity (anxiety/depression)											
Normal	4 020 865		86.3	2 651 467	65.9	Referent					
Limited	639 729		13.7	371 919	58.1	0.717	0.554 to 0.929	0.012			
EQ-5D index (%)											
Index<0.75	560 616		12.0	316 793	56.5	Referent					
0.75≤index < 1.00§	1 479 603		31.7	885 908	59.9	1.148	0.841 to 1.568	0.638	0.841	0.584 to 1.210	0.573
Index=1.00§	2 620 375		56.2	1 820 686	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)	4 660 594		62.0†	3 023 386	64.9	1.008	1.003 to 1.012	0.001			
Psychological factors											
Perceived health status											
Good§	1 279 057		27.4	922 424	72.1	1.311	1.007 to 1.707	0.043	1.255	0.958 to 1.643	0.120
Average	2 077 480		44.6	1 378 474	66.4	Referent					
Bad§	1 304 058		28.0	722 488	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§	981 355		21.1	617 482	62.9	0.914	0.697 to 1.707	0.456			
Just right	2 055 525		44.1	1 336 044	65.0	Referent					
Too fat§	1 623 715		34.8	1 069 861	65.9	1.040	0.814 to 1.330	0.719			

Continued

Table 2 Continued

Variables	Total population with AHL			Underestimated HI* Prevalence (%)†		Univariable analysis			Multivariable analysis		
	Weighted frequency	Mean† or %	Weighted frequency	Prevalence (%)‡	OR	95% CI	P value	OR	95% CI	P value	P value
<i>Stress level</i>											
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	0.998
<i>Depressive mood lasting for 2 weeks</i>											
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	0.162
Health-related factors											
<i>Vigorous physical activity practice</i>											
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				
<i>Moderate physical activity practice</i>											
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				
<i>Light physical activity practice</i>											
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				
<i>Restricted use of medical services</i>											
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	0.120
No	3 795 601	81.4	2 530 863	66.7	Referent						
<i>Health screening</i>											
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						
<i>Hospital visit in past 2 weeks</i>											
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	0.301
No	2 738 335	58.8	1 867 037	68.2	Referent						
<i>Hospitalisation in past year</i>											
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						
<i>Obesity occurrence</i>											
Underweight§	159 020	3.4	97 392	61.2	0.894	0.491 to 1.628	1.000				

Continued

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	P value
Normal	2 881 216	61.8	1 840 506	63.9	Referent						
Overweight§	1 620 358	34.8	1 085 489	67.0	1.148	0.918 to 1.435	0.335				
Medical history											
<i>Hypertension</i>											
Yes	1 684 501	36.1	1 066 151	63.3	0.898	0.742 to 1.086	0.266				
No	2 976 094	63.9	1 957 235	65.8	Referent						
<i>Myocardial infarction</i>											
Yes	70 821	1.5	34 451	48.6	0.507	0.258 to 0.999	0.050	0.538	0.242 to 1.198	0.129	
No	4 589 773	98.5	2 988 935	65.1	Referent						
<i>Angina</i>											
Yes	169 542	3.6	89 693	52.9	0.596	0.381 to 0.900	0.024	0.803	0.500 to 1.288	0.363	
No	4 491 052	96.4	2 933 694	65.3	Referent						
<i>Asthma</i>											
Yes	192 575	4.1	101 638	52.8	0.591	0.389 to 0.899	0.014	0.765	0.498 to 1.175	0.221	
No	4 468 019	95.9	2 921 748	65.4	Referent						
<i>Depression</i>											
Yes	202 039	4.3	130 770	64.7	0.993	0.663 to 1.487	0.974				
No	4 458 555	95.7	2 892 616	64.9	Referent						
<i>Renal failure</i>											
Yes	42 069	0.9	19 908	47.3	0.483	0.184 to 1.268	0.139	0.707	0.255 to 1.956	0.503	
No	4 618 526	99.1	3 003 479	65.0	Referent						
<i>Diabetes mellitus</i>											
Yes	658 868	14.1	396 751	60.2	0.792	0.618 to 1.202	0.067	0.974	0.740 to 1.281	0.849	
No	4 001 727	85.9	2 626 635	65.6	Referent						
Auditory factors											
<i>Tinnitus</i>											
No	3 040 249	65.2	2 205 518	72.5	Referent						
Yes	1 620 345	34.8	817 869	50.5	0.386	0.316 to 0.472	<0.0001	0.425	0.344 to 0.525	<0.0001	
<i>Occupational noise exposure</i>											
Yes	800 620	17.2	459 993	57.5	0.683	0.520 to 0.897	0.006	0.566	0.423 to 0.758	<0.0001	

Continued

Table 2 Continued

Total population with AHL											
Variables	Weighted frequency		Mean† or %		Underestimated HI*		Univariable analysis			Multivariable analysis	
	Weighted frequency	Mean† or %	Weighted frequency	Prevalence (%)‡	OR	95% CI	P value	OR	95% CI	P value	
No	3 859 974	82.8	2 563 394	66.4	Referent						
Laboratory measures											
Systolic BP (mm Hg)	4 660 594	126.4†	3 023 386	64.9	1.001	0.996 to 1.007	0.573				
Diastolic BP (mm Hg)	4 660 594	77.0†	3 023 386	64.9	1.015	1.006 to 1.024	0.002	1.009	1.000 to 1.019	0.058	
Total cholesterol (mg/dL)	4 394 622	191.7†	2 859 596	65.1	1.001	0.998 to 1.003	0.683				
HDL cholesterol (mg/dL)	4 394 622	50.3†	2 859 596	65.1	1.005	0.998 to 1.013	0.158				
Serum TG (mg/dL)	4 394 622	148.7†	2 859 596	65.1	1.000	1.000 to 1.001	0.411				
Haemoglobin (g/dL)	4 369 845	14.1†	2 848 403	65.2	1.029	0.968 to 1.093	0.360				
Haematocrit (%)	4 369 845	41.9†	2 848 403	65.2	1.008	0.986 to 1.032	0.471				
BUN (mg/dL)	4 394 622	15.5†	2 859 596	65.1	0.978	0.958 to 0.998	0.033				
Serum creatinine (mg/dL)	4 394 622	0.9†	2 859 596	65.1	1.095	0.725 to 1.655	0.665				
Urine protein											
Negative	3 913 238	89.1	2 519 106	64.4	Referent						
Positive	477 957	10.9	315 207	65.9	1.072	0.774 to 1.484	0.675				
Urine glucose											
Negative	4 199 401	95.6	2 708 365	64.5	Referent						
Positive	191 793	4.4	125 948	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	Mean† or %	Weighted frequency	Prevalence (%)‡		OR	95% CI	P value	OR	95% CI
Personal factors										
Age (years)	3089060	56.3†	1 451 852	47.0		0.915	0.904 to 0.927	<0.0001	0.905	0.890 to 0.921
Sex										
Male	1 574 262	51.0	682 372	43.3		0.741	0.576 to 0.954	0.020	0.660	0.424 to 1.029
Female	1 514 797	49.0	769 480	50.8	Referent					
Smoke										
Never	1 568 370	50.8	787 885	50.2	Referent					
Past smoker§	799 930	25.9	314 073	39.3	0.640	0.458 to 0.895		0.006	0.866	0.520 to 1.445
Current smoker§	720 760	23.3	349 894	48.5	0.935	0.640 to 1.365		1.000	0.597	0.351 to 1.017
Drinking alcohol in past year										
Non-drinker	998 495	32.3	343 984	34.5	Referent					
Drinker	2 090 565	67.7	1 107 867	53.0	2.145	1.650 to 2.788		<0.0001	1.150	0.784 to 1.687
Marital status										
Ever married	2 792 856	90.4	1 191 925	42.7	0.104	0.048 to 0.223		<0.0001	1.276	0.511 to 3.184
Never married	296 204	9.6	259 927	87.8	Referent					
Waist circumference (cm)	3 089 060	83.2†	1 451 852	47.0	0.977	0.964 to 0.991		0.001	0.988	0.964 to 1.014
Body mass index (kg/m²)	3 089 060	24.0†	1 451 852	47.0	1.018	0.979 to 1.059		0.375		
Socioeconomic factors										
Income										
Lower	847 736	27.4	232 347	27.4	Referent					
Lower middle§	862 386	27.9	399 476	46.3	2.286	1.481 to 3.526		<0.0001	0.957	0.577 to 1.584
Upper middle§	681 338	22.1	387 641	56.9	3.496	2.187 to 5.588		<0.0001	1.244	0.739 to 2.093
Upper§	697 599	22.6	432 388	62.0	4.318	2.833 to 6.582		<0.0001	1.468	0.857 to 2.514
Education										
Less than high school	1 610 010	52.1	515 579	32.0	Referent					
High school or more	1 479 050	47.9	936 273	63.3	3.661	2.858 to 4.690		<0.0001	1.166	0.792 to 1.716
Employment status										
Employed	1 738 450	56.3	902 568	51.9	1.575	1.224 to 2.027		0.0004	0.912	0.625 to 1.330
Unemployed	1 350 609	43.7	549 284	40.7	Referent					
Quality of life										

Continued

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
EQ-5D (%)									
<i>Physical activity (mobility)</i>									
Normal	2262057	73.2	1 203 774	53.2	Referent				
Limited	827002	26.8	248078	30.0	0.377	0.291 to 0.488	<0.0001		
<i>Physical activity (self-care)</i>									
Normal	2855547	92.4	1 396 588	48.9	Referent				
Limited	233513	7.6	55264	23.7	0.324	0.200 to 0.524	<0.0001		
<i>Physical activity (usual activities)</i>									
Normal	2566840	83.1	1 296 758	50.5	Referent				
Limited	522220	16.9	155094	29.7	0.414	0.306 to 0.560	<0.0001		
<i>Physical activity (pain/discomfort)</i>									
Normal	2084203	67.5	1 008 232	48.4	Referent				
Limited	1004857	32.5	443620	44.1	0.844	0.667 to 1.067	0.156		
<i>Physical activity (anxiety/depression)</i>									
Normal	2575106	83.4	1 205 708	46.8	Referent				
Limited	513954	16.6	246144	47.9	1.044	0.769 to 1.418	0.783		
EQ-5D index (%)									
Index<0.75	352500	11.4	108676	30.8	Referent				
0.75≤index < 1.00§	1112495	36.0	518799	46.6	1.960	1.219 to 3.151	0.003	0.987	0.563 to 1.730
Index=1.00§	1624065	52.6	824376	50.8	2.312	1.470 to 3.638	<0.0001	0.705	0.389 to 1.275
EQ-VAS (0 to 100)	3089060	69.1†	1 451 852	47.0	1.011	1.005 to 1.017	0.001		
Psychological factors									
<i>Perceived health status</i>									
Good§	759297	24.6	402665	53.0	1.164	0.798 to 1.697	0.736	1.342	0.893 to 2.017
Fair	1 377 238	44.6	678232	49.2	Referent				
Poor§	952524	30.8	370955	38.9	0.657	0.484 to 0.892	0.004	0.957	0.640 to 1.431
<i>Body shape perception</i>									
Too thin§	549060	17.8	185188	33.7	0.641	0.422 to 0.973	0.035	1.031	0.608 to 1.746
Just right	1 290 616	41.8	571 135	44.3	Referent				
Too fat§	1 249 383	40.4	695530	55.7	1.582	1.158 to 2.162	0.002	1.312	0.874 to 1.968

Continued

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
<i>Stress level</i>										
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
<i>Depressive mood lasting for 2 weeks</i>										
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										
<i>Vigorous physical activity practice</i>										
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
<i>Moderate physical activity practice</i>										
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
<i>Light physical activity practice</i>										
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			
<i>Restricted use of medical services</i>										
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					
<i>Health screening in past 2 years</i>										
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					
<i>Hospital visit in past 2 weeks</i>										
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					
<i>Hospitalisation in past year</i>										
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					
<i>Obesity occurrence</i>										
Underweight§	112 572	3.6	50 943	45.3	0.955	0.467 to 1.957	1.000			

Continued

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
Normal	1 941 254	62.8	900 545	46.4	Referent				
Overweight§	1 035 234	33.5	500 364	48.3	1.081	0.819 to 1.428	1.000		
Medical history									
<i>Hypertension</i>									
Yes	937 031	30.3	318 681	34.0	0.463	0.361 to 0.595	<0.0001	1.501	1.061 to 2.123
No	2 152 029	69.7	1 133 171	52.7	Referent				0.022
<i>Myocardial infarction</i>									
Yes	47 034	1.5	10 664	22.7	0.326	0.101 to 1.052	0.061	0.582	0.129 to 2.621
No	3 042 026	98.5	1 441 188	47.4	Referent				0.480
<i>Angina</i>									
Yes	1 055 69	3.4	257 19	24.4	0.352	0.198 to 0.625	0.0004	0.848	0.422 to 1.705
No	2 983 490	96.6	1 426 132	47.8	Referent				0.643
<i>Asthma</i>									
Yes	142 099	4.6	51 162	36.0	0.621	0.342 to 1.128	0.117	0.991	0.482 to 2.037
No	2 946 961	95.4	1 400 690	47.5	Referent				0.980
<i>Depression</i>									
Yes	167 870	5.4	96 600	57.5	1.566	1.009 to 2.432	0.046	1.772	1.041 to 3.016
No	2 921 190	94.6	1 355 251	46.4	Referent				0.035
<i>Renal failure</i>									
Yes	27 962	0.9	5801	20.7	0.292	0.049 to 1.733	0.175	0.442	0.065 to 2.987
No	3 061 098	99.1	1 446 051	47.2	Referent				0.402
<i>Diabetes mellitus</i>									
Yes	375 984	12.2	113 868	30.3	0.447	0.303 to 0.658	<0.0001	1.140	0.725 to 1.792
No	2 713 075	87.8	1 337 984	49.3	Referent				0.569
Auditory factors									
<i>Tinnitus</i>									
No	1 787 254	57.9	952 523	53.3	Referent				
Yes	1 301 805	42.1	499 329	38.4	0.545	0.427 to 0.697	<0.0001	0.523	0.391 to 0.699
<i>Occupational noise exposure</i>									
Yes	630 805	20.4	290 178	46.0	0.951	0.687 to 1.315	0.760		

Continued

Table 3 Continued

Variables	Total population with SHD			Overestimated HI*		Univariable analysis			Multivariable analysis		
	Weighted frequency	Mean† or %	Prevalence (%)‡	Weighted frequency	Prevalence (%)‡	OR	95% CI	P value	OR	95% CI	P value
						Referent					
No	2458254	79.6	47.3	1161674	47.3	Referent					
Laboratory measures											
Systolic BP (mm Hg)	3089060	122.8†	47.0	1451852	47.0	0.974	0.966 to 0.981	<0.0001	0.996	0.984 to 1.008	0.469
Diastolic BP (mm Hg)	3089060	76.5†	47.0	1451852	47.0	1.011	0.999 to 1.023	0.083	1.013	0.993 to 1.033	0.215
Total cholesterol (mg/dL)	2931858	191.5†	47.6	1396832	47.6	1.001	0.997 to 1.004	0.723			
HDL cholesterol (mg/dL)	2931858	50.7†	47.6	1396832	47.6	1.013	1.003 to 1.023	0.011			
Serum TG (mg/dL)	2931858	141.3†	47.6	1396832	47.6	0.999	0.998 to 1.000	0.149			
Haemoglobin (g/dL)	2913750	14.1†	47.8	1392308	47.8	1.038	0.953 to 1.132	0.392			
Haematocrit (%)	2913750	41.9†	47.8	1392308	47.8	1.012	0.980 to 1.045	0.463			
BUN (mg/dL)	2931858	14.9†	52.4	1535026	52.4	0.904	0.873 to 0.936	<0.0001			
Serum creatinine (mg/dL)	2931858	0.9†	52.4	1535026	52.4	0.330	0.169 to 0.646	0.001			
Urine protein											
Negative	2602155	89.2	46.4	1208023	46.4	Referent					
Positive	314670	10.8	48.3	151920	48.3	1.077	0.700 to 1.658	0.734			
Urine glucose											
Negative	2812935	96.4	47.0	1321898	47.0	Referent					
Positive	103890	3.6	36.6	38045	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*⁸ 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 ≥ 50 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*⁵ 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*⁵ 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

Acknowledgements We thank the 150 residents of Otorhinolaryngology Departments of 47 training hospitals in South Korea and members of the Division of Chronic Disease Surveillance in Korea Centers for Disease Control and Prevention for collecting data in this survey and their dedicated work.

Contributors JEC and IJM designed research and wrote the main paper. S-YB and SWK collected and analysed data. Y-SC provided critical revision and discussed the results and implications and commented on the manuscript at all stages.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Obtained.

Ethics approval All participants provided written informed consent before completing the survey. KNHANES followed the tenets of the Declaration of Helsinki for biomedical research. It was approved by the Institutional Review Board of the Korean Centers for Disease Control and Prevention (IRB No. 2010-02CON-21-C, 2011-02CON-06-C and 2012-01EXP-01-2C). Approval for this research study was obtained from the Institutional Review Board of Samsung Medical Center (IRB No. 2016-06-142).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Data are available from the Korea National Health and Nutrition Examination Survey (KNHANES) Data Access for researchers. Because annually, Korea Center for Disease Control and Prevention published the reports and microdata of KNHANES with survey manuals through the official website of KNHANES (<http://knhanes.cdc.go.kr>), all KNHANES data are de-identified and available to the public.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given,

any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

REFERENCES

1. Kiely KM, Gopinath B, Mitchell P, *et al.* Evaluating a dichotomized measure of self-reported hearing loss against gold standard audiometry: prevalence estimates and age bias in a pooled national data set. *J Aging Health* 2012;24:439–58.
2. Nondahl DM, Cruickshanks KJ, Wiley TL, *et al.* Accuracy of self-reported hearing loss. *Audiology* 1998;37:295–301.
3. Kamil RJ, Genther DJ, Lin FR. Factors associated with the accuracy of subjective assessments of hearing impairment. *Ear Hear* 2015;36:164–7.
4. Diao M, Sun J, Jiang T, *et al.* Comparison between self-reported hearing and measured hearing thresholds of the elderly in China. *Ear Hear* 2014;35:e228–32.
5. Kim SY, Kim HJ, Kim MS, *et al.* Discrepancy between self-assessed hearing status and measured audiometric evaluation. *PLoS One* 2017;12:e0182718.
6. Kirk KM, McGuire A, Nasveld PE, *et al.* Comparison of self-reported and audiometrically-measured hearing loss in the Australian Defence Force. *Int J Audiol* 2012;51:294–8.
7. Tremblay KL, Pinto A, Fischer ME, *et al.* Self-Reported Hearing Difficulties Among Adults With Normal Audiograms: The Beaver Dam Offspring Study. *Ear Hear* 2015;36:e290–9.
8. Sindhusake D, Mitchell P, Smith W, *et al.* Validation of self-reported hearing loss. The Blue Mountains Hearing Study. *Int J Epidemiol* 2001;30:1371–8.
9. Wiley TL, Cruickshanks KJ, Nondahl DM, *et al.* Self-reported hearing handicap and audiometric measures in older adults. *J Am Acad Audiol* 2000;11:67–75.
10. Spankovich C, Gonzalez VB, Su D, *et al.* Self reported hearing difficulty, tinnitus, and normal audiometric thresholds, the National Health and Nutrition Examination Survey 1999–2002. *Hear Res* 2017.
11. Hannula S, Bloigu R, Majamaa K, *et al.* Self-reported hearing problems among older adults: prevalence and comparison to measured hearing impairment. *J Am Acad Audiol* 2011;22:550–9.
12. Clinard CG, Tremblay KL, Krishnan AR. Aging alters the perception and physiological representation of frequency: evidence from human frequency-following response recordings. *Hear Res* 2010;264:48–55.
13. Swanepoel deW, Eikelboom RH, Hunter ML, *et al.* Self-reported hearing loss in baby boomers from the Busselton Healthy Ageing Study: audiometric correspondence and predictive value. *J Am Acad Audiol* 2013;24:514–21. quiz 29.
14. Chen DS, Genther DJ, Betz J, *et al.* Association between hearing impairment and self-reported difficulty in physical functioning. *J Am Geriatr Soc* 2014;62:850–6.
15. Ramkissoon I, Cole M. Self-reported hearing difficulty versus audiometric screening in younger and older smokers and nonsmokers. *J Clin Med Res* 2011;3:183–90.
16. Kweon S, Kim Y, Jang MJ, *et al.* Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). *Int J Epidemiol* 2014;43:69–77.
17. Institute. ANS. *Specification for audiometers. ANSI S3.6–1996*. New York: American National Standards Institute, 1996.
18. Sullivan PW, Ghushchyan V. Preference-Based EQ-5D index scores for chronic conditions in the United States. *Med Decis Making* 2006;26:410–20.
19. EuroQol Group. EuroQol - a new facility for the measurement of health-related quality of life. *Health Policy* 1990;16:199–208.
20. Choo J, Jeon S, Lee J. Gender differences in health-related quality of life associated with abdominal obesity in a Korean population. *BMJ Open* 2014;4:e003954.
21. Noh JW, Lee SA, Choi HJ, *et al.* Relationship between the intensity of physical activity and depressive symptoms among Korean adults: analysis of Korea Health Panel data. *J Phys Ther Sci* 2015;27:1233–7.
22. Seo YJ, Ko SB, Ha TH, *et al.* Association of hearing impairment with chronic kidney disease: a cross-sectional study of the Korean general population. *BMC Nephrol* 2015;16:154.
23. Hong JW, Jeon JH, Ku CR, *et al.* The prevalence and factors associated with hearing impairment in the Korean adults: the 2010–2012 Korea National Health and Nutrition Examination Survey (observational study). *Medicine* 2015;94:e611.
24. Humes LE. Understanding the speech-understanding problems of older adults. *Am J Audiol* 2013;22:303–5.
25. Barbee CM, James JA, Park JH, *et al.* Effectiveness of Auditory Measures for Detecting Hidden Hearing Loss and/or Cochlear Synaptopathy: A Systematic Review. *Semin Hear* 2018;39:172–209.
26. Meister H, Schreitmüller S, Ortmann M, *et al.* Effects of Hearing Loss and Cognitive Load on Speech Recognition with Competing Talkers. *Front Psychol* 2016;7:301.
27. Füllgrabe C, Rosen S. Investigating the Role of Working Memory in Speech-in-noise Identification for Listeners with Normal Hearing. *Adv Exp Med Biol* 2016;894:29–36.
28. Clinard CG, Tremblay KL. Aging degrades the neural encoding of simple and complex sounds in the human brainstem. *J Am Acad Audiol* 2013;24:590–9. quiz 643–4.
29. Przewoźny T, Gójska-Grymajto A, Kwarciany M, *et al.* Hypertension and cochlear hearing loss. *Blood Press* 2015;24:199–205.
30. Chang HP, Ho CY, Chou P. The factors associated with a self-perceived hearing handicap in elderly people with hearing impairment—results from a community-based study. *Ear Hear* 2009;30:576–83.
31. Cox RM, Alexander GC, Gray GA. Personality, hearing problems, and amplification characteristics: contributions to self-report hearing aid outcomes. *Ear Hear* 2007;28:141–62.
32. Jang Y, Mortimer JA, Haley WE, *et al.* Nonauditory determinants of self-perceived hearing problems among older adults: the role of stressful life conditions, neuroticism, and social resources. *J Gerontol A Biol Sci Med Sci* 2002;57:M466–9.
33. Navrady LB, Ritchie SJ, Chan SWY, *et al.* Intelligence and neuroticism in relation to depression and psychological distress: Evidence from two large population cohorts. *Eur Psychiatry* 2017;43:58–65.