BMJ Open

BMJ Open is committed to open peer review. As part of this commitment we make the peer review history of every article we publish publicly available.

When an article is published we post the peer reviewers' comments and the authors' responses online. We also post the versions of the paper that were used during peer review. These are the versions that the peer review comments apply to.

The versions of the paper that follow are the versions that were submitted during the peer review process. They are not the versions of record or the final published versions. They should not be cited or distributed as the published version of this manuscript.

BMJ Open is an open access journal and the full, final, typeset and author-corrected version of record of the manuscript is available on our site with no access controls, subscription charges or pay-per-view fees (http://bmjopen.bmj.com).

If you have any questions on BMJ Open's open peer review process please email info.bmjopen@bmj.com

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

BMJ Open

Discrepancies between self-reported hearing difficulty and hearing loss diagnosed by audiometry

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-022440
Article Type:	Research
Date Submitted by the Author:	21-Feb-2018
Complete List of Authors:	Choi, Ji Eun ; Dankook University Hospital, Department of Otorhinolaryngology - Head and Neck Surgery Moon, Il Joon ; Samsung Medical Center, Otorhinolaryngology-Head and Neck Surgery Baek, Sun-Young ; , Samsung Biomedical Research Institute, Biostatistics team Kim, Seon Woo; , Samsung Biomedical Research Institute, Biostatistics team Cho, Yang-Sun; Samsung Medical Center, Otorhinolaryngology-Head and Neck Surgery
Keywords:	Self-reported hearing loss, prevalence, national health and nutrition examination survey, subjective hearing loss

SCHOLARONE™
Manuscripts

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Original Article

Discrepancies between self-reported hearing difficulty and hearing loss diagnosed by audiometry

Short title: Self-reported and objective hearing loss

Ji Eun Choi[1*], Il Joon Moon[2*], Sun-Young Baek[3], Seonwoo Kim[3], Yang-Sun Cho[2]

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

* These authors equally contributed to this work

Correspondence: Yang-Sun Cho, MD, PhD
Department of Otorhinolaryngology-Head and Neck Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, 81 Irwon-ro, Gangnam-gu, Seoul 06351, Republic of Korea. Tel: +82 2 3410 3579. Fax: +82 2 3410 3879. E-mail: yscho@skku.edu

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

ABSTRACT

Objective This study evaluated prevalence discrepancies between self-reported hearing difficulties and hearing impairment diagnosed by audiometry and factors associated with such discrepancies.

Design and setting This study used data from 2010 to 2012 Korea National Health and Nutrition Examination Survey (KNHNES). The KNHANES is a nationwide cross-sectional survey conducted annually by the Korea Centers for Disease Control and Prevention to investigate health and nutritional status of a representative Korean population.

Participants We included 14,345 participants aged ≥ 19 years. All patients had normal tympanic membrane (TM) and completed both audiometric measurement and hearing questionnaires.

Measures Subjective hearing difficulties were assessed by asking participants to rate their difficulty in hearing. Pure-tone audiometry was administered for all participants in a sound-attenuating booth. Objective hearing impairment was defined as over 25 dB hearing level with average hearing thresholds measured at 0.5, 1, 2, and 4 kHz. Prevalence discrepancies between self-reported hearing difficulties and objective hearing impairment were calculated. Univariable and multivariable analyses were performed to examine factors associated with such discrepancies.

Results Among 14,345 participants, 1,876 (13.1%) had underestimated hearing impairment while 733 (5.1%) had overestimated hearing impairment. The overall prevalence of hearing discrepancy was 18.2%. Multivariable models revealed that auditory factors such as tinnitus and noise exposure and non-auditory factors such as age, hypertension, and depression were significantly associated with hearing discrepancy.

Conclusion Therefore, these newly-revealed factors should be incorporated into clinical practice and counseling.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Strengths and limitations of this study

- This study was based on a nationwide large-scale cross-sectional survey.
- We analyzed only participants with normal tympanic membrane to exclude the conductive hearing loss.
- Most previous studies have defined hearing loss as 40 dB HL or worse, but we defined hearing loss as hearing thresholds > 25dB HL in better ears.
- 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 hearing discrepancy.

Keywords:

Self-reported hearing loss, prevalence, national health and nutrition examination survey, subjective hearing loss

For peer review only

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

INTRODUCTION

Hearing ability is usually assessed using pure-tone audiometry to measure the smallest detectable level of pure tone at several frequencies, typically in the range 0.5 kHz to 8 kHz. However, audiometric thresholds do not always reflect difficulty to communicate in everyday life. Many studies have shown that self-reported hearing difficulty (HD) with a normal audiogram is related to cochlear neuropathy (or hidden hearing loss)[1-3] or auditory temporal deficits.[4] The ability to communicate in everyday life not only relies on auditory processing, but also relies on non-auditory contributions. Working memory capacity is also known to play a role in understanding speech in a noisy background.[5 6]

Several studies have examined non-auditory factors associated with the discrepancy between subjective and objective hearing assessments. Kamil *et al*.[7] have reported that hearing discrepancy between subjective and objective hearing assessments is associated with demographic factors such as gender, age, race/ethnicity, and education. The Beaver Dam Offspring Study (BOSS)[8] has examined audiometric testing as well as relevant factors such as sociodemographic and lifestyle factors, environmental exposure, medical history, health-related quality of life, and symptoms of neurological disorders among individuals reporting subjective HD with normal audiometric thresholds (< 20 dB HL at 0.5, 1, 2, 3, 4, 6, and 8 kHz bilaterally). Results of BOSS has demonstrated that self-reported HD is associated with auditory factors (e.g., noise exposure) and non-auditory factors (e.g., income, occupation, depression, vision difficulties, numbness, tingling, and loss of sensation). However, these studies have been confined to the elderly population[7] or self-reported HD.[8]

Therefore, the objective of this study was to evaluate the prevalence of hearing discrepancy between self-reported HD and hearing loss (HL) diagnosed by audiometry in terms of hearing discrepancy types (i.e., whether participants over- or under-estimated their subjective hearing compared to audiometry) based on national survey data from 2010 to 2012 obtained from

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Korea National Health and Nutrition Examination Survey (KNHANES). We also investigated whether non-auditory metrics such as socioeconomic factors, psychological factors, medical history, health care utilization, and other personal information could affect the accuracy of self-reported HD and types of hearing discrepancy.

METHODS

Study population and data collection

This study used data from the fifth KNHANES. The KNHANES is a nationwide cross-sectional survey conducted annually by the Korea Centers for Disease Control and Prevention to investigate health and nutritional status of a representative Korean population. Every year, about 10,000 individuals in 3,840 households are selected from a panel to represent the population through a multi-stage 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%. From 2010 to 2012, a total of 23,621 individuals (8,313 in 2010, 7,887 in 2011, and 7,421 in 2012) agreed to participate in health surveys. 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).

Among participants over 19 years of age, 15,071 participants with normal tympanic membrane (TM) completed both audiometric measurement and hearing questionnaires. We excluded participants whose information on outcome variables was missing. A total of 14,345 participants were ultimately eligible for this study. Approval for this research study was obtained from the Institutional Review Board of Samsung Medical Center (IRB No. 2016-06-

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

142).

Hearing survey, subjective and objective hearing assessments

Participants were first asked about their perceived HD. In detail, participants were asked to rate their difficulty in hearing with the following survey question: "Which sentence best describes your hearing status (while not using hearing aids)?". There were four answers 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". Subjective hearing loss 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 automatic audiometer (SA-203, Entomed AB, Malmö). TDH39P Phone type microphone (10ohm) 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 condition of 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. Automated testing was programmed using a modified Hughson-Westlake procedure with a single pure tone for 1–2 seconds. The lowest pure tone level at which the subject's response rate was 50% was set as the threshold. Participants responded by pushing a button when they heard a tone. Results were automatically recorded. Objective hearing loss was defined as average air conduction hearing thresholds > 25dB HL at 0.5, 1, 2, and 4 kHz in the better ear.

Hearing discrepancy between subjective and objective hearing assessments was classified in terms of underestimated and overestimated hearing impairment (HI). Underestimation of

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

HI was defined as having objective HL without subjective HD. Likewise, overestimation of HI was defined as having subjective HD without objective HL.

Otologic examination and questionnaire

An ear examination was conducted with a 4 mm 0°-angled rigid endoscope attached to a Charge-Coupled Device (CCD) camera by trained otolaryngologists. Endoscopic examination was performed to identify abnormal TM findings such as TM perforation, cholesteatoma (including retraction pocket), and otitis media with effusion (including the presence of a ventilation tube). Trained otolaryngologists categorized the right and left TMs into the following three groups: normal, abnormal, and could not examine. Participants were grouped as having normal TM only when TMs of both ears were normal. If participants had abnormal TM in either one ear or both ears, they were grouped as having abnormal TM. Participants whose TM could not be examined were excluded.

Participants were also asked about their tinnitus experiences using the following question "Within the past years, 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".

Outcome variables

Age, sex, smoking status, alcohol consumption, waist circumference (cm), and body mass index (kg/m^2) of each participant were categorized as personal factors in this study. Smoking status was divided into three groups: no smoking, past smoker, and current smoker. Alcohol consumption was divided into two groups according to the experience of drinking for the past one year.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

To evaluate socioeconomic factors, monthly income, marital status, education level, and occupation were assessed. By dividing household income by square root of the number of household members, monthly income level was divided into four quartiles; lower, lower middle, upper middle, and upper. Education level was divided into two groups: less than high school and high school or more.

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.[9 10] 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.[11] 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 categorized into three levels: good, fair, and poor. Participants were asked to report their body shape perception as "too thin", "just right, or "too fat". Participants were also asked to report their amount of stress and current depressive mood.

To evaluate health related factors, physical activity, the use of medical service, and medical histories were assessed. Physical activity questionnaire inquired about weekly frequency of vigorous physical activity for 20 minutes (e.g., soccer, basketball, aerobics,

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

running, fast cycling, and fast swimming), 30 minutes of moderate physical activity (e.g., cycling at a regular pace, swimming at a regular pace, slow swimming, noncompetitive volley ball, and doubles tennis), and 60 minutes of light physical activity (e.g., walking) in the past seven days. Medical services evaluated health screening, restriction of medical service, and medical use history. Participants were also asked about their histories of other comorbidities such as obesity, hypertension, myocardial infarction, angina, asthma, depression, renal failure, and diabetes mellitus. Those who reported a history of any of these diseases as diagnosed by a medical doctor were recorded as "yes".

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, NY, USA) on the right arm of the subject while sat after taking at least five minutes 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 analyzed within 24 hours after transportation. Total cholesterol, high-density lipoprotein (HDL) cholesterol, triglyceride, hemoglobin, hematocrit, 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 from Korea Centers for Disease Control and Prevention. The survey design created a sample weight

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 version 9.4 (SAS Institute, Cary, NC, USA).

Logistic regression or linear regression was used to evaluate factors associated with hearing discrepancies. Variables found to have possible association in univariable analysis ($P<0.20$) were entered into the multivariable analysis model except for some serologic data. In this study, the population group was classified into two categories: participants who had objective HL and those who had subjective HD. To evaluate factors associated with underestimated HI, we compared participants who reported subjective HD with those who did not report subjective HD among participants with objective HL. We also compared participants with objective HL and those without objective HL among participants who reported subjective HD to evaluate factors associated with overestimated HI. *P*-values were two-sided. Bonferroni's correction was applied to *P*-value and the corresponding confidence interval due to multiple testing. Statistical significance was considered when adjusted *P*-value was less than 0.05.

RESULTS

Prevalence of hearing discrepancies

Of 14,345 participants with normal TM, 3,001 (20.9%) had averaged audiometric thresholds > 25dB HL in the better ear. Table 1 shows the percentage and prevalence of hearing discrepancies. Of 3,001 participants with objective HL, 62.5% (1,876 out of 3,001) reported

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

no HD. However, 1,858 (13.0%) participants out of 14,345 participants self-reported as having HD. Averaged audiometric thresholds of 39.5% (733 out of 1,858) of these participants fell within 25dB HL either in one ear or both ears. The prevalence of hearing discrepancies was 18.2% (2.609 out of 14,345).

Factors associated with underestimated hearing impairment

A total of 3,001 participants who had bilateral objective HL (PTA > 25 dB HL in better ear) were analyzed to evaluate factors associated with subjective underestimated HI using linear and logistic regression analyses. Results are shown in table 2. In univariable analyses, age, alcohol consumption, education, occupation, quality of life, self-reported health status, depressive mood, restricted use of medical service, hospital visit, history of myocardial infarction, angina, asthma, tinnitus, and occupational noise exposure, diastolic blood pressure, and blood urea nitrogen were significantly associated with subjective underestimated HI among participants who had objective HL. In multivariable analysis, participants who underestimated HI showed significantly decreased age (OR: 0.979, 95% CI: 0.967 - 0.991) compared to those who showed concordant HI. Also, participants who underestimated HI were less likely to have tinnitus (OR: 0.425, 95% CI: 0.344 - 0.525) or exposure to occupational noise (OR: 0.566, 95% CI: 0.423 - 0.758) compared to those who had both objective HL and subjective HD.

Associated factors with overestimated hearing impairment

A total of 1,858 participants who had subjective HD were analyzed 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 occupation were

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

significantly associated with overestimated HI compare to those who had both objective HL and subjective HD. 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 blood pressure, 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 - 0.921) compared to those who had concordant HI. Participants who overestimated HI were more likely to have hypertension (OR: 1.501, 95% CI: 1.061 - 2.123) and depression (OR: 1.771, 95% CI: 1.041 - 3.016) but less likely to report tinnitus (OR 0.523, 95% CI 0.391 - 0.699) compared to participants who had both objective HL and subjective HD.

DISCUSSION

Using data from KNHANES 2010-2012, we found that the prevalence of hearing discrepancy in the Korean population aged 19 years or older was 18.2%. Most (71.9%) of these participants underestimated their HI while the rest (28.1%) of these participants overestimated their hearing status. Previously, Tremblay *et al.*[12] reported that 12.0% (82 of 682) of individuals with normal audiometric thresholds (< 20 dB HL bilaterally) self-reported HD. Our result showed that 6.5% (733 of 11.344) of such individuals self-reported HD, which was lower than the prevalence reported by Tremblay *et al.*,[8] although the definition of HL in the present study was less strict than the previous study.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Our results showed that both non-auditory factors (demographic factors and medical histories) and auditory factors (tinnitus and occupational noise exposure) were associated with hearing discrepancy in multivariable analysis. For demographic factors, participants who underestimated or overestimated their HI showed significant decrease in age compared to participants who had concordant HI (tables 2 and 3). This result indicated that younger participants were more likely to underestimate or overestimate hearing discrepancy. In contrast to our results, Kamil *et al*.[13] have reported that underestimation of HI is associated with older age groups regardless of race/ethnicity or sex. They assumed that older adults might consider their HL to be "normal" in their age. However, their study was comprised of participants who were 50 years or older. It is well-known that audiometric HL can dramatically increase with advancing age.[14] Subjective HL is also increased with age due to difficulty of speech understanding in adverse listening conditions[15] often attributed to decreased working memory capacity[5 6] or temporal processing disorders.[16 17] Therefore, it is natural that less discrepancies are associated with advanced age.

For medical related factors, participants who overestimated their HI significantly had more hypertension and depression than participant who had concordant HI (table 3). Previous studies have also reported correlations of self-reported HD with hypertension.[18] and depression.[8 19] Because hypertension is known to increase the risk of HL via decreasing vascular supply to stria vascularis,[14 20] it might be related to early development of pre-clinical HL in auditory way. Hypertension and depression may also lead to an increased anxiety about their health, thus increasing overestimated HL in non-auditory way. These results demonstrate a clear association of non-auditory factors with hearing discrepancy after filtering out many other non-auditory factors using multivariable analysis.

For auditory factors, participants who had tinnitus reported their hearing status accurately (tables 2 and 3). These participants might have had an audiometry for their tinnitus and been

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

informed about their hearing status. Also, participants who had been exposed to occupational noise hardly underestimated their HI among participants who had objective HL (table 2). As noise exposure could be related to hidden hearing loss, it might have increased subjective HL regardless of tinnitus.

Although hearing discrepancy in South Korea has been recently reported,[21] this study has several strengths. First, we analyzed data only from participants with normal TM. Individuals who have abnormal TM are more likely to have undergone a previous hearing evaluation. Therefore, they might perceive their HD more accurately than those who have normal TM. Second, we defined HL as hearing thresholds > 25dB HL in better ears. Other studies have defined HL as 40dB HL or worse.[21-23] Therefore, they might have less chance to underestimate and more chance to overestimate their HI. Lastly, this study analyzed more variables including noise exposure and used multivariable logistic analysis to investigate associated factors. Despite these strengths, our study also has limitations. Because the KNHANES did not assess the history of hearing evaluation for each participant, this might have influenced hearing discrepancy.

In summary, the prevalence of hearing discrepancy was 18.2% in South Korea. Such inconsistent result between subjective and objective hearing ability not only relies on auditory factors (tinnitus and noise exposure), but also depends on non-auditory factors (age and medical histories). Understanding the contribution of these factors to self-reported hearing will assist clinicians in interpreting subjective reports of hearing and researchers to use self-reported hearing data as a surrogate measure of objective audiometric hearing.

CONTRIBUTIONS

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

J.E.C. and I.J.M: designed research and wrote the main paper. S.B and S.K: collected data and analyzed data. Y.C: provided critical revision and discussed the results and implications and commented on the manuscript at all stages.

FUNDING

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

COMPETING INTERESTS

The authors have no conflicts of interest to disclose

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).

A 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 is de-identified and available to the public.

ACKNOWLEDGMENTS

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 & Prevention for participating in this survey and their dedicated work.

For peer review only

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

REFERENCES

1. Plack CJ, Barker D, Prendergast G. Perceptual consequences of "hidden" hearing loss. *Trends Hear* 2014;18.
2. Lin HW, Furman AC, Kujawa SG, *et al.* Primary neural degeneration in the Guinea pig cochlea after reversible noise-induced threshold shift. *J Assoc Res Otolaryngol* 2011;12:605-16.
3. Kujawa SG, Liberman MC. Adding insult to injury: cochlear nerve degeneration after "temporary" noise-induced hearing loss. *J Neurosci* 2009;29:14077-85.
4. Bharadwaj HM, Masud S, Mehraei G, *et al.* Individual differences reveal correlates of hidden hearing deficits. *J Neurosci* 2015;35:2161-72.
5. Meister H, Schreitmuller S, Ortmann M, *et al.* Effects of Hearing Loss and Cognitive Load on Speech Recognition with Competing Talkers. *Front Psychol* 2016;7:301.
6. Fullgrabe 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.
7. Kamil RJ, Genther DJ, Lin FR. Factors associated with the accuracy of subjective assessments of hearing impairment. *Ear Hear* 2015;36:164-7.
8. 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.
9. Sullivan PW, Ghushchyan V. Preference-Based EQ-5D index scores for chronic conditions in the United States. *Med Decis Making* 2006;26:410-20.
10. EuroQol G. EuroQol--a new facility for the measurement of health-related quality of life. *Health Policy* 1990;16:199-208.
11. 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.
12. Brandler ES, Sharma M, McCullough F, *et al.* Prehospital Stroke Identification: Factors Associated with Diagnostic Accuracy. *J Stroke Cerebrovasc Dis* 2015;24:2161-6.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

13. Ricci A, Carvalho PD, Amundson MC, *et al.* Factors associated with pregnancy-associated glycoprotein (PAG) levels in plasma and milk of Holstein cows during early pregnancy and their effect on the accuracy of pregnancy diagnosis. *J Dairy Sci* 2015;98:2502-14.

14. 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 (Baltimore)* 2015;94:e611.

15. Humes LE. Understanding the speech-understanding problems of older adults. *Am J Audiol* 2013;22:303-5.

16. 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.

17. 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.

18. Lasisi AO, Abiona T, Gureje O. The prevalence and correlates of self-reported hearing impairment in the Ibadan study of ageing. *Trans R Soc Trop Med Hyg* 2010;104:518-23.

19. Li CM, Zhang X, Hoffman HJ, *et al.* Hearing impairment associated with depression in US adults, National Health and Nutrition Examination Survey 2005-2010. *JAMA Otolaryngol Head Neck Surg* 2014;140:293-302.

20. Lin BM, Curhan SG, Wang M, *et al.* Hypertension, Diuretic Use, and Risk of Hearing Loss. *Am J Med* 2016;129:416-22.

21. Kim SY, Kim HJ, Kim MS, *et al.* Discrepancy between self-assessed hearing status and measured audiometric evaluation. *PLoS One* 2017;12:e0182718.

22. 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.

23. 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.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Table 1 Percentage and Prevalence Rates of Hearing Discrepancy.

Subjective / Objective	Hearing difficulty	No difficulty	Total
Hearing loss	1,125 (A)	1,876 (B)	3,001 (A+B)
Normal	733 (C)	10,611 (D)	11,344 (C+D)
Total	1,858 (A+C)	12, 487 (B+D)	14,345 (A+B+C+D)

Percent of Hearing 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)

For peer review only

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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

Variables	Total		Without Subjective HD		Univariable analysis			Multivariable analysis		
	Weighted frequency	% or average	Weighted frequency	Prevalence (%)	OR	95% C.I.	p-value	OR	95% C.I.	p-value
Personal factor										
Age (yr)	4,660,594	62.0	3,023,386	64.9	0.977	0.968 - 0.986	**<.0001**	0.979	0.967 - 0.991	**0.001**
Sex										
Male	2,594,824	55.7	1,702,933	65.6	1.078	0.897 - 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 - 1.306	1.000			
Current smoker	1,125,449	24.1	754,583	67.0	1.146	0.850 - 1.546	1.227			
Drinking alcohol in recent 1 year										
No	1,666,794	35.8	1,012,283	60.7	Referent					
Yes	2,993,800	64.2	2,011,103	67.2	1.323	1.102 - 1.589	**0.003**	1.025	0.831 - 1.266	0.814
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 - 1.547	0.800	0.806	0.585 - 1.111	0.324
Upper middle	934,922	20.1	641,226	68.6	1.393	0.994 - 1.952	0.057	0.949	0.659 - 1.366	1.000
Upper	849,526	18.2	584,315	68.8	1.406	0.999 - 1.978	0.052	0.963	0.651 - 1.427	1.000
Marital status										
Married	4,518,752	97.0	2,917,820	64.6	0.626	0.289 - 1.360	0.236			
Single	141,843	3.0	105,566	74.4	Referent					

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 - 1.704	**0.002**	1.087	0.853 - 1.386	0.498
Occupation										
Yes	2,566,437	55.1	1,730,554	67.4	1.283	1.066 - 1.545	**0.009**	0.966	0.777 - 1.202	0.757
No	2,094,158	44.9	1,292,832	61.7	Referent					
Quality of life										
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 - 0.759	**<.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 - 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 - 0.780	**<.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 - 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 - 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 - 1.568	0.638	0.841	0.584 - 1.210	0.573

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Index = 1.00	2,620,375	56.2	1,820,686	69.5	1.752	1.275 - 2.408	**<.0001**	0.930	0.606 - 1.426	1.000
EQ-VAS (ranged from 0 - 100)	4,660,594	62.0	3,023,386	64.9	1.008	1.003 - 1.012	**0.001**			
Psychological factors										
Perceived health status										
Good	1,279,057	27.4	922,424	72.1	1.311	1.007 - 1.707	**0.043**	1.255	0.958 - 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 - 0.806	**<.0001**	0.79	0.588 - 1.061	0.148
Body shape perception										
Slim	981,355	21.1	617,482	62.9	0.914	0.697 - 1.707	0.456			
Normal	2,055,525	44.1	1,336,044	65.0	Referent					
Obese	1,623,715	34.8	1,069,861	65.9	1.040	0.814 - 1.330	0.719			
Amount of stress in life										
Small	3,556,134	76.3	2,350,397	66.1	Referent					
Large	1,104,460	23.7	672,990	60.9	0.800	0.629 - 1.018	0.070	1.000	0.762 - 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 - 0.868	**0.003**	0.795	0.576 - 1.097	0.162
Health related factors										
Vigorous physical activity practice										
Do not practice	4,150,544	89.1	2,680,694	64.6	Referent					
Practice	510,050	10.9	342,693	67.2	1.123	0.822 - 1.534	0.467			
Moderate physical activity practice										
Do not practice	4,306,908	92.4	2,791,890	64.8	Referent					
Practice	353,687	7.6	231,496	65.5	1.028	0.733 - 1.442	0.873			
Low physical activity practice										
Do not practice	2,957,617	63.5	1,912,833	64.7	Referent					

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Practice	1,702,977	36.5	1,110,554	65.2	1.024	0.841 - 1.247	0.814			
Restricted use of medical services										
Yes	864,993	18.6	492,523	56.9	0.661	0.516 - 0.847	**0.001**	0.802	0.608 - 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 - 1.202	0.870			
No	1,706,441	36.6	1,111,120	65.1	Referent					
Hospital visit in recent 2 weeks										
Yes	1,922,260	41.2	1,156,350	60.2	0.705	0.583 - 0.851	**0.000**	0.896	0.727 - 1.104	0.301
No	2,738,335	58.8	1,867,037	68.2	Referent					
Hospitalization in recent 1 year										
Yes	572,508	12.3	360,689	63.0	0.912	0.700 - 1.188	0.492			
No	4,088,086	87.7	2,662,698	65.1	Referent					
Waist circumference (cm)	4,660,594	84.0	3,023,386	64.9	0.998	0.988 - 1.008	0.668			
Body mass index (kg/m^2)	4,660,594	24.0	3,023,386	64.9	1.012	0.982 - 1.042	0.447			
Obesity occurrence										
Underweight	159,020	3.4	97,392	61.2	0.894	0.491 - 1.628	1.000			
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 - 1.435	0.335			
Medical History (%)										
Hypertension										
No	2,976,094	63.9	1,957,235	65.8	Referent					
Yes	1,684,501	36.1	1,066,151	63.3	0.898	0.742 - 1.086	0.266			
Myocardial infarction										
No	4,589,773	98.5	2,988,935	65.1	Referent					
Yes	70,821	1.5	34,451	48.6	0.507	0.258 - 0.999	**0.050**	0.538	0.242 - 1.198	0.129

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Angina										
No	4,491,052	96.4	2,933,694	65.3	Referent					
Yes	169,542	3.6	89,693	52.9	0.596	0.381 - 0.900	**0.024**	0.803	0.500 - 1.288	0.363
Asthma										
No	4,468,019	95.9	2,921,748	65.4	Referent					
Yes	192,575	4.1	101,638	52.8	0.591	0.389 - 0.899	**0.014**	0.765	0.498 - 1.175	0.221
Depression										
No	4,458,555	95.7	2,892,616	64.9	Referent					
Yes	202,039	4.3	130,770	64.7	0.993	0.663 - 1.487	0.974			
Renal failure										
No	4,618,526	99.1	3,003,479	65.0	Referent					
Yes	42,069	0.9	19,908	47.3	0.483	0.184 - 1.268	0.139	0.707	0.255 - 1.956	0.503
Diabetes mellitus										
No	4,001,727	85.9	2,626,635	65.6	Referent					
Yes	658,868	14.1	396,751	60.2	0.792	0.618 - 1.202	0.067	0.974	0.740 -1.281	0.849
Auditory factors										
Tinnitus										
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 - 0.472	**<.0001**	0.425	0.344 - 0.525	**<.0001**
Occupational noise exposure										
Yes	800,620	17.2	459,993	57.5	0.683	0.520 - 0.897	**0.006**	0.566	0.423 - 0.758	**<.0001**
No	3,859,974	82.8	2,563,394	66.4	Referent					
Laboratory measures										
SBP (mmHg)	4,660,594	126.4	3,023,386	64.9	1.001	0.996 - 1.007	0.573			
DBP (mmHg)	4,660,594	77.0	3,023,386	64.9	1.015	1.006 - 1.024	**0.002**	1.009	1.000 - 1.019	0.058
Total cholesterol (mg/dL)	4,394,622	191.7	2,859,596	65.1	1.001	0.998 - 1.003	0.683			

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

HDL cholesterol (mg/dL)	4,394,622	50.3	2,859,596	65.1	1.005	0.998 - 1.013	0.158
Serum triglyceride, (mg/dL)	4,394,622	148.7	2,859,596	65.1	1.000	1.000 - 1.001	0.411
Hemoglobin (g/dl)	4,369,845	14.1	2,848,403	65.2	1.029	0.968 - 1.093	0.360
Hematocrit (%)	4,369,845	41.9	2,848,403	65.2	1.008	0.986 - 1.032	0.471
Blood urea nitrogen (mg/dL)	4,394,622	15.5	2,859,596	65.1	0.978	0.958 - 0.998	**0.033**
Serum creatinine (mg/dL)	4,394,622	0.9	2,859,596	65.1	1.095	0.725 - 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 - 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 - 1.699	0.833

3 The bold means significant difference ($p < .05$). CI = confidence interval, HD = hearing difficulty.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Table 3 Univariable and multivariable analyses of factors associated with overestimated hearing Loss

Variables	Total		Without Objective HL		Univariable analysis			Multivariable analysis		
	Weighted frequency	% or average	Weighted frequency	Prevalence (%)	OR	95% C.I.	p-value	OR	95% C.I.	p-value
Personal factor										
Age (yr)	3,089,060	56.3	1,451,852	47.0	0.915	0.904 - 0.927	**<.0001**	0.905	0.890 - 0.921	**<.0001**
Sex										
Male	1,574,262	51.0	682,372	43.3	0.741	0.576 - 0.954	**0.020**	0.660	0.424 - 1.029	0.067
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 - 0.895	**0.006**	0.866	0.520 - 1.445	1.000
Current smoker	720,760	23.3	349,894	48.5	0.935	0.640 - 1.365	1.000	0.597	0.351 - 1.017	0.061
Drinking alcohol in recent 1 year										
No	998,495	32.3	343,984	34.5	Referent					
Yes	2,090,565	67.7	1,107,867	53.0	2.145	1.650 - 2.788	**<.0001**	1.150	0.784 - 1.687	0.475
Waist circumference (cm)	3,089,060	83.2	1,451,852	47.0	0.977	0.964 - 0.991	**0.001**	0.988	0.964 - 1.014	0.363
Body mass index (kg/m^2)	3,089,060	24.0	1,451,852	47.0	1.018	0.979 - 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 - 3.526	**<.0001**	0.957	0.577 - 1.584	1.000
Upper middle	681,338	22.1	387,641	56.9	3.496	2.187 - 5.588	**<.0001**	1.244	0.739 - 2.093	0.951
Upper	697,599	22.6	432,388	62.0	4.318	2.833 - 6.582	**<.0001**	1.468	0.857 - 2.514	0.266
Marital status										
Married	2,792,856	90.4	1,191,925	42.7	0.104	0.048 - 0.223	**<.0001**	1.276	0.511 - 3.184	0.601

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Single	296,204	9.6	259,927	87.8	Referent					
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 - 4.690	**<.0001**	1.166	0.792 - 1.716	0.436
Occupation										
Yes	1,738,450	56.3	902,568	51.9	1.575	1.224 - 2.027	**0.000**	0.912	0.625 - 1.330	0.631
No	1,350,609	43.7	549,284	40.7	Referent					
Quality of life										
EQ-5D (%%)										
Physical activity (mobility)										
Normal	2,262,057	73.2	1,203,774	53.2	Referent					
Limited	827,002	26.8	248,078	30.0	0.377	0.291 - 0.488	**<.0001**			
Physical activity (self-care)										
Normal	2,855,547	92.4	1,396,588	48.9	Referent					
Limited	233,513	7.6	55,264	23.7	0.324	0.200 - 0.524	**<.0001**			
Physical activity (usual activities)										
Normal	2,566,840	83.1	1,296,758	50.5	Referent					
Limited	522,220	16.9	155,094	29.7	0.414	0.306 - 0.560	**<.0001**			
Physical activity (pain/discomfort)										
Normal	2,084,203	67.5	1,008,232	48.4	Referent					
Limited	1,004,857	32.5	443,620	44.1	0.844	0.667 - 1.067	0.156			
Physical activity (anxiety/depression)										
Normal	2,575,106	83.4	1,205,708	46.8	Referent					
Limited	513,954	16.6	246,144	47.9	1.044	0.769 - 1.418	0.783			
EQ-5D index (%)										
Index < 0.75	352,500	11.4	108,676	30.8	Referent					

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

0.75 ≤ index < 1.00	1,112,495	36.0	518,799	46.6	1.960	1.219 - 3.151	**0.003**	0.987	0.563 - 1.730	1.000
Index = 1.00	1,624,065	52.6	824,376	50.8	2.312	1.470 - 3.638	**<.0001**	0.705	0.389 - 1.275	0.373
EQ-VAS (ranged from 0 - 100)	3,089,060	69.1	1,451,852	47.0	1.011	1.005 - 1.017	**0.001**			
Psychological factors										
Perceived health status										
Good	759,297	24.6	402,665	53.0	1.164	0.798 - 1.697	0.736	1.342	0.893 - 2.017	0.212
Fair	1,377,238	44.6	678,232	49.2	Referent					
Poor	952,524	30.8	370,955	38.9	0.657	0.484 - 0.892	**0.004**	0.957	0.640 - 1.431	1.000
Body shape perception										
Too thin	549,060	17.8	185,188	33.7	0.641	0.422 - 0.973	**0.035**	1.031	0.608 - 1.746	1.000
Just right	1,290,616	41.8	571,135	44.3	Referent					
Too fat	1,249,383	40.4	695,530	55.7	1.582	1.158 - 2.162	**0.002**	1.312	0.874 - 1.968	0.269
Amount of stress in life										
Small	2,134,226	69.1	928,488	43.5	Referent					
Large	954,834	30.9	523,364	54.8	1.575	1.198 - 2.072	**0.001**	0.980	0.698 - 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 - 1.375	0.992			
Health related factors										
Vigorous physical activity practice										
Do not practice	2,676,411	86.6	1,206,561	45.1	Referent					
Practice	412,648	13.4	245,291	59.4	1.785	1.207 - 2.641	**0.004**	1.232	0.798 - 1.901	0.346
Moderate physical activity practice										
Do not practice	2,793,226	90.4	1,278,209	45.8	Referent					
Practice	295,834	9.6	173,643	58.7	1.684	1.103 - 2.571	**0.016**	1.191	0.738 - 1.923	0.474
Low physical activity practice										

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Do not practice	1,925,733	62.3	880,948	45.7	Referent					
Practice	1,163,327	37.7	570,903	49.1	1.143	0.887 - 1.473	0.302			
Restricted use of medical services										
Yes	714,039	23.1	341,569	47.8	1.045	0.774 - 1.409	0.775			
No	2,375,021	76.9	1,110,283	46.7	Referent					
Health screening in recent 2 years										
Yes	1,904,102	61.6	862,214	45.3	0.836	0.651 - 1.073	0.158	1.134	0.823 - 1.562	0.441
No	1,184,958	38.4	589,638	49.8	Referent					
Hospital visit in recent 2 weeks										
Yes	1,326,445	42.9	560,535	42.3	0.715	0.567 - 0.902	**0.005**	1.163	0.873 - 1.551	0.302
No	1,762,615	57.1	891,317	50.6	Referent					
Hospitalization in recent 1 year										
Yes	423,019	13.7	211,199	49.9	1.146	0.775 - 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 - 1.957	1.000			
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 - 1.428	1.000			
Medical History (%)										
Hypertension										
No	2,152,029	69.7	1,133,171	52.7	Referent					
Yes	937,031	30.3	318,681	34.0	0.463	0.361 - 0.595	**<.0001**	1.501	1.061 - 2.123	**0.022**
Myocardial infarction										
No	3,042,026	98.5	1,441,188	47.4	Referent					
Yes	47,034	1.5	10,664	22.7	0.326	0.101 - 1.052	0.061	0.582	0.129 - 2.621	0.480
Angina										

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

No	2,983,490	96.6	1,426,132	47.8	Referent					
Yes	105,569	3.4	25,719	24.4	0.352	0.198 - 0.625	**0.000**	0.848	0.422 - 1.705	0.643
Asthma										
No	2,946,961	95.4	1,400,690	47.5	Referent					
Yes	142,099	4.6	51,162	36.0	0.621	0.342 - 1.128	0.117	0.991	0.482 - 2.037	0.980
Depression										
No	2,921,190	94.6	1,355,251	46.4	Referent					
Yes	167,870	5.4	96,600	57.5	1.566	1.009 - 2.432	**0.046**	1.772	1.041 - 3.016	**0.035**
Renal failure										
No	3,061,098	99.1	1,446,051	47.2	Referent					
Yes	27,962	0.9	5,801	20.7	0.292	0.049 - 1.733	0.175	0.442	0.065 - 2.987	0.402
Diabetes mellitus										
No	2,713,075	87.8	1,337,984	49.3	Referent					
Yes	375,984	12.2	113,868	30.3	0.447	0.303 - 0.658	**<.0001**	1.140	0.725 - 1.792	0.569
Auditory factors										
Tinnitus										
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 - 0.697	**<.0001**	0.523	0.391 - 0.699	**<.0001**
Occupational noise exposure										
Yes	630,805	20.4	290,178	46.0	0.951	0.687 - 1.315	0.760			
No	2,458,254	79.6	1,161,674	47.3	Referent					
Laboratory measures										
SBP (mmHg)	3,089,060	122.8	1,451,852	47.0	0.974	0.966 - 0.981	**<.0001**	0.996	0.984 - 1.008	0.469
DBP (mmHg)	3,089,060	76.5	1,451,852	47.0	1.011	0.999 - 1.023	0.083	1.013	0.993 - 1.033	0.215
Total cholesterol (mg/dL)	2,931,858	191.5	1,396,832	47.6	1.001	0.997 - 1.004	0.723			
HDL cholesterol (mg/dL)	2,931,858	50.7	1,396,832	47.6	1.013	1.003 - 1.023	**0.011**			

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Serum triglyceride, (mg/dL)	2,931,858	141.3	1,396,832	47.6	0.999	0.998 - 1.000	0.149
Hemoglobin (g/dl)	2,913,750	14.1	1,392,308	47.8	1.038	0.953 - 1.132	0.392
Hematocrit (%)	2,913,750	41.9	1,392,308	47.8	1.012	0.980 - 1.045	0.463
Blood urea nitrogen (mg/dL)	2,931,858	14.9	1,535,026	52.4	0.904	0.873 - 0.936	**<.0001**
Serum creatinine (mg/dL)	2,931,858	0.9	1,535,026	52.4	0.330	0.169 - 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 - 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 - 1.243	0.193

5 The bold means significant difference ($p < .05$). CI = confidence interval, HL = hearing loss.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

BMJ Open

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

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-022440.R1
Article Type:	Research
Date Submitted by the Author:	02-Aug-2018
Complete List of Authors:	Choi, Ji Eun ; Dankook University Hospital, Department of Otorhinolaryngology - Head and Neck Surgery Moon, Il Joon ; Samsung Medical Center, Otorhinolaryngology-Head and Neck Surgery Baek, Sun-Young ; , Samsung Biomedical Research Institute, Biostatistics team Kim, Seon Woo; , Samsung Biomedical Research Institute, Biostatistics team Cho, Yang-Sun; Samsung Medical Center, Otorhinolaryngology-Head and Neck Surgery
Primary Subject Heading:	Ear, nose and throat/otolaryngology
Secondary Subject Heading:	Ear, nose and throat/otolaryngology
Keywords:	prevalence, national health and nutrition examination survey, Self-reported hearing difficulty, audiometry

SCHOLARONE™
Manuscripts

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Original Article

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

For peer review only

Short title: Self-reported hearing difficulty and audiometrically-measured hearing loss

Ji Eun Choi[1*], Il Joon Moon[2*], Sun-Young Baek[3], Seonwoo Kim[3], Yang-Sun Cho[2]

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

* These authors equally contributed to this work

Correspondence: Yang-Sun Cho, MD, PhD

Department of Otorhinolaryngology-Head and Neck Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, 81 Irwon-ro, Gangnam-gu, Seoul 06351, Republic of Korea. Tel: +82 2 3410 3579. Fax: +82 2 3410 3879. E-mail: yscho@skku.edu

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

ABSTRACT

Objective To evaluate prevalence discrepancies between self-reported hearing difficulty (SHD) and audiometrically-measured hearing loss (AHL) diagnosed by audiometry 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 on both ears.

Measures Self-reported hearing was assessed by asking participants whether they had difficulty in hearing. AHL was defined as over 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 to concordant HL.

Results Among 14,345 participants, 1,876 (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: 0.967-0.991 for the underestimated HI, OR: 0.905, 95% CI: 0.890-0.921 for the overestimated HI) and tinnitus (OR: 0.425, 95% CI: 0.344-0.525 for the underestimated HI and OR 0.523, 95% CI 0.391-0.699 for the overestimated HI) compared to those who had concordant HI. Exposure to occupational noise (OR: 0.566, 95% CI: 0.423-0.758) was associated with underestimated HI, and medical

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

history of hypertension (OR: 1.501, 95% CI: 1.061-2.123) and depression (OR: 1.771, 95% CI: 1.041-3.016) were associated with overestimated HI.

Conclusion Therefore, older 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 analyzed only participants with normal tympanic membranes to exclude participants who have undergone a previous hearing evaluation.
- Most previous studies have defined hearing loss as 40 dB HL or worse, but we used more comprehensive definition of hearing loss as mean hearing thresholds of > 25dB HL measured at 0.5, 1, 2, and 4 kHz in the better ear in accordance with the World Health Organization 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.

Keywords:

Self-reported hearing difficulty, prevalence, national health and nutrition examination survey, audiometry

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 0.5 kHz to 8 kHz. Sometimes, the use of self-reported hearing measurements is attractive in occupational health screening programs or 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 frequency 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 (e.g., degree of hearing loss, frequencies of hearing loss, middle ear infection etc.)[5-7 9 10 12 13] as well as demographic factors.[3 5 7 14 15] However, these studies mainly have focused on elderly population[3 8 11 14] or SHD with normal audiogram.[1 7] Few studies have focused on the non-auditory factors (socioeconomic factors, psychological factors, health care utilization, 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 over- or under-estimation in a

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

population with normal TM based on national survey data. We also comprehensively investigated whether non-auditory metrics such as socioeconomic factors, psychological factors, medical history, health care utilization, and other personal information could affect the accuracy of S HD 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 3,840 households are selected from a panel to represent the population through a multi-stage 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 publicly 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 (8,313 in 2010, 7,887 in 2011, and 7,421 in 2012) agreed to participate in health surveys. All participants in KNHANES 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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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). Among participants over 19 years of age, we included participants who completed hearing questionnaire, audiometric measurement, and examination of TM. As individuals with abnormal TM are more likely to have a correct information on their hearing from the prior hearing tests, we excluded participants with abnormal TM, and whose information on outcome variables was missing. Approval for this research study was obtained from the Institutional Review Board of Samsung Medical Center (IRB No. 2016-06-142).

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 answers 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). A TDH39P Phone type headphone (10ohm) 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. An 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 on both ears in accordance with the American National Standards Institute (ANSI) standard.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Hearing loss (HL) in this study was defined as the mean air conduction hearing thresholds > 25dB 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 (CCD) 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 categorized both TMs into the following three groups: normal, abnormal, and could not examine. Only participants with both normal TMs 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 also were 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 louder to communicate with others because of noisy sound?"

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Outcome variables

Age, sex, smoking status, alcohol consumption, waist circumference (cm), and body mass index (kg/m^2) of each participant were collected and categorized as personal factors in this study. Smoking status was divided into three groups: never smoked, past smoker, and current smoker. Alcohol consumption was divided into two groups according to their drinking frequency: non-drinker and drinker. A non-drinker was defined as participant who had never drunk during the last year.

To evaluate socioeconomic factors, monthly income, marital status, education level, and employment status were assessed. Monthly income indicates equalized 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. 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. Education level was divided into two groups: less than high school and high school or more. Employment status was divided into employed and unemployed groups.

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.[17 18] Each dimension has three grades of severity: no problem (score of 1), moderate problem (score of 2), or serious problem (score of 3).

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

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.[19] 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 categorized into three levels: good, fair, and poor. Participants were asked to report their body shape perception as "too thin", "just right, or "too fat". 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-categorized 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. Physical activity questionnaire inquired about weekly frequency of vigorous physical activity for 20 minutes (e.g., soccer, basketball, aerobics, running, fast cycling, and fast swimming), 30 minutes of moderate physical activity (e.g., cycling at a regular pace, swimming at a regular pace, slow swimming, noncompetitive volley ball, and doubles tennis), and 60 minutes of light physical activity (e.g., walking) in the past seven days. Medical services

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

evaluated restriction of medical service, health screening, and medical use history. Restricted use of medical service was defined as if the patients had been unable to use the medical service (except for dentistry) during the past year. Health screening is defined as whether a health checkup has been performed for the last two years. Participants were also asked about their current disease diagnosed by a medical doctor. Among these, histories of hearing-related diseases such as obesity, hypertension, myocardial infarction, angina, asthma, depression, renal failure, and diabetes mellitus were selected as variables.[20 21]

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, NY, USA) on the right arm of the subject while sitting after taking at least five minutes 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 analyzed within 24 hours after transportation. Total cholesterol, high-density lipoprotein (HDL) cholesterol, triglyceride, hemoglobin, hematocrit, 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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 version 9.4 (SAS Institute, Cary, NC, USA).

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. Serologic data was 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 confidence interval 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 not involved in designing the study or developing the research questions, nor were they involved in analyzing or interpreting the findings. There are no plans for the study results to be disseminated directly to participants.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 ± SD age of the study population was 49.2 ± 16.1 years (ranged from 19 to 97). The study population consisted of 42.5% male and 57.5% female.

Prevalence of discrepancies between self-reported hearing and audiometry

Of 14,345 participants with normal TMs, 3,001 (20.9%) participants had AHL and 1,858 (13.0%) had SHD. Table 1 shows the percentage and prevalence of discrepancies between self-reported hearing and audiometry. Of 3,001 participants with AHL, 62.5% (1,876 out of 3,001) reported no SHD. On the other hand, 733 (39.5%) of 1,858 participants with SHD had mean audiometric thresholds in the better ear of more than 25 dB HL. 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% (2.609 out of 14,345).

Factors associated with underestimated hearing impairment

A total of 3,001 participants who had bilateral HL (mean hearing thresholds > 25dB HL at 0.5, 1, 2, and 4 kHz) were analyzed to evaluate factors associated with underestimated HI using linear and logistic regression analyses. Results are shown in table 2. In univariable analyses, age,

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

alcohol consumption, education, occupation, 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 blood pressure, 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 - 0.991) compared to 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 - 0.525) or exposure to occupational noise (OR: 0.566, 95% CI: 0.423 - 0.758) compared to those who showed concordant HI.

Associated factors with overestimated hearing impairment

A total of 1,858 participants who had SHD were analyzed 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 occupation were significantly associated with overestimated HI compared to 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 blood pressure, HDL cholesterol, blood urea nitrogen, and serum creatinine levels were also significantly associated

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

with overestimated HI. In multivariable analysis, participants who overestimated HI showed significantly decreased age (OR: 0.905, 95% CI: 0.890 - 0.921) compared to those who had concordant HI. Participants who overestimated HI were more likely to have hypertension (OR: 1.501, 95% CI: 1.061 - 2.123) and depression (OR: 1.771, 95% CI: 1.041 - 3.016) but less likely to report tinnitus (OR 0.523, 95% CI 0.391 - 0.699) compared to those who had both SHD and AHL.

DISCUSSION

A 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 underestimated their HI while the rest (28.1%) overestimated their hearing status (Table 1). The accuracy of hearing assessments in the present study (81.8%) was higher than that reported in elderly population (71.8%)[3], but similar to that reported in the general population (80-82%)[5 6]. This can be explained by the fact that young adults generally perceive their hearing status more accurately than the elderly population. Previously, Kim *et al.*[5] (2017) categorized 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 (< 25dB, ≥ 15dB and < 40dB, and ≥ 40dB). When the participants of previous study[5] was 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% (1,876 of 14,325) reported underestimated HI. However, reclassified results in Kim *et al.* (2017) showed that 6.3% (1,237 of 19,642) of participants reported overestimated HI and 10.5% (2,059 of 19,642) of participants reported underestimated HI. Despite the similar populations,

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

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 to participants who had concordant HI (tables 2 and 3). It is well-known that audiometric HL dramatically increases with increasing age.[21] SHD is also increased with age as difficulty of speech understanding in adverse listening conditions increases[22] due to decreased working memory capacity[23 24] or impaired temporal processing.[12 25] Therefore, it is not surprising that younger participants were less likely to have SHD among participants with audiometric HL (Table 2) and had fewer audiometric HL among participants with SHD (Table 3). In contrast to our result, Kamil *et al.* (2015)[3] has been reported that old age was related to underestimation of HI. This difference may be due to the fact that younger people who had underestimated HI did not included because they examined participants aged 50 and older. Among 2,609 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" in 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,[21 26-28] it might be related to early development of pre-clinical HL in auditory way.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Unlike the hypertension, depression may influence the SHD in non-auditory way. Studies have suggested that personality traits of neuroticism had a more adverse perception of their HD[29 30], and it is widely known as an important factor that influences depression[31]. Accordingly, depression may lead to an increased perception of HD.

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 program 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 and without SHD in the analysis, and confined the concordant HI group to those who showed both SHD and AHL. Kim *et al.*[5] set a reference as concordance group including normal hearing population whose self-reported hearing assessment was matched to their audiometric thresholds. Since most of the concordance group (93%) had no SHD and normal audiometry (<25dB), their analysis is likely to have a bias of depending on the hearing level rather than the discrepancy between subjective hearing assessment and audiometry itself. Sub-group analysis for participants with ≥ 25dB in Kim *et al.*[5] showed that age, sex, education, occupation, and stress was irrelevant to discrepancy between subjective hearing assessment and audiometric thresholds. Lastly, this study analyzed more comprehensive variables including smoking status, alcohol consumption, waist circumference,

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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, and current disease, and serologic data. Therefore, we expected that this study could provide more reasonable information related to discrepancy between SHD and AHL.

In summary, the prevalence of discrepancy between SHD and AHL was 18.2% in South Korea. Non-auditory factors (age and medical histories) as well as auditory factors (tinnitus and occupational noise exposure) were associated with inconsistent results between self-reported and audiometrically-measured hearing assessment. 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.

CONTRIBUTIONS

J.E.C. and I.J.M: designed research and wrote the main paper. S.B and S.K: collected data and analyzed data. Y.C: provided critical revision and discussed the results and implications and commented on the manuscript at all stages.

FUNDING

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

COMPETING INTERESTS

None declared.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

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).

A 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 is de-identified and available to the public.

ACKNOWLEDGMENTS

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 & Prevention for collecting data in this survey and their dedicated work.

For peer review only

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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.

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

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 de W, 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. Sullivan PW, Ghushchyan V. Preference-Based EQ-5D index scores for chronic conditions in the United States. *Med Decis Making* 2006;26:410-20.

18. EuroQol G. EuroQol--a new facility for the measurement of health-related quality of life. *Health Policy* 1990;16:199-208.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

19. 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.

20. 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.

21. 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 (Baltimore)* 2015;94:e611.

22. Humes LE. Understanding the speech-understanding problems of older adults. *Am J Audiol* 2013;22:303-5.

23. Meister H, Schreitmuller S, Ortmann M, *et al.* Effects of Hearing Loss and Cognitive Load on Speech Recognition with Competing Talkers. *Front Psychol* 2016;7:301.

24. Fullgrabe 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.

25. 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.

26. Lin BM, Curhan SG, Wang M, *et al.* Hypertension, Diuretic Use, and Risk of Hearing Loss. *Am J Med* 2016;129:416-22.

27. Tan TY, Rahmat O, Prepageran N, *et al.* Hypertensive retinopathy and sensorineural hearing loss. *Indian J Otolaryngol Head Neck Surg* 2009;61:275-9.

28. Przewozny T, Gojska-Grymajlo A, Kwarciany M, *et al.* Hypertension and cochlear hearing loss. *Blood Press* 2015;24:199-205.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

29. 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.

30. 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.

31. 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.

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Table 1 Percentage and Prevalence Rates of Discrepancy between Self-reported hearing and Audiometry.

Questionnaire / Audiometry	Hearing difficulty	No difficulty	Total
Hearing loss	1,125 (A)	1,876 (B)	3,001 (A+B)
Normal	733 (C)	10,611 (D)	11,344 (C+D)
Total	1,858 (A+C)	12, 487 (B+D)	14,345 (A+B+C+D)

Percent 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)]

For peer review only

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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

Variables	Total		Without self-reported HD		Univariable analysis			Multivariable analysis		
	Weighted frequency	%	Weighted frequency	Prevalence (%)	OR	95% C.I.	p-value	OR	95% C.I.	p-value
Personal factor										
Age (yr)*	4,660,594	62.0	3,023,386	64.9	0.977	0.968 - 0.986	**<.0001**	0.979	0.967 - 0.991	**0.001**
Sex										
Male	2,594,824	55.7	1,702,933	65.6	1.078	0.897 - 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 - 1.306	1.000			
Current smoker†	1,125,449	24.1	754,583	67.0	1.146	0.850 - 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 - 1.589	**0.003**	1.025	0.831 - 1.266	0.814
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 - 1.547	0.800	0.806	0.585 - 1.111	0.324
Upper middle†	934,922	20.1	641,226	68.6	1.393	0.994 - 1.952	0.057	0.949	0.659 - 1.366	1.000
Upper†	849,526	18.2	584,315	68.8	1.406	0.999 - 1.978	0.052	0.963	0.651 - 1.427	1.000
Marital status										
Ever married	4,518,752	97.0	2,917,820	64.6	0.626	0.289 - 1.360	0.236			
Never married	141,843	3.0	105,566	74.4	Referent					

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 - 1.704	**0.002**	1.087	0.853 - 1.386	0.498
Employment status										
Employed	2,566,437	55.1	1,730,554	67.4	1.283	1.066 - 1.545	**0.009**	0.966	0.777 - 1.202	0.757
Unemployed	2,094,158	44.9	1,292,832	61.7	Referent					
Quality of life										
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 - 0.759	**<.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 - 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 - 0.780	**<.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 - 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 - 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 - 1.568	0.638	0.841	0.584 - 1.210	0.573

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Index = 1.00†	2,620,375	56.2	1,820,686	69.5	1.752	1.275 - 2.408	**<.0001**	0.930	0.606 - 1.426	1.000
EQ-VAS (ranged from 0-100)*	4,660,594	62.0	3,023,386	64.9	1.008	1.003 - 1.012	**0.001**			
Psychological factors										
Perceived health status										
Good†	1,279,057	27.4	922,424	72.1	1.311	1.007 - 1.707	**0.043**	1.255	0.958 - 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 - 0.806	**<.0001**	0.79	0.588 - 1.061	0.148
Body shape perception										
Slim†	981,355	21.1	617,482	62.9	0.914	0.697 - 1.707	0.456			
Normal	2,055,525	44.1	1,336,044	65.0	Referent					
Obese†	1,623,715	34.8	1,069,861	65.9	1.040	0.814 - 1.330	0.719			
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 - 1.018	0.070	1.000	0.762 - 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 - 0.868	**0.003**	0.795	0.576 - 1.097	0.162
Health related factors										
Vigorous physical activity practice										
Do not practice	4,150,544	89.1	2,680,694	64.6	Referent					
Practice	510,050	10.9	342,693	67.2	1.123	0.822 - 1.534	0.467			
Moderate physical activity practice										
Do not practice	4,306,908	92.4	2,791,890	64.8	Referent					
Practice	353,687	7.6	231,496	65.5	1.028	0.733 - 1.442	0.873			
Low physical activity practice										
Do not practice	2,957,617	63.5	1,912,833	64.7	Referent					

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Practice	1,702,977	36.5	1,110,554	65.2	1.024	0.841 - 1.247	0.814			
Restricted use of medical services										
Yes	864,993	18.6	492,523	56.9	0.661	0.516 - 0.847	**0.001**	0.802	0.608 - 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 - 1.202	0.870			
No	1,706,441	36.6	1,111,120	65.1	Referent					
Hospital visit in recent 2 weeks										
Yes	1,922,260	41.2	1,156,350	60.2	0.705	0.583 - 0.851	**0.000**	0.896	0.727 - 1.104	0.301
No	2,738,335	58.8	1,867,037	68.2	Referent					
Hospitalization in recent 1 year										
Yes	572,508	12.3	360,689	63.0	0.912	0.700 - 1.188	0.492			
No	4,088,086	87.7	2,662,698	65.1	Referent					
Waist circumference (cm)*	4,660,594	84.0	3,023,386	64.9	0.998	0.988 - 1.008	0.668			
Body mass index (kg/m^2)*	4,660,594	24.0	3,023,386	64.9	1.012	0.982 - 1.042	0.447			
Obesity occurrence										
Underweight†	159,020	3.4	97,392	61.2	0.894	0.491 - 1.628	1.000			
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 - 1.435	0.335			
Medical History (%)										
Hypertension										
Yes	1,684,501	36.1	1,066,151	63.3	0.898	0.742 - 1.086	0.266			
No	2,976,094	63.9	1,957,235	65.8	Referent					
Myocardial infarction										
Yes	70,821	1.5	34,451	48.6	0.507	0.258 - 0.999	**0.050**	0.538	0.242 - 1.198	0.129
No	4,589,773	98.5	2,988,935	65.1	Referent					

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Angina										
Yes	169,542	3.6	89,693	52.9	0.596	0.381 - 0.900	**0.024**	0.803	0.500 - 1.288	0.363
No	4,491,052	96.4	2,933,694	65.3	Referent					
Asthma										
Yes	192,575	4.1	101,638	52.8	0.591	0.389 - 0.899	**0.014**	0.765	0.498 - 1.175	0.221
No	4,468,019	95.9	2,921,748	65.4	Referent					
Depression										
Yes	202,039	4.3	130,770	64.7	0.993	0.663 - 1.487	0.974			
No	4,458,555	95.7	2,892,616	64.9	Referent					
Renal failure										
Yes	42,069	0.9	19,908	47.3	0.483	0.184 - 1.268	0.139	0.707	0.255 - 1.956	0.503
No	4,618,526	99.1	3,003,479	65.0	Referent					
Diabetes mellitus										
Yes	658,868	14.1	396,751	60.2	0.792	0.618 - 1.202	0.067	0.974	0.740 -1.281	0.849
No	4,001,727	85.9	2,626,635	65.6	Referent					
Auditory factors										
Tinnitus										
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 - 0.472	**<.0001**	0.425	0.344 - 0.525	**<.0001**
Occupational noise exposure										
Yes	800,620	17.2	459,993	57.5	0.683	0.520 - 0.897	**0.006**	0.566	0.423 - 0.758	**<.0001**
No	3,859,974	82.8	2,563,394	66.4	Referent					
Laboratory measures										
Systolic BP (mmHg)*	4,660,594	126.4	3,023,386	64.9	1.001	0.996 - 1.007	0.573			
Diastolic BP (mmHg)*	4,660,594	77.0	3,023,386	64.9	1.015	1.006 - 1.024	**0.002**	1.009	1.000 - 1.019	0.058
Total cholesterol (mg/dL)*	4,394,622	191.7	2,859,596	65.1	1.001	0.998 - 1.003	0.683			

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

HDL cholesterol (mg/dL)*	4,394,622	50.3	2,859,596	65.1	1.005	0.998 - 1.013	0.158
Serum triglyceride, (mg/dL)*	4,394,622	148.7	2,859,596	65.1	1.000	1.000 - 1.001	0.411
Hemoglobin (g/dl)*	4,369,845	14.1	2,848,403	65.2	1.029	0.968 - 1.093	0.360
Hematocrit (%)*	4,369,845	41.9	2,848,403	65.2	1.008	0.986 - 1.032	0.471
BUN (mg/dL)*	4,394,622	15.5	2,859,596	65.1	0.978	0.958 - 0.998	**0.033**
Serum creatinine (mg/dL)*	4,394,622	0.9	2,859,596	65.1	1.095	0.725 - 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 - 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 - 1.699	0.833

The bold means significant difference ($p < .05$).

*Continuous variables are denoted by mean.

†Probability values and 95% CIs for OR were corrected using Bonferroni's method in case of multiple testing.

CI = confidence interval, HD = hearing difficulty, BP = blood pressure, HDL = high-density lipoprotein, BUN = Blood urea nitrogen.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Table 3 Univariable and multivariable analyses of factors associated with overestimated hearing Loss

Variables	Total		Without audiometric HL		Univariable analysis			Multivariable analysis		
	Weighted frequency	% or average	Weighted frequency	Prevalence (%)	OR	95% C.I.	p-value	OR	95% C.I.	p-value
Personal factor										
Age (yr)*	3,089,060	56.3	1,451,852	47.0	0.915	0.904 - 0.927	**<.0001**	0.905	0.890 - 0.921	**<.0001**
Sex										
Male	1,574,262	51.0	682,372	43.3	0.741	0.576 - 0.954	**0.020**	0.660	0.424 - 1.029	0.067
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 - 0.895	**0.006**	0.866	0.520 - 1.445	1.000
Current smoker†	720,760	23.3	349,894	48.5	0.935	0.640 - 1.365	1.000	0.597	0.351 - 1.017	0.061
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 - 2.788	**<.0001**	1.150	0.784 - 1.687	0.475
Waist circumference (cm)*	3,089,060	83.2	1,451,852	47.0	0.977	0.964 - 0.991	**0.001**	0.988	0.964 - 1.014	0.363
Body mass index (kg/m^2)*	3,089,060	24.0	1,451,852	47.0	1.018	0.979 - 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 - 3.526	**<.0001**	0.957	0.577 - 1.584	1.000
Upper middle†	681,338	22.1	387,641	56.9	3.496	2.187 - 5.588	**<.0001**	1.244	0.739 - 2.093	0.951
Upper†	697,599	22.6	432,388	62.0	4.318	2.833 - 6.582	**<.0001**	1.468	0.857 - 2.514	0.266
Marital status										
Ever married	2,792,856	90.4	1,191,925	42.7	0.104	0.048 - 0.223	**<.0001**	1.276	0.511 - 3.184	0.601

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Never married	296,204	9.6	259,927	87.8	Referent					
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 - 4.690	**<.0001**	1.166	0.792 - 1.716	0.436
Employment status										
Employed	1,738,450	56.3	902,568	51.9	1.575	1.224 - 2.027	**0.000**	0.912	0.625 - 1.330	0.631
Unemployed	1,350,609	43.7	549,284	40.7	Referent					
Quality of life										
EQ-5D (%)										
Physical activity (mobility)										
Normal	2,262,057	73.2	1,203,774	53.2	Referent					
Limited	827,002	26.8	248,078	30.0	0.377	0.291 - 0.488	**<.0001**			
Physical activity (self-care)										
Normal	2,855,547	92.4	1,396,588	48.9	Referent					
Limited	233,513	7.6	55,264	23.7	0.324	0.200 - 0.524	**<.0001**			
Physical activity (usual activities)										
Normal	2,566,840	83.1	1,296,758	50.5	Referent					
Limited	522,220	16.9	155,094	29.7	0.414	0.306 - 0.560	**<.0001**			
Physical activity (pain/discomfort)										
Normal	2,084,203	67.5	1,008,232	48.4	Referent					
Limited	1,004,857	32.5	443,620	44.1	0.844	0.667 - 1.067	0.156			
Physical activity (anxiety/depression)										
Normal	2,575,106	83.4	1,205,708	46.8	Referent					
Limited	513,954	16.6	246,144	47.9	1.044	0.769 - 1.418	0.783			
EQ-5D index (%)										
Index < 0.75	352,500	11.4	108,676	30.8	Referent					

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

0.75 ≤ index < 1.00†	1,112,495	36.0	518,799	46.6	1.960	1.219 - 3.151	**0.003**	0.987	0.563 - 1.730	1.000
Index = 1.00†	1,624,065	52.6	824,376	50.8	2.312	1.470 - 3.638	**<.0001**	0.705	0.389 - 1.275	0.373
EQ-VAS (ranged from 0 - 100)*	3,089,060	69.1	1,451,852	47.0	1.011	1.005 - 1.017	**0.001**			
Psychological factors										
Perceived health status										
Good†	759,297	24.6	402,665	53.0	1.164	0.798 - 1.697	0.736	1.342	0.893 - 2.017	0.212
Fair	1,377,238	44.6	678,232	49.2	Referent					
Poor†	952,524	30.8	370,955	38.9	0.657	0.484 - 0.892	**0.004**	0.957	0.640 - 1.431	1.000
Body shape perception										
Too thin†	549,060	17.8	185,188	33.7	0.641	0.422 - 0.973	**0.035**	1.031	0.608 - 1.746	1.000
Just right	1,290,616	41.8	571,135	44.3	Referent					
Too fat†	1,249,383	40.4	695,530	55.7	1.582	1.158 - 2.162	**0.002**	1.312	0.874 - 1.968	0.269
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 - 2.072	**0.001**	0.980	0.698 - 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 - 1.375	0.992			
Health related factors										
Vigorous physical activity practice										
Do not practice	2,676,411	86.6	1,206,561	45.1	Referent					
Practice	412,648	13.4	245,291	59.4	1.785	1.207 - 2.641	**0.004**	1.232	0.798 - 1.901	0.346
Moderate physical activity practice										
Do not practice	2,793,226	90.4	1,278,209	45.8	Referent					
Practice	295,834	9.6	173,643	58.7	1.684	1.103 - 2.571	**0.016**	1.191	0.738 - 1.923	0.474
Low physical activity practice										

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Do not practice	1,925,733	62.3	880,948	45.7	Referent					
Practice	1,163,327	37.7	570,903	49.1	1.143	0.887 - 1.473	0.302			
Restricted use of medical services										
Yes	714,039	23.1	341,569	47.8	1.045	0.774 - 1.409	0.775			
No	2,375,021	76.9	1,110,283	46.7	Referent					
Health screening in recent 2 years										
Yes	1,904,102	61.6	862,214	45.3	0.836	0.651 - 1.073	0.158	1.134	0.823 - 1.562	0.441
No	1,184,958	38.4	589,638	49.8	Referent					
Hospital visit in recent 2 weeks										
Yes	1,326,445	42.9	560,535	42.3	0.715	0.567 - 0.902	**0.005**	1.163	0.873 - 1.551	0.302
No	1,762,615	57.1	891,317	50.6	Referent					
Hospitalization in recent 1 year										
Yes	423,019	13.7	211,199	49.9	1.146	0.775 - 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 - 1.957	1.000			
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 - 1.428	1.000			
Medical History (%)										
Hypertension										
Yes	937,031	30.3	318,681	34.0	0.463	0.361 - 0.595	**<.0001**	1.501	1.061 - 2.123	**0.022**
No	2,152,029	69.7	1,133,171	52.7	Referent					
Myocardial infarction										
Yes	47,034	1.5	10,664	22.7	0.326	0.101 - 1.052	0.061	0.582	0.129 - 2.621	0.480
No	3,042,026	98.5	1,441,188	47.4	Referent					
Angina										

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Yes	105,569	3.4	25,719	24.4	0.352	0.198 - 0.625	**0.000**	0.848	0.422 - 1.705	0.643
No	2,983,490	96.6	1,426,132	47.8	Referent					
Asthma										
Yes	142,099	4.6	51,162	36.0	0.621	0.342 - 1.128	0.117	0.991	0.482 - 2.037	0.980
No	2,946,961	95.4	1,400,690	47.5	Referent					
Depression										
Yes	167,870	5.4	96,600	57.5	1.566	1.009 - 2.432	**0.046**	1.772	1.041 - 3.016	**0.035**
No	2,921,190	94.6	1,355,251	46.4	Referent					
Renal failure										
Yes	27,962	0.9	5,801	20.7	0.292	0.049 - 1.733	0.175	0.442	0.065 - 2.987	0.402
No	3,061,098	99.1	1,446,051	47.2	Referent					
Diabetes mellitus										
Yes	375,984	12.2	113,868	30.3	0.447	0.303 - 0.658	**<.0001**	1.140	0.725 - 1.792	0.569
No	2,713,075	87.8	1,337,984	49.3	Referent					
Auditory factors										
Tinnitus										
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 - 0.697	**<.0001**	0.523	0.391 - 0.699	**<.0001**
Occupational noise exposure										
Yes	630,805	20.4	290,178	46.0	0.951	0.687 - 1.315	0.760			
No	2,458,254	79.6	1,161,674	47.3	Referent					
Laboratory measures										
Systolic BP (mmHg)*	3,089,060	122.8	1,451,852	47.0	0.974	0.966 - 0.981	**<.0001**	0.996	0.984 - 1.008	0.469
Diastolic BP (mmHg)*	3,089,060	76.5	1,451,852	47.0	1.011	0.999 - 1.023	0.083	1.013	0.993 - 1.033	0.215
Total cholesterol (mg/dL)*	2,931,858	191.5	1,396,832	47.6	1.001	0.997 - 1.004	0.723			
HDL cholesterol (mg/dL)*	2,931,858	50.7	1,396,832	47.6	1.013	1.003 - 1.023	**0.011**			

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Serum triglyceride, (mg/dL)*	2,931,858	141.3	1,396,832	47.6	0.999	0.998 - 1.000	0.149
Hemoglobin (g/dl)*	2,913,750	14.1	1,392,308	47.8	1.038	0.953 - 1.132	0.392
Hematocrit (%)*	2,913,750	41.9	1,392,308	47.8	1.012	0.980 - 1.045	0.463
BUN (mg/dL)*	2,931,858	14.9	1,535,026	52.4	0.904	0.873 - 0.936	**<.0001**
Serum creatinine (mg/dL)*	2,931,858	0.9	1,535,026	52.4	0.330	0.169 - 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 - 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 - 1.243	0.193

The bold means significant difference ($p < .05$).

*Continuous variables are denoted by mean.

†Probability values and 95% CIs for OR were corrected using Bonferroni's method in case of multiple testing.

CI = confidence interval, HD = hearing difficulty, BP = blood pressure, HDL = high-density lipoprotein, BUN = Blood urea nitrogen.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	P1 L2-4 P2 L28
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	P2 L41- P3 L29
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	P4 L69-89
Objectives	3	State specific objectives, including any prespecified hypotheses	P4 L90 - P5 L97
Methods			
Study design	4	Present key elements of study design early in the paper	P5 L101-103
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	P5 L101-114
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	P5 L113 - P6 L114
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	P6-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	P6-10
Bias	9	Describe any efforts to address potential sources of bias	N/A

For Peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Study size	10	Explain how the study size was arrived at	P5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	P6-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	P10-11
		(*b*) Describe any methods used to examine subgroups and interactions	N/A
		(*c*) Explain how missing data were addressed	P11
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	P10
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	P11
		(b) Give reasons for non-participation at each stage	P11
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	P11
		(b) Indicate number of participants with missing data for each variable of interest	P11
Outcome data	15*	Report numbers of outcome events or summary measures	Tables 2 and 3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Tables 2 and 3
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Supplementary table 1
Discussion			
Key results	18	Summarise key results with reference to study objectives	P16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	P 16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	P 13-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	P16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	P17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

BMJ Open

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

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-022440.R2
Article Type:	Research
Date Submitted by the Author:	12-Jan-2019
Complete List of Authors:	Choi, Ji Eun ; Dankook University Hospital, Department of Otorhinolaryngology - Head and Neck Surgery Moon, Il Joon ; Samsung Medical Center, Otorhinolaryngology-Head and Neck Surgery Baek, Sun-Young ; , Samsung Biomedical Research Institute, Biostatistics team Kim, Seon Woo; , Samsung Biomedical Research Institute, Biostatistics team Cho, Yang-Sun; Samsung Medical Center, Otorhinolaryngology-Head and Neck Surgery
Primary Subject Heading:	Ear, nose and throat/otolaryngology
Secondary Subject Heading:	Ear, nose and throat/otolaryngology
Keywords:	prevalence, national health and nutrition examination survey, Self-reported hearing difficulty, audiometry

SCHOLARONE™
Manuscripts

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Original Article

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

Short title: Self-reported hearing difficulty and audiometrically-measured hearing loss

Ji Eun Choi[1*], Il Joon Moon[2*], Sun-Young Baek[3], Seonwoo Kim[3], Yang-Sun Cho[2]

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

* These authors equally contributed to this work

Correspondence: Yang-Sun Cho, MD, PhD

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

Department of Otorhinolaryngology-Head and Neck Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, 81 Irwon-ro, Gangnam-gu, Seoul 06351, Republic of Korea. Tel: +82 2 3410 3579. Fax: +82 2 3410 3879. E-mail: yscho@skku.edu

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

ABSTRACT

Objective To evaluate prevalence discrepancies 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 over 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 to concordant HL.

Results Among 14,345 participants, 1,876 (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 to those who had concordant HI. Exposure to occupational noise (OR: 0.566, 95% CI: 0.423 to 0.758) was associated with underestimated HI,

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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) were 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 analyzed only participants who had normal tympanic membranes to exclude participants who have undergone a previous hearing evaluation.
- Previous studies have defined hearing loss as 40 dB HL or worse, but we used another definition of hearing loss as mean hearing threshold of > 25dB HL measured at 0.5, 1, 2, and 4 kHz in the better ear in accordance with the World Health Organization 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.

Keywords: Self-reported hearing difficulty, prevalence, national health and nutrition examination survey, audiometry

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 0.5 kHz to 8 kHz. Sometimes, the use of self-reported hearing measurements is attractive in occupational health screening programs or 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 (e.g., degree of hearing loss, frequencies of hearing loss, middle ear infection etc.)[5-7 9 10 12 13] as well as demographic factors.[3 5 7 14 15] However, these studies mainly have 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, health care utilization, 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 over- or under-estimation in a

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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, health care utilization, 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 3,840 households are selected from a panel to represent the population through a multi-stage 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 publicly 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 (8,313 in 2010, 7,887 in 2011, and 7,421 in 2012) agreed to participate in health surveys. All participants in KNHANES 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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

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). Among participants over 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. Approval for this research study was obtained from the Institutional Review Board of Samsung Medical Center (IRB No. 2016-06-142).

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). A TDH39P Phone type headphone (10ohm) 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 (ANSI) standard. [17]

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Hearing loss (HL) in this study was defined as the mean air conduction hearing thresholds > 25dB 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 (CCD) 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 categorized 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 also were 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?”

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

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 categorized 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 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 equalized 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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 one 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 categorized 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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

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-categorized 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 categorized 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 volley ball, 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*. (2015)[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, and these activities were categorized as follows: those who perform vigorous-intensity activity for a minimum of 20 minutes at least three days each week; those who perform moderate-intensity physical activity for a minimum of 30 minutes at least five days each week; and those who light-intensity activity for a minimum of 30 minutes for at least five days weekly. Individuals who did not exercise regularly were placed into the non-exercising group. Medical services evaluated restriction of medical service, health

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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, NY, USA) on the right arm of the subject while sitting after taking at least five minutes 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 analyzed within 24 hours after transportation. Total cholesterol, high-density lipoprotein (HDL) cholesterol, triglyceride, hemoglobin, hematocrit, 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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 version 9.4 (SAS Institute, Cary, NC, USA).

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. Serologic data was 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 confidence interval due to multiple testing. Statistical significance was considered when adjusted P-value was less than 0.05.

Patient and Public Involvement

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Participants and the public were not involved in designing the study or developing the research questions, nor were they involved in analyzing 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 ± SD age of the study population was 49.2 ± 16.1 years (ranged from 19 to 97). The study population consisted of 42.5% male and 57.5% female.

Prevalence of discrepancies between self-reported hearing and audiometry

Of 14,345 participants with normal TMs, 3,001 (20.9%) participants had AHL and 1,858 (13.0%) had SHD. Table 1 shows the percentage and prevalence of discrepancies between self-reported hearing and audiometry. Of 3,001 participants with AHL, 62.5% (n=1,876) reported no SHD. On the other hand, 733 (39.5%) of 1,858 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).

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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

Questionnaire / Audiometry	Hearing difficulty	No difficulty	Total
Hearing loss	1,125 (A)	1,876 (B)	3,001 (A+B)
Normal	733 (C)	10,611 (D)	11,344 (C+D)
Total	1,858 (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)]

For peer review only

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Factors associated with underestimated hearing impairment

A total of 3,001 participants who had bilateral HL (mean hearing thresholds > 25dB HL at 0.5, 1, 2, and 4 kHz) were analyzed 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 blood pressure, 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 to 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 to those who showed concordant HI.

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

309 **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% C.I.	p-value	OR	95% C.I.	p-value
Personal factor										
Age (yr)	4,660,594	62.0*	3,023,386	64.9	0.977	0.968 - 0.986	**<.0001**	0.979	0.967 - 0.991	**0.001**
Sex										
Male	2,594,824	55.7	1,702,933	65.6	1.078	0.897 - 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 - 1.306	1.000			
Current smoker†	1,125,449	24.1	754,583	67.0	1.146	0.850 - 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 - 1.589	**0.003**	1.025	0.831 - 1.266	0.814
Marital status										
Ever married	4,518,752	97.0	2,917,820	64.6	0.626	0.289 - 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 - 1.008	0.668			
Body mass index (kg/m^2)	4,660,594	24.0*	3,023,386	64.9	1.012	0.982 - 1.042	0.447			
Socioeconomic factors										
Income										
Lower	1,579,965	33.9	964,575	61.1	Referent					

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

36/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Lower middle†	1,296,182	27.8	833,271	64.3	1.148	0.853 - 1.547	0.800	0.806	0.585 - 1.111	0.324
Upper middle†	934,922	20.1	641,226	68.6	1.393	0.994 - 1.952	0.057	0.949	0.659 - 1.366	1.000
Upper†	849,526	18.2	584,315	68.8	1.406	0.999 - 1.978	0.052	0.963	0.651 - 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 - 1.704	**0.002**	1.087	0.853 - 1.386	0.498
Employment status										
Employed	2,566,437	55.1	1,730,554	67.4	1.283	1.066 - 1.545	**0.009**	0.966	0.777 - 1.202	0.757
Unemployed	2,094,158	44.9	1,292,832	61.7	Referent					
Quality of life										
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 - 0.759	**<.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 - 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 - 0.780	**<.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 - 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 - 0.929	**0.012**			

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

36/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 - 1.568	0.338	0.841	0.584 - 1.210	0.573
Index = 1.00†	2,620,375	56.2	1,820,686	69.5	1.752	1.275 - 2.408	**<.0001**	0.930	0.606 - 1.426	1.000
EQ-VAS (0–100)	4,660,594	62.0*	3,023,386	64.9	1.008	1.003 - 1.012	**0.001**			
Psychological factors										
Perceived health status										
Good†	1,279,057	27.4	922,424	72.1	1.311	1.007 - 1.707	**0.043**	1.255	0.958 - 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 - 0.806	**<.0001**	0.79	0.588 - 1.061	0.148
Body shape perception										
Too thin†	981,355	21.1	617,482	62.9	0.914	0.697 - 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 - 1.330	0.719			
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 - 1.018	0.070	1.000	0.762 - 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 - 0.868	**0.003**	0.795	0.576 - 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 - 1.534	0.467			
Moderate physical activity practice										
Non-exercising	4,306,908	92.4	2,791,890	64.8	Referent					

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

36/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Exercising	353,687	7.6	231,496	65.5	1.028	0.733 - 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 - 1.247	0.814			
Restricted use of medical services										
Yes	864,993	18.6	492,523	56.9	0.661	0.516 - 0.847	**0.001**	0.802	0.608 - 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 - 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 - 0.851	**0.0003**	0.896	0.727 - 1.104	0.301
No	2,738,335	58.8	1,867,037	68.2	Referent					
Hospitalization in past year										
Yes	572,508	12.3	360,689	63.0	0.912	0.700 - 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 - 1.628	1.000			
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 - 1.435	0.435			
Medical history										
Hypertension										
Yes	1,684,501	36.1	1,066,151	63.3	0.898	0.742 - 1.086	0.266			
No	2,976,094	63.9	1,957,235	65.8	Referent					
Myocardial infarction										
Yes	70,821	1.5	34,451	48.6	0.507	0.258 - 0.999	**0.050**	0.538	0.242 - 1.198	0.129

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

http://bmjopen.bmj.com/ on April 19, 2024 by guest. Protected by copyright.

36/bmjopen-2018-022440 on 1 May 2019. Downloaded from

No	4,589,773	98.5	2,988,935	65.1	Referent					
Angina										
Yes	169,542	3.6	89,693	52.9	0.596	0.381 - 0.900	**0.024**	0.803	0.500 - 1.288	0.363
No	4,491,052	96.4	2,933,694	65.3	Referent					
Asthma										
Yes	192,575	4.1	101,638	52.8	0.591	0.389 - 0.899	**0.014**	0.765	0.498 - 1.175	0.221
No	4,468,019	95.9	2,921,748	65.4	Referent					
Depression										
Yes	202,039	4.3	130,770	64.7	0.993	0.663 - 1.487	0.974			
No	4,458,555	95.7	2,892,616	64.9	Referent					
Renal failure										
Yes	42,069	0.9	19,908	47.3	0.483	0.184 - 1.268	0.139	0.707	0.255 - 1.956	0.503
No	4,618,526	99.1	3,003,479	65.0	Referent					
Diabetes mellitus										
Yes	658,868	14.1	396,751	60.2	0.792	0.618 - 1.202	0.067	0.974	0.740 -1.281	0.849
No	4,001,727	85.9	2,626,635	65.6	Referent					
Auditory factors										
Tinnitus										
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 - 0.472	**<.0001**	0.425	0.344 - 0.525	**<.0001**
Occupational noise exposure										
Yes	800,620	17.2	459,993	57.5	0.683	0.520 - 0.897	**0.006**	0.566	0.423 - 0.758	**<.0001**
No	3,859,974	82.8	2,563,394	66.4	Referent					
Laboratory measures										
Systolic BP (mmHg)	4,660,594	126.4*	3,023,386	64.9	1.001	0.996 - 1.007	0.573			
Diastolic BP (mmHg)	4,660,594	77.0*	3,023,386	64.9	1.015	1.006 - 1.024	**0.002**	1.009	1.000 - 1.019	0.058

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

36/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 at guest. Protected by copyright.

Total cholesterol (mg/dL)	4,394,622	191.7*	2,859,596	65.1	1.001	0.998 - 1.003	0.683
HDL cholesterol (mg/dL)	4,394,622	50.3*	2,859,596	65.1	1.005	0.998 - 1.013	0.158
Serum TG, (mg/dL)	4,394,622	148.7*	2,859,596	65.1	1.000	1.000 - 1.001	0.411
Hemoglobin (g/dl)	4,369,845	14.1*	2,848,403	65.2	1.029	0.968 - 1.093	0.360
Hematocrit (%)	4,369,845	41.9*	2,848,403	65.2	1.008	0.986 - 1.032	0.471
BUN (mg/dL)	4,394,622	15.5*	2,859,596	65.1	0.978	0.958 - 0.998	**0.033**
Serum creatinine (mg/dL)	4,394,622	0.9*	2,859,596	65.1	1.095	0.725 - 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 - 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 - 1.699	0.833

Bold type indicates significant differences ($p < .05$).

¶Underestimated hearing impairment (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.

SHD = self-reported hearing difficulty, AHL = audiometrically measured hearing loss, CI = confidence interval, HD = hearing difficulty, BP = blood pressure, HDL = high-density lipoprotein, TG = triglycerides, BUN = Blood urea nitrogen.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

36/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Associated factors with overestimated hearing impairment

A total of 1,858 participants who had SHD were analyzed 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 to 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 blood pressure, 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 to 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 to those who had both SHD and AHL.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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% C.I.	p-value	OR	95% C.I.	p-value
Personal factor										
Age (yr)	3,089,060	56.3*	1,451,852	47.0	0.915	0.904 - 0.927	**<.0001**	0.905	0.890 - 0.921	**<.0001**
Sex										
Male	1,574,262	51.0	682,372	43.3	0.741	0.576 - 0.954	**0.020**	0.660	0.424 - 1.029	0.067
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 - 0.895	**0.006**	0.866	0.520 - 1.445	1.000
Current smoker†	720,760	23.3	349,894	48.5	0.935	0.640 - 1.365	1.000	0.597	0.351 - 1.017	0.061
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 - 2.788	**<.0001**	1.150	0.784 - 1.687	0.475
Marital status										
Ever married	2,792,856	90.4	1,191,925	42.7	0.104	0.048 - 0.223	**<.0001**	1.276	0.511 - 3.184	0.601
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 - 0.991	**0.001**	0.988	0.964 - 1.014	0.363
Body mass index (kg/m^2)	3,089,060	24.0*	1,451,852	47.0	1.018	0.979 - 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 - 3.526	**<.0001**	0.957	0.577 - 1.584	1.000

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Upper middle†	681,338	22.1	387,641	56.9	3.496	2.187 - 5.588	**<.0001**	1.244	0.739 - 2.093	0.951
Upper†	697,599	22.6	432,388	62.0	4.318	2.833 - 6.582	**<.0001**	1.468	0.857 - 2.514	0.266
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 - 4.690	**<.0001**	1.166	0.792 - 1.716	0.436
Employment status										
Employed	1,738,450	56.3	902,568	51.9	1.575	1.224 - 2.027	**0.0004**	0.912	0.625 - 1.330	0.631
Unemployed	1,350,609	43.7	549,284	40.7	Referent					
Quality of life										
EQ-5D (%)										
Physical activity (mobility)										
Normal	2,262,057	73.2	1,203,774	53.2	Referent					
Limited	827,002	26.8	248,078	30.0	0.377	0.291 - 0.488	**<.0001**			
Physical activity (self-care)										
Normal	2,855,547	92.4	1,396,588	48.9	Referent					
Limited	233,513	7.6	55,264	23.7	0.324	0.200 - 0.524	**<.0001**			
Physical activity (usual activities)										
Normal	2,566,840	83.1	1,296,758	50.5	Referent					
Limited	522,220	16.9	155,094	29.7	0.414	0.306 - 0.560	**<.0001**			
Physical activity (pain/discomfort)										
Normal	2,084,203	67.5	1,008,232	48.4	Referent					
Limited	1,004,857	32.5	443,620	44.1	0.844	0.667 - 1.067	0.156			
Physical activity (anxiety/depression)										
Normal	2,575,106	83.4	1,205,708	46.8	Referent					
Limited	513,954	16.6	246,144	47.9	1.044	0.769 - 1.418	0.783			
EQ-5D index (%)										
Index < 0.75	352,500	11.4	108,676	30.8	Referent					
0.75 ≤ index < 1.00†	1,112,495	36.0	518,799	46.6	1.960	1.219 - 3.151	**0.003**	0.987	0.563 - 1.730	1.000
Index = 1.00†	1,624,065	52.6	824,376	50.8	2.312	1.470 - 3.638	**<.0001**	0.705	0.389 - 1.275	0.373

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

EQ-VAS (0 - 100)	3,089,060	69.1*	1,451,852	47.0	1.011	1.005 - 1.017	**0.001**			
Psychological factors										
Perceived health status										
Good†	759,297	24.6	402,665	53.0	1.164	0.798 - 1.697	0.736	1.342	0.893 - 2.017	0.212
Fair	1,377,238	44.6	678,232	49.2	Referent					
Poor†	952,524	30.8	370,955	38.9	0.657	0.484 - 0.892	**0.004**	0.957	0.640 - 1.431	1.000
Body shape perception										
Too thin†	549,060	17.8	185,188	33.7	0.641	0.422 - 0.973	**0.035**	1.031	0.608 - 1.746	1.000
Just right	1,290,616	41.8	571,135	44.3	Referent					
Too fat†	1,249,383	40.4	695,530	55.7	1.582	1.158 - 2.162	**0.002**	1.312	0.874 - 1.968	0.269
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 - 2.072	**0.001**	0.980	0.698 - 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 - 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 - 2.641	**0.004**	1.232	0.798 - 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 - 2.571	**0.016**	1.191	0.738 - 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 - 1.473	0.302			
Restricted use of medical services										
Yes	714,039	23.1	341,569	47.8	1.045	0.774 - 1.409	0.775			
No	2,375,021	76.9	1,110,283	46.7	Referent					

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Health screening in past 2 years										
Yes	1,904,102	61.6	862,214	45.3	0.836	0.651 - 1.073	0.158	1.134	0.823 - 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 - 0.902	**0.005**	1.163	0.873 - 1.551	0.302
No	1,762,615	57.1	891,317	50.6	Referent					
Hospitalization in past year										
Yes	423,019	13.7	211,199	49.9	1.146	0.775 - 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 - 1.957	1.000			
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 - 1.428	1.000			
Medical history										
Hypertension										
Yes	937,031	30.3	318,681	34.0	0.463	0.361 - 0.595	**<.0001**	1.501	1.061 - 2.123	**0.022**
No	2,152,029	69.7	1,133,171	52.7	Referent					
Myocardial infarction										
Yes	47,034	1.5	10,664	22.7	0.326	0.101 - 1.052	0.061	0.582	0.129 - 2.621	0.480
No	3,042,026	98.5	1,441,188	47.4	Referent					
Angina										
Yes	105,569	3.4	25,719	24.4	0.352	0.198 - 0.625	**0.0004**	0.848	0.422 - 1.705	0.643
No	2,983,490	96.6	1,426,132	47.8	Referent					
Asthma										
Yes	142,099	4.6	51,162	36.0	0.621	0.342 - 1.128	0.117	0.991	0.482 - 2.037	0.980
No	2,946,961	95.4	1,400,690	47.5	Referent					
Depression										
Yes	167,870	5.4	96,600	57.5	1.566	1.009 - 2.432	**0.046**	1.772	1.041 - 3.016	**0.035**
No	2,921,190	94.6	1,355,251	46.4	Referent					

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Renal failure										
Yes	27,962	0.9	5,801	20.7	0.292	0.049 - 1.733	0.175	0.442	0.065 - 2.987	0.402
No	3,061,098	99.1	1,446,051	47.2	Referent					
Diabetes mellitus										
Yes	375,984	12.2	113,868	30.3	0.447	0.303 - 0.658	**<.0001**	1.140	0.725 - 1.792	0.569
No	2,713,075	87.8	1,337,984	49.3	Referent					
Auditory factors										
Tinnitus										
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 - 0.697	**<.0001**	0.523	0.391 - 0.699	**<.0001**
Occupational noise exposure										
Yes	630,805	20.4	290,178	46.0	0.951	0.687 - 1.315	0.760			
No	2,458,254	79.6	1,161,674	47.3	Referent					
Laboratory measures										
Systolic BP (mmHg)	3,089,060	122.8*	1,451,852	47.0	0.974	0.966 - 0.981	**<.0001**	0.996	0.984 - 1.008	0.469
Diastolic BP (mmHg)	3,089,060	76.5*	1,451,852	47.0	1.011	0.999 - 1.023	0.083	1.013	0.993 - 1.033	0.215
Total cholesterol (mg/dL)	2,931,858	191.5*	1,396,832	47.6	1.001	0.997 - 1.004	0.723			
HDL cholesterol (mg/dL)	2,931,858	50.7*	1,396,832	47.6	1.013	1.003 - 1.023	**0.011**			
Serum TG, (mg/dL)	2,931,858	141.3*	1,396,832	47.6	0.999	0.998 - 1.000	0.149			
Hemoglobin (g/dl)	2,913,750	14.1*	1,392,308	47.8	1.038	0.953 - 1.132	0.392			
Hematocrit (%)	2,913,750	41.9*	1,392,308	47.8	1.012	0.980 - 1.045	0.463			
BUN (mg/dL)	2,931,858	14.9*	1,535,026	52.4	0.904	0.873 - 0.936	**<.0001**			
Serum creatinine (mg/dL)	2,931,858	0.9*	1,535,026	52.4	0.330	0.169 - 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 - 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 - 1.243	0.193			

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Bold text indicates significant differences ($p < .05$).

¶Overestimated hearing impairment (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.

SHD = self-reported hearing difficulty, AHL = audiometrically measured hearing loss, CI = confidence interval, HD = hearing difficulty, BP = blood pressure, HDL = high-density lipoprotein, TG = triglycerides, BUN = Blood urea nitrogen.

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

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 US (71.8%)[3], but similar to that reported in the general population of Australia (82%)[6]. Previously, Kim *et al.*[5] (2017) categorized 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 (< 25dB, ≥ 25dB and < 40dB, and ≥ 40dB). When the participants of previous study[5] was 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% (1,876 of 14,325) reported underestimated HI. However, reclassified results in Kim *et al.* (2017) showed that 6.3% (1,237 of 19,642) of participants reported overestimated HI and 10.5% (2,059 of 19,642) of participants reported underestimated HI. Although present study and Kim *et al.* (2017) analyzed using same dataset, participants with abnormal TMs were excluded in our study, but included in Kim *et al.* (2017). 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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

compared to 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 increases[24] 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 SDH 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 audiometric HL among participants with SHD (Table 3). In contrast to our result, Kamil *et al.* (2015)[3] has been reported that old age was related to underestimation of HI. The opposite result between our study and Kamil *et al.* (2015) may be due to the fact that younger people who underestimated HI did not included because they examined participants aged 50 and older. Among 2,609 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 pre-clinical HL in auditory way. Also, hypertension and depression may influence the SHD in non-auditory way. Subject 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],

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 program 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 (<25dB) and without SHD in the reference group, and confined the concordant HI group to those who showed both SHD and AHL as reference. While Kim *et al.*[5] had the concordance group including normal hearing population as reference. Because large number of normal hearing population (93%) included in the 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. Sub-group analysis for participants with ≥ 25dB in Kim *et al.*[5] showed that age, sex, education, occupation, and stress was not associated with the discrepancy between subjective hearing assessment and audiometric thresholds. Lastly, this study analyzed more variables including smoking status, alcohol consumption, waist circumference, body mass index, monthly income, marital status,

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

quality of life, self-reported health status, body shape perception, noise exposure, physical activity, the use of medical service, and current disease, and serologic 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. Also, these factors need to be considered when deciding to conduct a hearing test in the clinics, even if the patients had no SDH.

CONTRIBUTIONS

Ji Eun Choi and Il Joon Moon designed research and wrote the main paper; Sun-Young Baek and Seonwoo Kim collected data and analyzed data; Yang-Sun Cho provided critical revision and discussed the results and implications and commented on the manuscript at all stages.

FUNDING

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

COMPETING INTERESTS

None declared.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

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).

A 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 is de-identified and available to the public.

ACKNOWLEDGMENTS

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 & Prevention for collecting data in this survey and their dedicated work.

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

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.

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

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 de W, 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.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

19. EuroQol G. 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 (Baltimore)* 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, Schreitmuller S, Ortmann M, *et al.* Effects of Hearing Loss and Cognitive Load on Speech Recognition with Competing Talkers. *Front Psychol* 2016;7:301.

27. Fullgrabe 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.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

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. Przewozny T, Gojska-Grymajlo 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.

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	P1 L2-4 P2 L28
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	P2 L41- P3 L29
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	P4 L69-89
Objectives	3	State specific objectives, including any prespecified hypotheses	P4 L90 - P5 L97
Methods			
Study design	4	Present key elements of study design early in the paper	P5 L101-103
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	P5 L101-114
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	P5 L113 - P6 L114
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	P6-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	P6-10
Bias	9	Describe any efforts to address potential sources of bias	N/A

For Peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Study size	10	Explain how the study size was arrived at	P5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	P6-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	P10-11
		(*b*) Describe any methods used to examine subgroups and interactions	N/A
		(*c*) Explain how missing data were addressed	P11
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	P10
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	P11
		(b) Give reasons for non-participation at each stage	P11
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	P11
		(b) Indicate number of participants with missing data for each variable of interest	P11
Outcome data	15*	Report numbers of outcome events or summary measures	Tables 2 and 3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Tables 2 and 3
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Supplementary table 1
Discussion			
Key results	18	Summarise key results with reference to study objectives	P16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	P 16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	P 13-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	P16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	P17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

BMJ Open

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

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-022440.R3
Article Type:	Research
Date Submitted by the Author:	27-Feb-2019
Complete List of Authors:	Choi, Ji Eun ; Dankook University Hospital, Department of Otorhinolaryngology - Head and Neck Surgery Moon, Il Joon ; Samsung Medical Center, Otorhinolaryngology-Head and Neck Surgery Baek, Sun-Young ; , Samsung Biomedical Research Institute, Biostatistics team Kim, Seon Woo; , Samsung Biomedical Research Institute, Biostatistics team Cho, Yang-Sun; Samsung Medical Center, Otorhinolaryngology-Head and Neck Surgery
Primary Subject Heading:	Ear, nose and throat/otolaryngology
Secondary Subject Heading:	Ear, nose and throat/otolaryngology
Keywords:	prevalence, national health and nutrition examination survey, Self-reported hearing difficulty, audiometry

SCHOLARONE™
Manuscripts

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Original Article

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

Short title: Self-reported hearing difficulty and audiometrically-measured hearing loss

Ji Eun Choi[1*], Il Joon Moon[2*], Sun-Young Baek[3], Seonwoo Kim[3], Yang-Sun Cho[2]

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

* These authors equally contributed to this work

Correspondence: Yang-Sun Cho, MD, PhD

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

Department of Otorhinolaryngology-Head and Neck Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, 81 Irwon-ro, Gangnam-gu, Seoul 06351, Republic of Korea. Tel: +82 2 3410 3579. Fax: +82 2 3410 3879. E-mail: yscho@skku.edu

ABSTRACT

Objective To evaluate prevalence discrepancies 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 over 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 to concordant HL.

Results Among 14,345 participants, 1,876 (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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

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 to 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) were 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 analyzed 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 > 25dB HL measured at 0.5, 1, 2, and 4 kHz in the better ear in accordance with the World Health Organization 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.

Keywords:

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Self-reported hearing difficulty, prevalence, national health and nutrition examination survey, audiometry

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

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 0.5 kHz to 8 kHz. Sometimes, the use of self-reported hearing measurements is attractive in occupational health screening programs or 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 (e.g., degree of hearing loss, frequencies of hearing loss, middle ear infection etc.)[5-7 9 10 12 13] as well as demographic factors.[3 5 7 14 15] However, these studies mainly have 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, health care utilization, 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 over- or under-estimation in a

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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, health care utilization, 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 3,840 households are selected from a panel to represent the population through a multi-stage 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 publicly 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 (8,313 in 2010, 7,887 in 2011, and 7,421 in 2012) agreed to participate in health surveys. All participants in KNHANES 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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

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). Among participants over 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. Approval for this research study was obtained from the Institutional Review Board of Samsung Medical Center (IRB No. 2016-06-142).

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). A TDH39P Phone type headphone (10ohm) 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 (ANSI) standard. [17]

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Hearing loss (HL) in this study was defined as the mean air conduction hearing thresholds > 25dB 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 (CCD) 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 categorized 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 also were 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?”

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

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 categorized 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 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 equalized 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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 one 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 categorized 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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

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-categorized 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 categorized 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 volley ball, 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*. (2015)[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 categorized as follows: those who perform vigorous-intensity activity for a minimum of 20 minutes at least three days each week; those who perform moderate-intensity physical activity for a minimum of 30 minutes at least five days each week; and those who light-intensity activity for a minimum of 30 minutes for at least five days weekly. Individuals who did not exercise regularly were placed into the non-exercising group. Medical services evaluated restriction of medical service, health

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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, NY, USA) on the right arm of the subject while sitting after taking at least five minutes 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 analyzed within 24 hours after transportation. Total cholesterol, high-density lipoprotein (HDL) cholesterol, triglyceride, hemoglobin, hematocrit, 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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 version 9.4 (SAS Institute, Cary, NC, USA).

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. Serologic data was 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 confidence interval due to multiple testing. Statistical significance was considered when adjusted P-value was less than 0.05.

Patient and Public Involvement

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Participants and the public were not involved in designing the study or developing the research questions, nor were they involved in analyzing 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 ± SD age of the study population was 49.2 ± 16.1 years (ranged from 19 to 97). The study population consisted of 42.5% male and 57.5% female.

Prevalence of discrepancies between self-reported hearing and audiometry

Of 14,345 participants with normal TMs, 3,001 (20.9%) participants had AHL and 1,858 (13.0%) had SHD. Table 1 shows the percentage and prevalence of discrepancies between self-reported hearing and audiometry. Of 3,001 participants with AHL, 62.5% (n=1,876) reported no SHD. On the other hand, 733 (39.5%) of 1,858 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).

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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

Questionnaire / Audiometry	Hearing difficulty	No difficulty	Total
Hearing loss	1,125 (A)	1,876 (B)	3,001 (A+B)
Normal	733 (C)	10,611 (D)	11,344 (C+D)
Total	1,858 (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)]

For peer review only

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Factors associated with underestimated hearing impairment

A total of 3,001 participants who had bilateral HL (mean hearing thresholds > 25dB HL at 0.5, 1, 2, and 4 kHz) were analyzed 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 blood pressure, 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 to 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 to those who showed concordant HI.

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

309 **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% C.I.	p-value	OR	95% C.I.	p-value
Personal factor										
Age (yr)	4,660,594	62.0*	3,023,386	64.9	0.977	0.968 - 0.986	**<.0001**	0.979	0.967 - 0.991	**0.001**
Sex										
Male	2,594,824	55.7	1,702,933	65.6	1.078	0.897 - 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 - 1.306	1.000			
Current smoker†	1,125,449	24.1	754,583	67.0	1.146	0.850 - 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 - 1.589	**0.003**	1.025	0.831 - 1.266	0.814
Marital status										
Ever married	4,518,752	97.0	2,917,820	64.6	0.626	0.289 - 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 - 1.008	0.668			
Body mass index (kg/m^2)	4,660,594	24.0*	3,023,386	64.9	1.012	0.982 - 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 - 1.547	0.800	0.806	0.585 - 1.111	0.324
Upper middle†	934,922	20.1	641,226	68.6	1.393	0.994 - 1.952	0.057	0.949	0.659 - 1.366	1.000
Upper†	849,526	18.2	584,315	68.8	1.406	0.999 - 1.978	0.052	0.963	0.651 - 1.427	1.000

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 - 1.704	**0.002**	1.087	0.853 - 1.386	0.498
Employment status										
Employed	2,566,437	55.1	1,730,554	67.4	1.283	1.066 - 1.545	**0.009**	0.966	0.777 - 1.202	0.757
Unemployed	2,094,158	44.9	1,292,832	61.7	Referent					
Quality of life										
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 - 0.759	**<.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 - 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 - 0.780	**<.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 - 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 - 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 - 1.568	0.638	0.841	0.584 - 1.210	0.573
Index = 1.00[†]	2,620,375	56.2	1,820,686	69.5	1.752	1.275 - 2.408	**<.0001**	0.930	0.606 - 1.426	1.000
EQ-VAS (0–100)	4,660,594	62.0[*]	3,023,386	64.9	1.008	1.003 - 1.012	**0.001**			
Psychological factors										

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Perceived health status										
Good†	1,279,057	27.4	922,424	72.1	1.311	1.007 - 1.707	**0.043**	1.255	0.958 - 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 - 0.806	**<.0001**	0.79	0.588 - 1.061	0.148
Body shape perception										
Too thin†	981,355	21.1	617,482	62.9	0.914	0.697 - 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 - 1.330	0.719			
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 - 1.018	0.070	1.000	0.762 - 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 - 0.868	**0.003**	0.795	0.576 - 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 - 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 - 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 - 1.247	0.814			
Restricted use of medical services										
Yes	864,993	18.6	492,523	56.9	0.661	0.516 - 0.847	**0.001**	0.802	0.608 - 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 - 1.202	0.870			

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 - 0.851	**0.0003**	0.896	0.727 - 1.104	0.301
No	2,738,335	58.8	1,867,037	68.2	Referent					
Hospitalization in past year										
Yes	572,508	12.3	360,689	63.0	0.912	0.700 - 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 - 1.628	1.000			
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 - 1.435	0.335			
Medical history										
Hypertension										
Yes	1,684,501	36.1	1,066,151	63.3	0.898	0.742 - 1.086	0.266			
No	2,976,094	63.9	1,957,235	65.8	Referent					
Myocardial infarction										
Yes	70,821	1.5	34,451	48.6	0.507	0.258 - 0.999	**0.050**	0.538	0.242 - 1.198	0.129
No	4,589,773	98.5	2,988,935	65.1	Referent					
Angina										
Yes	169,542	3.6	89,693	52.9	0.596	0.381 - 0.900	**0.024**	0.803	0.500 - 1.288	0.363
No	4,491,052	96.4	2,933,694	65.3	Referent					
Asthma										
Yes	192,575	4.1	101,638	52.8	0.591	0.389 - 0.899	**0.014**	0.765	0.498 - 1.175	0.221
No	4,468,019	95.9	2,921,748	65.4	Referent					
Depression										
Yes	202,039	4.3	130,770	64.7	0.993	0.663 - 1.487	0.974			
No	4,458,555	95.7	2,892,616	64.9	Referent					
Renal failure										
Yes	42,069	0.9	19,908	47.3	0.483	0.184 - 1.268	0.139	0.707	0.255 - 1.956	0.503

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

No	4,618,526	99.1	3,003,479	65.0	Referent					
Diabetes mellitus										
Yes	658,868	14.1	396,751	60.2	0.792	0.618 - 1.202	0.067	0.974	0.740 -1.281	0.849
No	4,001,727	85.9	2,626,635	65.6	Referent					
Auditory factors										
Tinnitus										
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 - 0.472	**<.0001**	0.425	0.344 - 0.525	**<.0001**
Occupational noise exposure										
Yes	800,620	17.2	459,993	57.5	0.683	0.520 - 0.897	**0.006**	0.566	0.423 - 0.758	**<.0001**
No	3,859,974	82.8	2,563,394	66.4	Referent					
Laboratory measures										
Systolic BP (mmHg)	4,660,594	126.4*	3,023,386	64.9	1.001	0.996 - 1.007	0.573			
Diastolic BP (mmHg)	4,660,594	77.0*	3,023,386	64.9	1.015	1.006 - 1.024	**0.002**	1.009	1.000 - 1.019	0.058
Total cholesterol (mg/dL)	4,394,622	191.7*	2,859,596	65.1	1.001	0.998 - 1.003	0.683			
HDL cholesterol (mg/dL)	4,394,622	50.3*	2,859,596	65.1	1.005	0.998 - 1.013	0.158			
Serum TG, (mg/dL)	4,394,622	148.7*	2,859,596	65.1	1.000	1.000 - 1.001	0.411			
Hemoglobin (g/dl)	4,369,845	14.1*	2,848,403	65.2	1.029	0.968 - 1.093	0.360			
Hematocrit (%)	4,369,845	41.9*	2,848,403	65.2	1.008	0.986 - 1.032	0.471			
BUN (mg/dL)	4,394,622	15.5*	2,859,596	65.1	0.978	0.958 - 0.998	**0.033**			
Serum creatinine (mg/dL)	4,394,622	0.9*	2,859,596	65.1	1.095	0.725 - 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 - 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 - 1.699	0.833			

310 Bold type indicates significant differences ($p < .05$).

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

¶Underestimated hearing impairment (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.

SHD = self-reported hearing difficulty, AHL = audiometrically measured hearing loss, CI = confidence interval, HD = hearing difficulty, BP = blood pressure, HDL = high-density lipoprotein, TG = triglycerides, BUN = Blood urea nitrogen

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Associated factors with overestimated hearing impairment

A total of 1,858 participants who had SHD were analyzed 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 to 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 blood pressure, 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 to 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 to those who had both SHD and AHL.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

10.1136/bmjopen-2023-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

336 **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% C.I.	p-value	OR	95% C.I.	p-value
Personal factor										
Age (yr)	3,089,060	56.3*	1,451,852	47.0	0.915	0.904 - 0.927	**<.0001**	0.905	0.890 - 0.921	**<.0001**
Sex										
Male	1,574,262	51.0	682,372	43.3	0.741	0.576 - 0.954	**0.020**	0.660	0.424 - 1.029	0.067
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 - 0.895	**0.006**	0.866	0.520 - 1.445	1.000
Current smoker†	720,760	23.3	349,894	48.5	0.935	0.640 - 1.365	1.000	0.597	0.351 - 1.017	0.061
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 - 2.788	**<.0001**	1.150	0.784 - 1.687	0.475
Marital status										
Ever married	2,792,856	90.4	1,191,925	42.7	0.104	0.048 - 0.223	**<.0001**	1.276	0.511 - 3.184	0.601
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 - 0.991	**0.001**	0.988	0.964 - 1.014	0.363
Body mass index (kg/m^2)	3,089,060	24.0*	1,451,852	47.0	1.018	0.979 - 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 - 3.526	**<.0001**	0.957	0.577 - 1.584	1.000

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Upper middle†	681,338	22.1	387,641	56.9	3.496	2.187 - 5.588	**<.0001**	1.244	0.739 - 2.093	0.951
Upper†	697,599	22.6	432,388	62.0	4.318	2.833 - 6.582	**<.0001**	1.468	0.857 - 2.514	0.266
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 - 4.690	**<.0001**	1.166	0.792 - 1.716	0.436
Employment status										
Employed	1,738,450	56.3	902,568	51.9	1.575	1.224 - 2.027	**0.0004**	0.912	0.625 - 1.330	0.631
Unemployed	1,350,609	43.7	549,284	40.7	Referent					
Quality of life										
EQ-5D (%)										
Physical activity (mobility)										
Normal	2,262,057	73.2	1,203,774	53.2	Referent					
Limited	827,002	26.8	248,078	30.0	0.377	0.291 - 0.488	**<.0001**			
Physical activity (self-care)										
Normal	2,855,547	92.4	1,396,588	48.9	Referent					
Limited	233,513	7.6	55,264	23.7	0.324	0.200 - 0.524	**<.0001**			
Physical activity (usual activities)										
Normal	2,566,840	83.1	1,296,758	50.5	Referent					
Limited	522,220	16.9	155,094	29.7	0.414	0.306 - 0.560	**<.0001**			
Physical activity (pain/discomfort)										
Normal	2,084,203	67.5	1,008,232	48.4	Referent					
Limited	1,004,857	32.5	443,620	44.1	0.844	0.667 - 1.067	0.156			
Physical activity (anxiety/depression)										
Normal	2,575,106	83.4	1,205,708	46.8	Referent					
Limited	513,954	16.6	246,144	47.9	1.044	0.769 - 1.418	0.783			
EQ-5D index (%)										
Index < 0.75	352,500	11.4	108,676	30.8	Referent					
0.75 ≤ index < 1.00†	1,112,495	36.0	518,799	46.6	1.960	1.219 - 3.151	**0.003**	0.987	0.563 - 1.730	1.000
Index = 1.00†	1,624,065	52.6	824,376	50.8	2.312	1.470 - 3.638	**<.0001**	0.705	0.389 - 1.275	0.373

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

EQ-VAS (0 - 100)	3,089,060	69.1*	1,451,852	47.0	1.011	1.005 - 1.017	**0.001**			
Psychological factors										
Perceived health status										
Good†	759,297	24.6	402,665	53.0	1.164	0.798 - 1.697	0.736	1.342	0.893 - 2.017	0.212
Fair	1,377,238	44.6	678,232	49.2	Referent					
Poor†	952,524	30.8	370,955	38.9	0.657	0.484 - 0.892	**0.004**	0.957	0.640 - 1.431	1.000
Body shape perception										
Too thin†	549,060	17.8	185,188	33.7	0.641	0.422 - 0.973	**0.035**	1.031	0.608 - 1.746	1.000
Just right	1,290,616	41.8	571,135	44.3	Referent					
Too fat†	1,249,383	40.4	695,530	55.7	1.582	1.158 - 2.162	**0.002**	1.312	0.874 - 1.968	0.269
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 - 2.072	**0.001**	0.980	0.698 - 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 - 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 - 2.641	**0.004**	1.232	0.798 - 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 - 2.571	**0.016**	1.191	0.738 - 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 - 1.473	0.302			
Restricted use of medical services										
Yes	714,039	23.1	341,569	47.8	1.045	0.774 - 1.409	0.775			
No	2,375,021	76.9	1,110,283	46.7	Referent					

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Health screening in past 2 years										
Yes	1,904,102	61.6	862,214	45.3	0.836	0.651 - 1.073	0.158	1.134	0.823 - 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 - 0.902	**0.005**	1.163	0.873 - 1.551	0.302
No	1,762,615	57.1	891,317	50.6	Referent					
Hospitalization in past year										
Yes	423,019	13.7	211,199	49.9	1.146	0.775 - 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 - 1.957	1.000			
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 - 1.428	1.000			
Medical history										
Hypertension										
Yes	937,031	30.3	318,681	34.0	0.463	0.361 - 0.595	**<.0001**	1.501	1.061 - 2.123	**0.022**
No	2,152,029	69.7	1,133,171	52.7	Referent					
Myocardial infarction										
Yes	47,034	1.5	10,664	22.7	0.326	0.101 - 1.052	0.061	0.582	0.129 - 2.621	0.480
No	3,042,026	98.5	1,441,188	47.4	Referent					
Angina										
Yes	105,569	3.4	25,719	24.4	0.352	0.198 - 0.625	**0.0004**	0.848	0.422 - 1.705	0.643
No	2,983,490	96.6	1,426,132	47.8	Referent					
Asthma										
Yes	142,099	4.6	51,162	36.0	0.621	0.342 - 1.128	0.117	0.991	0.482 - 2.037	0.980
No	2,946,961	95.4	1,400,690	47.5	Referent					
Depression										
Yes	167,870	5.4	96,600	57.5	1.566	1.009 - 2.432	**0.046**	1.772	1.041 - 3.016	**0.035**
No	2,921,190	94.6	1,355,251	46.4	Referent					

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Renal failure										
Yes	27,962	0.9	5,801	20.7	0.292	0.049 - 1.733	0.175	0.442	0.065 - 2.987	0.402
No	3,061,098	99.1	1,446,051	47.2	Referent					
Diabetes mellitus										
Yes	375,984	12.2	113,868	30.3	0.447	0.303 - 0.658	**<.0001**	1.140	0.725 - 1.792	0.569
No	2,713,075	87.8	1,337,984	49.3	Referent					
Auditory factors										
Tinnitus										
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 - 0.697	**<.0001**	0.523	0.391 - 0.699	**<.0001**
Occupational noise exposure										
Yes	630,805	20.4	290,178	46.0	0.951	0.687 - 1.315	0.760			
No	2,458,254	79.6	1,161,674	47.3	Referent					
Laboratory measures										
Systolic BP (mmHg)	3,089,060	122.8*	1,451,852	47.0	0.974	0.966 - 0.981	**<.0001**	0.996	0.984 - 1.008	0.469
Diastolic BP (mmHg)	3,089,060	76.5*	1,451,852	47.0	1.011	0.999 - 1.023	0.083	1.013	0.993 - 1.033	0.215
Total cholesterol (mg/dL)	2,931,858	191.5*	1,396,832	47.6	1.001	0.997 - 1.004	0.723			
HDL cholesterol (mg/dL)	2,931,858	50.7*	1,396,832	47.6	1.013	1.003 - 1.023	**0.011**			
Serum TG, (mg/dL)	2,931,858	141.3*	1,396,832	47.6	0.999	0.998 - 1.000	0.149			
Hemoglobin (g/dl)	2,913,750	14.1*	1,392,308	47.8	1.038	0.953 - 1.132	0.392			
Hematocrit (%)	2,913,750	41.9*	1,392,308	47.8	1.012	0.980 - 1.045	0.463			
BUN (mg/dL)	2,931,858	14.9*	1,535,026	52.4	0.904	0.873 - 0.936	**<.0001**			
Serum creatinine (mg/dL)	2,931,858	0.9*	1,535,026	52.4	0.330	0.169 - 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 - 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 - 1.243	0.193			

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Bold text indicates significant differences ($p < .05$).

¶Overestimated hearing impairment (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.

SHD = self-reported hearing difficulty, AHL = audiometrically measured hearing loss, CI = confidence interval, HD = hearing difficulty, BP = blood pressure, HDL = high-density lipoprotein, TG = triglycerides, BUN = Blood urea nitrogen.

For peer review only

10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

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 US (71.8%)[3], but similar to that reported in the general population of Australia (82%)[6]. Previously, Kim *et al.*[5] (2017) categorized 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 (< 25dB, ≥ 25dB and < 40dB, and ≥ 40dB). When the participants of previous study[5] was 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% (1,876 of 14,325) reported underestimated HI. However, reclassified results in Kim *et al.* (2017) showed that 6.3% (1,237 of 19,642) of participants reported overestimated HI and 10.5% (2,059 of 19,642) of participants reported underestimated HI. Although present study and Kim *et al.* (2017) analyzed using same dataset, participants with abnormal TMs were excluded in our study, but included in Kim *et al.* (2017). 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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

compared to 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 increases[24] 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 SDH 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 audiometric HL among participants with SHD (Table 3). In contrast to our result, Kamil *et al.* (2015)[3] has been reported that old age was related to underestimation of HI. The opposite result between our study and Kamil *et al.* (2015) may be due to the fact that younger people who underestimated HI did not included because they examined participants aged 50 and older. Among 2,609 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 pre-clinical 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],

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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 program 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 (<25dB) 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. Sub-group analysis for participants with ≥ 25dB in Kim *et al.*[5] showed that age, sex, education, occupation, and stress was not associated with the discrepancy between subjective hearing assessment and audiometric thresholds. Lastly, this study analyzed more variables including smoking status, alcohol consumption, waist circumference, body mass index, monthly income,

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

marital status, quality of life, self-reported health status, body shape perception, noise exposure, physical activity, the use of medical service, and current disease, and serologic 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 dose not report a hearing impairment.

CONTRIBUTIONS

J.E.C. and I.J.M: designed research and wrote the main paper. S.B and S.K: collected data and analyzed data. Y.C: provided critical revision and discussed the results and implications and commented on the manuscript at all stages.

FUNDING

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

COMPETING INTERESTS

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

None declared.

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).

A 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 is de-identified and available to the public.

ACKNOWLEDGMENTS

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 & Prevention for collecting data in this survey and their dedicated work.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

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.

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

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 de W, 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.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

19. EuroQol G. 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 (Baltimore)* 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, Schreitmuller S, Ortmann M, *et al.* Effects of Hearing Loss and Cognitive Load on Speech Recognition with Competing Talkers. *Front Psychol* 2016;7:301.

27. Fullgrabe 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.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only

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. Przewozny T, Gojska-Grymajlo 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.

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	P1 L2-4 P2 L28
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	P2 L41- P3 L29
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	P4 L69-89
Objectives	3	State specific objectives, including any prespecified hypotheses	P4 L90 - P5 L97
Methods			
Study design	4	Present key elements of study design early in the paper	P5 L101-103
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	P5 L101-114
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	P5 L113 - P6 L114
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	P6-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	P6-10
Bias	9	Describe any efforts to address potential sources of bias	N/A

For Peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Study size	10	Explain how the study size was arrived at	P5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	P6-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	P10-11
		(*b*) Describe any methods used to examine subgroups and interactions	N/A
		(*c*) Explain how missing data were addressed	P11
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	P10
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	P11
		(b) Give reasons for non-participation at each stage	P11
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	P11
		(b) Indicate number of participants with missing data for each variable of interest	P11
Outcome data	15*	Report numbers of outcome events or summary measures	Tables 2 and 3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Tables 2 and 3
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.

Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Supplementary table 1
Discussion			
Key results	18	Summarise key results with reference to study objectives	P16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	P 16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	P 13-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	P16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	P17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

For peer review only

BMJ Open: first published as 10.1136/bmjopen-2018-022440 on 1 May 2019. Downloaded from http://bmjopen.bmj.com/ on April 9, 2024 by guest. Protected by copyright.