The Prevalence and Factors Associated with Hearing Impairment in the Korean Adults

The 2010–2012 Korea National Health and Nutrition Examination Survey (Observational Study)

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Abstract: There are few studies that have used audiometric testing to gauge the demographic characteristics and associated risk factors for hearing loss at the national-level. Here, we investigated the weighted prevalence and associated factors of hearing impairment in 16,040 Korean adult population. Subjects completed audiometric test and laboratory examination as part of the data from The 2010–2012 Korea National Health and Nutrition Examination Survey (KNHANES). In our respective study, the overall weighted ($n = 33,762,584$) prevalence of mild hearing impairment among the Korean adult population was 20.5% (95% clearance [CI], 19.6–21.6), whereas moderate-to-profound hearing impairment was 9.2% (95% CI, 8.6–9.9). The weighted prevalence of mild hearing impairment in younger adults (19–39 years' old) was 4.4% (3.5–5.5), in middle-age adults (40–64 years), it was 21.1% (19.8–22.5), and in older adults ($\geq$65 years' old), it was 69.7% (67.8–71.6). Logistic regression analyses were performed for low/mid frequency or high-frequency mild hearing impairment with age, sex, tobacco use, heavy alcohol use, educational background, occupational noise exposure, obesity, hypertension, diabetes, total serum cholesterol, and estimated glomerular filtration rate (eGFR) $<$60 mL/min/1.73m^2 as covariates. The analyses revealed independent correlations between increased age, tobacco use, education, hypertension, and eGFR $<$60 mL/min/1.73m^2, and low/mid frequency and high frequency mild hearing impairment. High frequency mild hearing impairment was positively correlated with male sex, diabetes, and an increase in total serum cholesterol. Taken together, hearing impairment in Korea is highly prevalent with approximately one-fifth of Korean adult reporting mild hearing impairment. This study suggests that individuals with cardiovascular risk factors such as hypertension, diabetes, smoking, increased serum cholesterol, or decreased eGFR are at particular risk of developing hearing impairment. As such, these groups may benefit from hearing loss screening in addition to those groups typically considered to be of elevated risk including geriatrics, those of low socioeconomic status, and those with considerable occupational noise exposure.

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Abbreviations: BMI = body mass index, CI = confidence interval, eGFR = Estimated glomerular filtration rate, FPG = fasting plasma glucose, KNHANES = Korea National Health and Nutrition Examination Survey, LDL-C = low-density lipoprotein cholesterol, OR = odds ratio, TG = triglyceride.

INTRODUCTION

Hearing impairment is one of the most highly prevalent, chronic conditions after hypertension and arthritis.[1] The prevalence of hearing impairment is increasing due to an ever-aging society and the growing use of personal listening devices.[2] The number of individuals with impaired hearing more than doubled from 120 million to 275 million from 1995 to 2004.[3] The World Health Organization (WHO) reported that 328 million adults and approximately one-third of people over 65 suffer from disabling hearing loss globally.[4]

There are many causes of hearing loss including a genetic predisposition, maternal rubella or complications at birth, aging, certain infectious diseases such as meningitis, chronic ear infections, use of ototoxic drugs, or exposure to excessive noise. Presbycusis, which is sensorineural hearing loss related to aging, is the most common cause of hearing loss, and is characterized by gradual, bilateral, high-frequency hearing loss.[5] The risk of developing hearing impairment is enhanced in the male sex, and in those with less education, or a history of industrial or military service and occupational noise exposure.[6,7]

Hearing loss can limit meaningful communication and social connectivity[8] leading to a lower health-related quality of life and decreased physical and cognitive function.[9,10] In respect to public health, hearing impairment is known to be associated with depression, diabetes, and dementia.[3,11,12]

Despite this concern, there are few studies that have used audiometric testing to gauge the demographic characteristics and associated risk factors for hearing loss at the national-level.[2,12–14]

As such, we investigated the prevalence and associated risk factors of hearing impairment in the Korean adult population using the data from The 2011–2012 Korea National Health and Nutrition Examination Survey (KNHANES).

METHODS

Study Population and Data Collection

This study is based on data from the 2010–2012 KNHANES, a cross-sectional and nationally representative survey conducted by the Korean Center for Disease Control for Health Statistics. The KNHANES has been conducted periodically since 1998 to assess the health and nutritional status of the civilian, noninstitutionalized population of Korea. Participants were selected using proportional allocation-systemic sampling with multistage stratification. A standardized interview was conducted in the homes of the participants to collect information on demographic variables, family history, medical history, medications used, and a variety of other health-related variables. The Health Interview included an established questionnaire to determine the demographic and socioeconomic characteristics of the subjects including age, education level, occupation, income, marital status, smoking habit, alcohol consumption, exercise, previous and current diseases, and family disease history.

Subjects were asked whether they exercise with an intensity that leaves them sweating or with a slight difficulty in breathing. Subjects who exercised regularly and at a moderate intensity were asked about the frequency at which they exercised per week and the length of time per exercise session. Regular exercise was defined as exercising ≥ 5 times per week. Alcohol consumption was assessed by questioning the subjects about their drinking behavior during the month before the interview. Heavy alcohol use was categorized as drinking ≥ 4 times per week during the month before the interview. Hypertension was defined as systolic blood pressure ≥ 140 mmHg, diastolic blood pressure ≥ 90 mmHg, or use of antihypertensive medications irrespective of blood pressure. Diabetes was defined by fasting plasma glucose (FPG) ≥ 7.0 mmol/L, current anti-diabetes medication, or a previous diagnosis of diabetes by a physician. Obesity was defined as body mass index (BMI) ≥ 25 kg/m^2 according to the Asia-Pacific obesity classification.[15]

Height and weight were obtained using standardized techniques and equipment. Height was measured to the nearest 0.1 cm using a portable stadiometer (Seriter, Bismarck, ND, USA). Weight was measured to the nearest 0.1 kg using a Giant-150N calibrated balance-beam scale (Hana, Seoul, Korea). BMI was calculated by dividing weight by the square of their height (kg/m^2). Systolic and diastolic blood pressure was measured by standard methods using a sphygmomanometer while the patient was seated. Three measurements were recorded for all subjects at 5-min intervals, and the average of the second and third measurements was used in the analysis.

Audiometric Measure

In the 2011–2012 KNHANES, the audiometric examination was administered to adults, aged 19 years or older (n = 16,799). Air-conduction pure-tone thresholds were obtained in a soundproof booth using an automatic audiometer (GSI SA-203; Entomed Diagnostics AB, Lena Nodin, Sweden). Trained otolaryngologists collected data independently for each ear at 6 frequencies: 0.5, 1.0, 2.0, 3.0, 4.0, and 6.0 kHz. All audiometric testing was performed under the supervision of an otolaryngologist. To obtain reliable results from the survey, the Epidemiologic Survey Committee of the Korean Society of Otorhinolaryngology-Head and neck surgery carried out the quality control of the survey, which was conducted by periodic education of participating otolaryngologists.

We determined hearing impairment for 2 categories of frequency (low/mid, high) and severity (mild, moderate-to-profound). To produce low/mid frequency pure tone means, we averaged pure tone thresholds measured at 0.5, 1.0, and 2.0 kHz for each ear. To produce high-frequency pure tone means, we averaged high-frequency pure tone thresholds measured at 3.0, 4.0, and 6.0 kHz for each ear.

Mild-hearing impairment was defined as an unaided pure-tone hearing threshold level for the superior ear of 26 to 40 decibels (Db), and average hearing threshold levels (HLs) for the frequencies of 0.5, 1.0, 2.0, 3.0, 4.0, and 6.0 kHz. Moderate-to-profound hearing impairment was defined as unaided pure-tone hearing threshold level for the superior ear of 40 Db or greater, and HLs for the frequencies of 0.5, 1.0, 2.0, 3.0, 4.0, and 6.0 kHz.

Laboratory Methods

Blood samples were collected in the morning after fasting for at least 8 h. Total cholesterol, FPG, triglyceride (TG), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol, and serum creatinine levels were measured by Hitachi Automatic Analyzer 7600 (Hitachi, Tokyo, Japan). Estimated glomerular filtration rate (eGFR) was calculated using the abbreviated equation from the Modification of Diet in Renal Disease study: eGFR (mL/min/1.73 m^2) = $175 \times (S_{Cr}/88.4$, μmol/l)$^{-1.154} \times$ Age$^{-0.203} \times 0.742$ (if female).[16] HbA1c was measured using a high-performance liquid chromatography method (HLC-723G7, Tosoh, Tokyo, Japan). Detailed methods for comparing and validating the reliability of each survey are described elsewhere.[17]

Ethics Statement

This study was approved by the institutional review board of Ilsan Paik Hospital, Republic of Korea (IB-1410–043). After approval of the study proposal, the KNHANES dataset was made available at the request of the investigator. Because the dataset did not include any personal information and participants' consent had already been given for the KNHANES, our study was exempted from participant consent.

Statistical Analyses

The KNHANES participants were not randomly sampled. The survey was designed using a complex, stratified, multistage probability-sampling model; thus, individual participants were not equally representative of the Korean population. To obtain representative prevalence rates from the dataset, it was necessary to consider the power of each participant (sample weight) as representative of the Korean population. Following approval from the Korea Centers for Disease Control and Prevention, we received a survey dataset that included information regarding the survey location, strata by age, sex, and various other factors, and the sample weight for each participant. The survey sample weights, which were calculated by taking into account the sampling rate, response rate, and age/sex proportions of the reference population (2005 Korean National Census Registry), were used in all of the analyses to provide representative estimates of the noninstitutionalized Korean civilian population.

Statistical analyses were performed using SPSS software (ver. 21.0 for Windows; SPSS, Chicago, IL, USA). To compare the weighted prevalence of hearing impairment among groups according to age and sex, the chi-square test was performed. We

compared age- and sex-adjusted clinical characteristics by the presence of hearing impairment using an analysis of covariance (ANCOVA). A logistic regression analysis was used to evaluate the odds ratios for hearing impairment as covariates with age, sex, tobacco use, heavy alcohol use, education level, occupational noise exposure, obesity, hypertension, diabetes, total serum cholesterol, and eGFR <60 mL/min/1.73 m^2. All of the tests were 2-sided, and *P* values <0.05 were considered statistical significance.

RESULTS

Demographics and Clinical Characteristics of the Study Population

The weighted demographics and clinical characteristics of study population are presented in Table 1.

Among 19,599 adults (≥19 years) who participated in the 2010–2012 KNHANES, a total of 16,040 subjects completed audiometric test and laboratory examination and were included in this analysis. The average age of participants was 44.9 years, and the percentage of women was 49.8 %. The prevalence of hypertension was 26.5 %, and 8.4 % of participants were diabetic. Occupational noise exposure and current tobacco use were reported in 13.5% and 26.4 % of the participants, respectively.

Prevalence of Hearing Impairment in the Korean Population by Age and Sex

Overall, the weighted prevalence of mild and moderate-to-profound hearing impairment among the Korean population was 20.5% (19.6–21.6) (n = 6,934,125/33,762,584) and 9.2% (8.6–9.9) (n = 3,106,598/33,762,584), respectively. The prevalence of mild and moderate-to-profound hearing impairment increased significantly with age. Among adults older than 65 years, the weighted prevalence of mild and moderate-to-profound hearing impairment was 69.7% (67.8–71.6)

TABLE 1. Weighted Clinical Characteristics of Study Population (Unweighted n = 16,040; Weighted, n = 33,762,584)

	Mean (95% CI)
Age, years	44.9 (44.4–45.4)
Women (%)	49.8 (49.0–50.6)
Tobacco use (%)	26.4 (25.5–27.4)
Heavy alcohol use (%)	7.4 (6.9–8.0)
Occupational noise exposure (%)	13.5 (12.6–14.4)
College graduation (%)	32.4 (31.0–33.8)
Body mass index, kg/m^2	23.7 (23.6–23.8)
Obesity (%)	32.0 (31.1–33.0)
Systolic blood pressure, mmHg	118.1 (117.6–118.5)
Diastolic blood pressure, mmHg	76.5 (76.2–76.8)
Hypertension (%)	26.5 (25.5–27.6)
Serum total cholesterol, mg/dL	188.0 (187.1–188.8)
Serum triglyceride, mg/dL	133.4 (130.9–135.9)
Fasting plasma glucose, mg/dL	96.7 (96.2–97.1)
Diabetes (%)	8.4 (7.9–9.0)
eGFR <60 mL/min/1.73m^2 (%)	2.7 (2.4–3.0)

Occupational noise exposure: a history of loud noise at work that required speaking in a loud voice to be heard longer than three months. CI = confidence interval, eGFR = estimated glomerular filtration rate.

(n = 3,008,498/4,313,675) and 36.8 % (34.7–39) (n = 1,587, 634/4,313,675), respectively (Table 2).

According to the frequency, the weighted prevalence of low/mid frequency and high frequency mild hearing impairment was 17.1% (16.2–18.0) (n = 5,762,770/33,762,584) and 40.4 % (39.3–41.6) (n = 13,651,924/33,762,584), respectively, and increased with age. With regards to low/mid frequency mild hearing impairment, women were more likely to be affected compared with men (18.3% [17.2–19.5] vs 15.8% [14.8–17.0], *P* < 0.001). In contrast, men demonstrated a higher percentage of high-frequency mild hearing impairments compared with women (47.4% [45.7–49.1] vs 33.4% [32.1–34.8], *P* < 0.001) (Table 3).

Age- and Sex-adjusted Clinical Characteristics by the Presence of Mild Hearing Impairment

Data for age- and sex-adjusted clinical characteristics in the presence of mild-hearing impairment are presented in Table 4.

Subjects with mild hearing impairment demonstrated a greater percentage of tobacco use, hypertension, eGFR <60 mL/min/1.73 m^2, and anti-diabetes drug use compared with subjects without hearing impairment for both low/mid and high frequencies. However, the level of total serum cholesterol, waist circumference, BMI, and percentage of college graduates were lower in adults with mild hearing impairment compared with adults without hearing impairment.

Heavy alcohol drinking (8.7% vs 6.5%, *P* = 0.002), occupational noise exposure (15.8% vs 11.9%, *P* < 0.001), and diabetes (9.9% vs 7.4%, *P* < 0.001) were more common for high-frequency hearing impairment, but not for low/mid frequency impairment. On the contrary, the percentage of obese subjects was lower in low/mid frequency mild impairment (28.2% vs 32.8%, *P* < 0.001), and not in high-frequency impairment.

Factors Associated With Hearing Impairment at Low/Mid and High Frequency

In the logistic regression analysis for mild hearing impairment, age, current smoking, education level, occupational noise exposure, hypertension, and eGFR <60 mL/min/1.73 m^2 were associated with low/mid and high frequency mild hearing impairment (Table 5).

Subject age of 40 to 64 years (low/mid frequency: odds ratio [OR] 3.34, 95% confidence interval [CI] 2.64–4.22, *P* < 0.001; high frequency: OR 6.47, 95% CI 5.57–5.71, *P* < 0.001) and ages >65 years (low/mid frequency: OR 16.58, 95% CI 12.62–21.78, *P* < 0.001; high frequency: OR 57.08, 95% CI 45.26–72.00, *P* < 0.001) were correlated with mild hearing impairment, respectively. Subjects aged 19 to 39 years were used as a control group.

Smoking tobacco (low/mid-frequency: OR 1.19, 95% CI 1.02–1.40, *P* = 0.032; high-frequency: OR 1.28, 95% CI 1.11–1.47, *P* = 0.001) and occupational noise exposure (low/mid-frequency: OR 1.20, 95% CI 1.02–1.41, *P* = 0.024; high-frequency: OR 1.23, 95% CI 1.07–1.43, *P* = 0.005) both increased the likelihood of a hearing impairment.

Educational level was inversely correlated with the prevalence of hearing loss. People who had only completed elementary graduation were about 3 times more likely to have experience hearing loss than those with a college education (low/mid-frequency: OR 0.32, 95% CI 0.26–0.39, *P* < 0.001) and 2 times more likely compared with those with a senior high

TABLE 2. Estimated Prevalence of Hearing Impairment in the Korean Adult Population, by Age and Sex

	Mild Hearing Impairment			Moderate-to-profound hearing impairment		
	Unweighted Prevalence, % (n = 16,040)	Weighted Prevalence, % [95% CI] (n = 33,762,584)	*P*	Unweighted Prevalence, % (n = 16,040)	Weighted Prevalence, % [95% CI] (n = 33 762 584)	*P*
Total % (n)	27.0 (4324)	20.5 [19.6−21.6] (6,934,125)		12.3 (1975)	9.2 [8.6−9.9] (3,106,598)	
Age, year			<0.001*			<0.001*
19−39	4.0 (197/4919)	4.4 [3.5−5.5] (599,198/13,700,980)		1.9 (92/4919)	2.1 [1.6−2.7] (281,457/13,700,980)	
40−64	22.2 (1676/7559)	21.1 [19.8−22.5] (3,326,429/15,747,929)		8.3 (631/7559)	7.9 [7.0−8.8] (1,237,506/15,747,929)	
≥65	68.8 (2451/3562)	69.7 [67.8−71.6] (3,008,498/4,313,675)		35.1 (1252/3562)	36.8 [34.7−39.0] (1,587,634/4,313,675)	
Sex			0.167†			0.070†
Men	30.2 (2084/6911)	21.1 [19.8−22.3] (3,569,448/16,956,372)		14.5 (999/6911)	9.7 [8.8−10.6] (1,640,019/16,956,372)	
Women	24.5 (2240/9129)	20.0 [18.8−21.3] (3,364,676/16,806,212)		10.7 (976/9129)	8.7 [8.0−9.5] (1,466,579/16,806,212)	

Mild hearing impairment: unaided pure-tone hearing threshold level for the better ear of 26 to 40 decibels (Db), average of the hearing threshold levels (HL) for the frequencies of 0.5, 1.0, 2.0, 3.0, 4.0, and 6.0 kHz. Moderate-to-profound hearing impairment: unaided pure-tone hearing threshold level for the better ear of 40 Db or greater, average of the hearing threshold levels (HL) for the frequencies of 0.5, 1.0, 2.0, 3.0, 4.0, and 6.0 kHz. CI = confidence interval.
* *P* for difference of weighted prevalence among 3 age groups.
† *P* for difference of weighted prevalence between each sex.

TABLE 3. Estimated Prevalence of Mild Hearing Impairment (Low/Mid Frequency or High Frequency) in the Korean Adult Population, by Age and Sex

	Low/Mid Mild Hearing Impairment			High Mild Hearing Impairment		
	Unweighted prevalence, % (n = 16,040)	Weighted prevalence, % [95% CI] (n = 33,762,584)	*P*	Unweighted prevalence (n = 16,040) %	Weighted prevalence, % [95% CI] (n = 33,762,584)	*P*
Total % (n)	22.7 (3638)	17.1 [16.2−18.0] (5,762,770)		48.3 (7751)	40.4 [39.3−41.6] (13,651,924)	
Age, year			<0.001*			<0.001*
19−39	3.6 (177/4919)	3.9 [3.1−5.0] (534,708/13,700,980)		10.3 (509/4919)	11.1 [9.9−12.5] (1,525,307/13,700,980)	
40−64	17.7 (1388/7559)	16.5 [15.4−17.7] (2,600,519/15,747,929)		51.8 (3917/7559)	51.4 [50.0−52.8] (8,091,722/15,747,929)	
≥65	59.6 (2123/3562)	60.9 [58.9−62.9] (2,627,543/4,313,675)		93.3 (3325/3562)	93.5 [92.5−94.4] (4,034,894/4,313,675)	
Sex			<0.001†			<0.001†
Men	23.2 (1605/6911)	15.8 [14.8−17.0] (2,686,768/16,956,372)		52.2 (4049/6911)	47.4 [45.7−49.1] (8,032,252/16,956,372)	
Women	22.3 (2033/9129)	18.3 [17.2−19.5] (3,076,002/16,806,212)		47.8 (3702/9129)	33.4 [32.1−34.8] (5,619,672/16,806,212)	

Low/mid frequency mild hearing impairment: pure tone average >25 decibels hearing level measured at 0.5, 1.0, and 2.0 kHz for each individual and ear. High-frequency mild hearing impairment: pure tone average >25 decibels hearing level measured at 3.0, 4.0, and 6.0 kHz for each individual and ear. CI = confidence interval.
* *P* for difference of weighted prevalence among 3 age groups.
† *P* for difference of weighted prevalence between each sex.

TABLE 4. Age- and Sex-adjusted Clinical Characteristics by the Presence of Mild Hearing Impairment

	Low/Mid-frequency Mild Impairment			High-frequency Mild Impairment		
	Normal (Weighted n = 27,998,814)	**Impaired (Weighted n = 5,762,770)**	**P**	**Normal (Weighted n = 2,0110,660)**	**Impaired (Weighted n = 13,651,924)**	**P**
Age, years	41.6 ± 0.2	60.9 ± 0.5	<0.001	37.2 ± 0.	56.3 ± 0.3	<0.001
Women (%)	49.0 ± 0.5	53.0 ± 1.0	<0.001	56.0 ± 0.7	41.0 ± 0.7	<0.001
Current smoking (%)	25.9 ± 0.5	29.0 ± 1.1	0.007	24.3 ± 0.6	29.5 ± 0.8	<0.001
Heavy alcohol use (%)	7.5 ± 0.3	7.1 ± 0.7	0.589	6.5 ± 0.4	8.7 ± 0.5	0.002
College graduation (%)	33.8 ± 0.7	25.3 ± 1.1	<0.001	37.2 ± 0.9	25.3 ± 1.0	<0.001
Occupational noise exposure (%)	13.2 ± 0.5	15.0 ± 0.9	0.071	11.9 ± 0.6	15.8 ± 0.7	<0.001
Body mass index (kg/m^2)	23.8 ± 0.1	23.4 ± 0.1	<0.001	23.8 ± 0.1	23.3 ± 0.1	<0.001
Waist circumference (cm)	81.2 ± 0.1	80.5 ± 0.3	0.007	81.3 ± 0.1	80.5 ± 0.3	0.005
Obesity (%)	32.8 ± 0.6	28.2 ± 1.1	<0.001	31.8 ± 0.7	32.4 ± 0.9	0.662
Systolic blood pressure, mmHg	118.0 ± 0.2	118.4 ± 0.4	0.393	118.0 ± 0.2	118.4 ± 0.4	0.265
Diastolic blood pressure, mmHg	76.9 ± 0.1	74.9 ± 0.3	<0.001	77.0 ± 0.1	74.9 ± 0.3	<0.001
Anti-hypertensive drug (%)	13.5 ± 0.4	18.2 ± 0.9	<0.001	13.0 ± 0.4	16.2 ± 0.6	<0.001
Hypertension (%)	26.0 ± 0.5	29.3 ± 1.1	0.011	24.9 ± 0.6	29.0 ± 0.8	<0.001
Total serum cholesterol, mg/dL	188.8 ± 0.4	183.8 ± 0.9	<0.001	189.0 ± 0.4	184.0 ± 0.9	<0.001
Serum triglyceride, mg/dL	134.3 ± 1.3	129.0 ± 3.2	0.115	134.6 ± 1.4	128.8 ± 2.8	0.071
Anti-lipid drug	4.6 ± 0.2	4.2 ± 0.6	0.587	4.6 ± 0.3	4.4 ± 0.4	0.757
Fasting plasma glucose, mg/dL	96.9 ± 0.2	95.6 ± 0.6	0.046	96.9 ± 0.2	95.7 ± 0.5	0.051
Anti-diabetes drug (%)	4.9 ± 0.2	6.5 ± 0.7	0.027	4.3 ± 0.2	6.4 ± 0.4	<0.001
Diabetes (%)	8.2 ± 0.3	9.4 ± 0.8	0.167	7.4 ± 0.3	9.9 ± 0.5	<0.001
eGFR <60 mL/min/1.73m^2 (%)	2.1 ± 0.1	5.5 ± 0.5	<0.001	2.1 ± 0.1	4.8 ± 0.5	<0.001

eGFR = estimated glomerular filtration rate.

school graduation (low/mid-frequency: OR 0.46, 95% CI 0.40–0.54, P < 0.001).

Hypertension (low/mid frequency: OR 1.24, 95% CI 1.10–1.42, P = 0.001; high-frequency: OR 1.29, 95%CI 1.16–1.45, P < 0.001) and eGFR <60 mL/min/1.73 m^2 (low/mid frequency: OR 1.83, 95% CI 1.42–2.36, P < 0.001; high-frequency: OR 2.04, 95% CI 1.43–2.92, P < 0.001) also increased the risk of hearing impairment. Being male and having diabetes also increased the risk of developing a hearing impairment at high-frequency hearing impairment, but not at low/mid frequencies.

We obtained similar results for moderate-to-profound hearing impairment. Age, level of education, obesity, hypertension, and eGFR <60 mL/min/1.73 m^2 were associated with low/mid and high-frequency hearing impairment. Being male, occupational noise exposure, and diabetes each increased the likelihood of having a high frequency hearing impairment. In contrast with mild hearing impairments, smoking did not increase the risk of moderate-to-profound hearing impairment.

DISCUSSION

Using data from the KNHANES 2010–2012 study, we demonstrate in our present study that the weighted prevalence of hearing impairments in the Korean population aged 19 years or older is 20.5%. This prevalence is similar to that previously reported for national estimates derived from adults of all ages, despite some potential differences in the method used to assess hearing loss. The prevalence of hearing impairment in a representative adult population in southern Taiwan was previously reported to be 21.4%.[18] In Norway,[19] the United Kingdom,[20] and Australia,[21] the proportion of the population with hearing impairment is reported to be 27%, 35%, and 22%, respectively.

Based on data from US NHANES (1999–2004) study, the prevalence of hearing impairment within adult US Population was 16.1%, which was lower than that might have been expected.[14] However, data from a recent US NHANES (2005–2010) study demonstrated an estimated prevalence of self-reported hearing impairment of 21.7%.[12]

Among adults older than 65 years, the weighted prevalence of hearing impairment increases to 69.7 %. In previous studies that reported the prevalence of hearing impairment in older adults, values ranged from 30% for people aged 65 to 74 years (US NHANES conducted in the 1970s)[22] to 49% for adults aged 60 to 69 years (US NHANES 1999–2004).[2] According to the most recent study data (US NHANES 2005–2006), the prevalence of hearing loss for adults aged 70 years and older is 63%.[23]

In the present study, we uncovered a frequency-specific difference between men and women in weighted prevalence of hearing impairment. At high frequency, mild hearing impairment was more common in men, which corresponds with previous results.[1,2,24] In contrast, women were more likely to be affected by low/mid-frequency hearing impairment than men. It is likely that men have a tendency to experience more occupational noise exposure, which typically affects hearing impairment at a higher frequency. However, being male was still independently associated with high-frequency mild hearing impairment, even after logistic regression. Therefore, further evaluation will be needed to understand why men are more vulnerable to mild hearing impairment at high frequency.

We also explored the effects of lifestyle parameters, including smoking, heavy alcohol use, and occupational noise exposure, education level, cardiovascular risks such as hypertension, total serum cholesterol, serum TG, diabetes, and decreased eGFR as well as age and sex on hearing impairment.

TABLE 5. Logistic Regression Analyses for Hearing Impairment

	Low/Mid-frequency Mild Impairment		High-frequency Mild Impairment		Low/Mid-frequency Moderate-to-profound Impairment		High-frequency Moderate-to-profound Impairment	
	Odds ratio (95% CI)	*P*	Odds ratio (95% CI)	*P*	Odds ratio (95% CI)	*P*	Odds ratio (95% CI)	*P*
Age, years								
19–39	Reference		Reference		Reference		Reference	
40–65	3.34 (2.64–4.22)	<0.001	6.47 (5.58–7.51)	<0.001	2.42 (1.78–3.29)	<0.001	5.93 (4.90–7.18)	<0.001
≥65	16.58 (12.62–21.78)	<0.001	57.08 (45.26–72.00)	<0.001	9.58 (6.72–13.63)	<0.001	35.41 (8.09–44.65)	<0.001
Men	1.02 (0.89–1.17)	0.772	2.93 (2.56–3.36)	0.001	1.13 (0.94–1.37)	0.205	3.49 (3.04–4.00)	<0.001
Current smoking	1.19 (1.02–1.40)	0.032	1.28 (1.11–1.47)	0.001	1.13 (0.92–1.40)	0.251	1.06 (0.91–1.23)	0.476
Heavy alcohol use	1.01 (0.83–1.22)	0.962	1.17 (0.96–1.44)	0.125	0.99 (0.77–1.27)	0.938	1.10 (0.92–1.33)	0.280
Education								
Elementary graduation	Reference		Reference		Reference		Reference	
Junior high school graduation	0.67 (0.57–0.79)	<0.001	0.65 (0.54–0.79)	0.001	0.74 (0.60–0.90)	0.003	0.64 (0.54–0.97)	0.003
Senior high school graduation	0.46 (0.40–0.54)	<0.001	0.35 (0.30–0.41)	<0.001	0.51 (0.41–0.63)	<0.001	0.48 (0.41–0.56)	<0.001
College graduation	0.32 (0.26–0.39)	<0.001	0.26 (0.22–0.31)	<0.001	0.36 (0.28–0.47)	<0.001	0.32 (0.26–0.38)	<0.001
Occupational noise exposure	1.20 (1.02–1.41)	0.024	1.23 (1.07–1.43)	0.005	1.16 (0.94–1.43)	0.159	1.35 (1.16–1.56)	<0.001
Obesity	0.83 (0.74–0.93)	0.001	0.95 (0.86–1.06)	0.386	0.80 (0.69–0.93)	0.004	0.86 (0.77–0.96)	0.008
Hypertension	1.24 (1.10–1.42)	0.001	1.29 (1.16–1.45)	<0.001	1.19 (1.02–1.39)	0.027	1.20 (1.07–1.35)	0.002
Diabetes	1.14 (0.97–1.35)	0.118	1.42 (1.20–1.69)	<0.001	1.13 (0.94–1.37)	0.218	1.24 (1.05–1.45)	0.009
Total serum cholesterol (20-mg/dL increase)	1.02 (0.99–1.04)	0.296	1.03 (1.00–1.06)	0.037	1.02 (0.98–1.06)	0.317	1.03 (1.00–1.06)	0.069
eGFR <60 mL/min/1.73m²	1.83 (1.42–2.36)	<0.001	2.04 (1.43–2.92)	<0.001	1.64 (1.30–2.07)	<0.001	1.64 (1.29–2.09)	<0.001

CI = confidence interval, eGFR = estimated glomerular filtration rate.

Our data indicate that current smokers are significantly more likely to have hearing impairment compared with non-smokers. Several studies have reported an association between smoking and hearing loss.[24–26] A meta-analysis study showed that the overall risk ratios were 1.33 (95% CI, 1.24–1.44) for 5 cross-sectional studies, 1.97 (95% CI, 1.44–2.70) for 4 cohort studies, and 2.89 (95% CI, 2.26–3.70) for 1 case-control study.[27] The mechanism responsible for the effect of smoking on hearing loss is unclear; however, some studies have suggested that direct ototoxic effects of nicotine or reactive oxygen species could induce necrotic and apoptotic hair cell death.[28,29,30] Indeed, recent studies have reported that antioxidant treatment reduced cochlear damage and hearing loss.[31,32]

Occupational noise exposure is known to contribute up to 37% of all adult causes of hearing loss, and remains a significant contributor to employment-related morbidity internationally.[33] Professions associated with an increase in noise exposure include mining, the armed forces, manufacturing, construction work, farming, piloting, engineering, and working in night club.[33] Our analysis showed that occupational noise exposure was significantly associated with mild hearing impairment across the frequency spectrum. However, in the case of moderate-to-profound hearing impairment, occupational noise exposure increased the likelihood of having an impairment in the high frequency range only. Ahmed et al[34] suggested that noise might initially induce damage at frequencies >8 kHz and hence high frequency audiometry may be useful as an early indicator of hearing loss.

Although a person with a lower level of education (eg, elementary graduation) might be more likely to work in a poor-quality environment with more noise exposure, such as in the laboring or manufacturing fields, a reverse association between the education level and hearing loss was observed across the frequency spectrum following logistic regression analysis. People with a higher level of education may have enhanced access to health care or may be better nourished or resilient to the biological effects of stress and infection.[35,36]

We also identified diabetes as a factor that increases the risk of high-frequency hearing impairment. Recent meta-analysis showed that overall pooled OR of hearing impairment for diabetic participants was 2.15 (1.72–2.68) compared with nondiabetic participants.[3] Another meta-analysis identified type 2 diabetic patients as experiencing a significantly greater incidence of mild degree of hearing loss compared with controls.[37] Mean pure tone audiometry thresholds were greater in diabetics for all frequencies, but were more clinically relevant at 6000 and 8000 Hz, or high frequency, which is analogous to our study. Cochlear microangiopathy, degeneration of the stria vascularis, and loss of cochlear outer hair cells have been suggested to cause hearing loss in patients with type 2 diabetes mellitus.[38]

There have been a few studies showing a correlation between cardiovascular risk factors, including hypertension, hypercholesterolemia, and hypertriglycemia, and an increased risk of developing hearing impairment. These studies reported that hypercholesterolemia was associated with age-related hearing-loss, possibly by a mechanism involving atherosclerosis.[39] In contrast, another study demonstrated that raised total fasting cholesterol was associated with significantly better hearing threshold levels.[40] Chang et al[41] found that individuals with hypertriglycemia are at a greater risk for noise-induced hearing loss. A large-scale study to investigate the relationship between hearing loss and cardiovascular risk factors was performed by Gates et al[42] In their study, hypertension and systolic blood pressure were linked to hearing thresholds in both men and women. High-density lipoprotein levels were inversely related to low-frequency hearing thresholds in women only. No relationship was observed between hearing impairment and total cholesterol, LDL-C, or TG levels. In this study, hypertension was associated with low/mid and high-frequency mild hearing impairment. However, neither hypercholesterolemia nor hypertriglycemia had any significant effect on hearing impairment.

Decreased renal function was also associated with low/mid and high-frequency hearing impairment in this study. Indeed, a few studies have observed a high incidence of hearing loss (up to 78%) among patients with chronic renal failure.[43,44] The cochlea and kidney have similar physiological mechanisms, namely, the active transport of fluid and electrolytes by the stria vascularis and glomerulus, respectively.[45] Several etiological factors seem to have cumulative effects on the deterioration of hearing in renal failure, including electrolyte disturbances, proteinuria, and hypertension, even after exclusion of known risk factors, such as noise exposure, ototoxic drugs, and head injuries.[46]

The major strength of our study is the large, nationally representative sample of adult Koreans analyzed. To the best of our knowledge, there are few other studies describing a national-level assessment of the demographic characteristics and associated risk factors for hearing loss using audiometric testing. Nevertheless, our study had some limitations. Although we adjusted for many confounding factors, residual or hidden confounding variables cannot be excluded, similar to other cross-sectional studies. We also cannot draw an inference as to causality due to the cross-sectional design of the study.

In conclusion, hearing impairment in Korea is extremely prevalent, and about one-fifth of Korean adults experience mild hearing impairment. This study suggests that individuals with cardiovascular risk factors, such as smoking, hypertension, diabetes, increased total serum cholesterol, and decreased eGFR are particularly at risk of hearing impairment, and may benefit from hearing loss screening. These risk factors are exacerbated in groups like those of advanced age, low socioeconomic status, and/or occupational noise exposure. An improved understanding of the etiologic risk factors related to hearing impairment can result in significant public health benefits.

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