CEO Clinical and Experimental Otorhinolaryngology Vol. 10, No. 2: 129-136, June 2017
http://dx.doi.org/10.21053/ceo.2016.00031
pISSN 1976-8710 eISSN 2005-0720

Original Article

Normative Hearing Threshold Levels in Koreans with Normal Tympanic Membranes and Estimated Prevalence of Hearing Loss

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Objectives. We investigated the normative data on the hearing threshold levels of Koreans with normal tympanic membranes and the prevalence of hearing loss (HL) and nonserviceable hearing using the data from the Korea National Health and Nutrition Examination Surveys (KNHANES) during 2010–2012.

Methods. Data obtained from 16,673 participants ≥12-year-of-age with normal tympanic membranes who completed audiometric testing. We defined HL as the pure tone average (PTA) >25 dB hearing level at 500, 1,000, 2,000, and 3,000 Hz and non-serviceable hearing as PTA >40 dB hearing level.

Results. The hearing levels at some frequencies (0.5, 3, and 6 kHz) did not differ in between the 10's and 20's, but the hearing thresholds at all frequencies increased gradually from the 30's. The hearing thresholds were higher in men than in women at high frequencies (3, 4, and 6 kHz) in the 30's and older. The prevalence of HL in either ear was 16.5% (estimates of 5.9 million), from 2.4% in the 10's up to 75.4% in the 70's and older. The prevalence of nonserviceable hearing in either ear was 6.8% (estimates of 2.5 million) and that of bilateral nonserviceable hearing was 2.5% (estimates of 0.9 million).

Conclusion. Hearing loss aggravated from the 30's at all frequencies and men showed poorer hearing levels than women at high frequencies. Hearing loss was a common condition and the prevalence of non-serviceable hearing in either ear, which needs hearing rehabilitation to help social communication, was 6.8%. Normative pure tone thresholds at each frequency can be used as referent values when counseling patients complaining of hearing loss.

Keywords. *Hearing Loss; Normative Data; Pure Tone; Audiometry; Thresholds*

INTRODUCTION

Hearing loss (HL) is well-known to be highly prevalent, and the prevalence is expected to rise significantly with progression of the aging process. Hearing loss can impair meaningful communication and social connectivity and it is significantly related with depression regardless of age and socioeconomic state [1]. Though there have been a few reports about audiologic data and age-related hearing loss in Koreans [2-4], there has been no report on normative audiologic data based on the distribution in Korean population with normal tympanic membranes. Level of hearing may be variable according to the demographic characteristics such as gender, ethnicity, and age [5,6]. Therefore, comparison with a demographically-matched reference group is required to determine whether a person's hearing is normal. This information can alert clinicians or patients to the need for additional diagnostic information in cases where the hearing is out of normal range. Furthermore, the representative estimates of

• Received January 5, 2016
Revised March 16, 2016
Accepted June 17, 2016

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the population with hearing loss may support the proper distribution of public health resources for hearing rehabilitation.

The present study was undertaken to report the national audiologic reference data and the prevalence of age-related hearing loss based on the audiometric testing in Koreans with normal tympanic membranes from the Korea National Health and Nutrition Examination Surveys (KNHANES) during 2010–2012.

MATERIALS AND METHODS

Study population and data collection

The KNHANES started in 1998 to examine the general health and nutrition status of populations in South Korea. The KNH ANES is an ongoing cross-sectional survey of the civilian noninstitutionalized population of South Korea. A field survey team that included an otolaryngologist, an ophthalmologist and nurse examiners for health assessment moved with a mobile examination unit and performed interviews and physical examinations. Participants underwent a basic health assessment and otolaryngologic examination. Close history of otologic symptoms was surveyed and physical examination of the tympanic membrane, and the evaluation of hearing was conducted in participants of appropriate ages. Every year, individuals in about 4,600 households are selected from a panel to represent the population by using the multistage clustered and stratified random sampling method that is based on the National Census Data. The participation rate of selected households in the past several cycles of KNHANES was high, ranging from 76% to 82%. Although individual participants were not equally representative of the Korean population, this survey provides representative estimates of the noninstitutionalized Korean civilian population by using the power of sample weight. A sample weight was assigned to each sample individual through three steps, calculating the base weight which is the inverse of probability for an individual to be selected, adjusting for nonresponse, and poststratification adjustment to match census population control.

The study population was 16,673 participants with normal tympanic membranes over 12-year-of-age who completed audiometric testing during 2010–2012. Any participants with abnormal tympanic membranes (n=3,767), <12 years of age (n=2,008) or insufficient data (n=1,173) were excluded. They represent the 35,882,248 individuals in South Korea ≥12 years of age. Written informed consents were obtained from all the participants prior to the survey and approval for this research was obtained from the Institutional Review Board of the Samsung Medical Center (IRB no. 2013-02-031).

HIGHLIGHTS

- Hearing is aggravated from the 30's at all frequencies.
- The prevalence of non-serviceable hearing in either ear was 6.8% (2.5 million) in Korea.
- Normative hearing thresholds can be used as a reference when counseling on hearing loss.

Otologic examination and audiometric measurement

An ear examination was conducted with a 4-mm 0°-angled rigid endoscope attached to a charge coupled device (CCD) camera for all participants to find tympanic membrane perforation or cholesteatoma, retraction pocket, otitis media with effusion or abnormal external auditory canal.

The pure tone air-conduction threshold was measured in a sound-proof booth using an automatic audiometer (GSI SA-203, Entomed Diagnostics AB, Lena Nodin, Sweden). Six hearing thresholds were measured in each ear by pure tone audiometry using an ascending/descending technique in 5-dB steps at the frequencies of 0.5, 1, 2, 3, 4, and 6 kHz. The order of sound frequency was assigned in a random way. Hearing loss was defined as >25 dB HL in average of air-conduction hearing thresholds at 0.5, 1, 2, and 3 kHz and nonserviceable hearing was defined as >40 dB HL in average of air-conduction hearing thresholds at 0.5, 1, 2, and 3 kHz. The data were divided in seven age groups (12–19; 20–29; 30–39; 40–49; 50–59; 60–69; 70 and older) and thresholds were presented separately for age and gender groups. Bone-conduction thresholds were not measured in this survey.

For normative hearing threshold levels, those from the better ears were presented in centiles at each specific frequency from 250 to 6,000 Hz. The sample was divided into seven age groups (12–19; 20–29; 30–39; 40–49; 50–59; 60–69; 70 and older) and the hearing thresholds were presented separately for gender and age groups. In order for the hearing thresholds to be representative for the population, they were weighted on age and gender according to the participation rate in the study.

Statistical analysis

All statistical analysis was performed taking account of weights from the complex sampling design according to the guideline for analysis of KNHAENS data from Korea Centers for Disease Control and Prevention. The sampling weights were adjusted so that the total sample will represent the population for the 3-year period (2010–2012), and weight for each individual from each year divided by 3 was used in the analysis. The prevalence for hearing loss and 95% confidence interval (CI) were estimated. We analyzed the linear trend of prevalence with age using logistic regression. Two sample *t*-test was used to test the difference of hearing thresholds between gender at each frequency. Tukey's test for multiple comparisons was used to test the difference of hearing thresholds among age groups at each frequency. Bonferroni correction was applied to the *P*-value due to multiple testing or subgroup analysis. *P*-values were two-sided, and $P<0.05$

was considered to be statistically significant. Statistical analysis was executed using SAS ver. 9.3 (SAS Inc., Cary, NC, USA).

RESULTS

The hearing threshold levels by age and gender

The hearing threshold results for each gender and age group are presented in Table 1. The mean thresholds for each frequency as a function of age in men and women are shown in Fig. 1. Overall, the hearing levels at some frequencies (0.5, 3, and 6 kHz) did not differ in between the 10's and 20's, but the hearing thresholds at all frequencies increased gradually from the 30's. In detail, there was no significant difference in the 10's and 20's at 0.5, 3, and 6 kHz and hearing thresholds increased with ages beyond the 20's at those frequencies ($P<0.001$, Tukey's test for multiple comparisons). At other frequencies (1, 2, and 4 kHz), hearing thresholds increased throughout the ages ($P<0.001$, Tukey's test for multiple comparisons). More specifically (Fig. 2), women did not show a significant difference in hearing levels in between the 10's and 20's in all frequencies and hearing thresholds deteriorated with ages beyond the 20's at all frequencies ($P<0.001$). In men, there was no significant difference in hearing levels in between the 10's and 20's in all frequencies except 4 kHz and hearing thresholds increased with ages beyond the 20's at all frequencies ($P<0.001$).

When comparing the hearing levels in men and women, the hearing thresholds were higher in men than in women at high frequencies (3, 4, and 6 kHz) in the 30's and older (Table 2). In the 10's, there was no significant difference of hearing levels between men and women at all frequencies except 6 kHz. In the 20's, there was no significant difference of hearing levels between men and women at all frequencies. In the 30's and older, the hearing levels were higher in men than in women at high frequencies (3, 4, and 6 kHz). Overall, men showed higher hearing levels at high frequencies (3, 4, and 6 kHz) and lower hearing levels at low frequencies (0.5 and 1 kHz) than women ($P<0.001$, by two sample t-test).

The prevalence of hearing loss according to the laterality and severity

Among the 16,673 participants ≥12-year-of-age, the prevalence

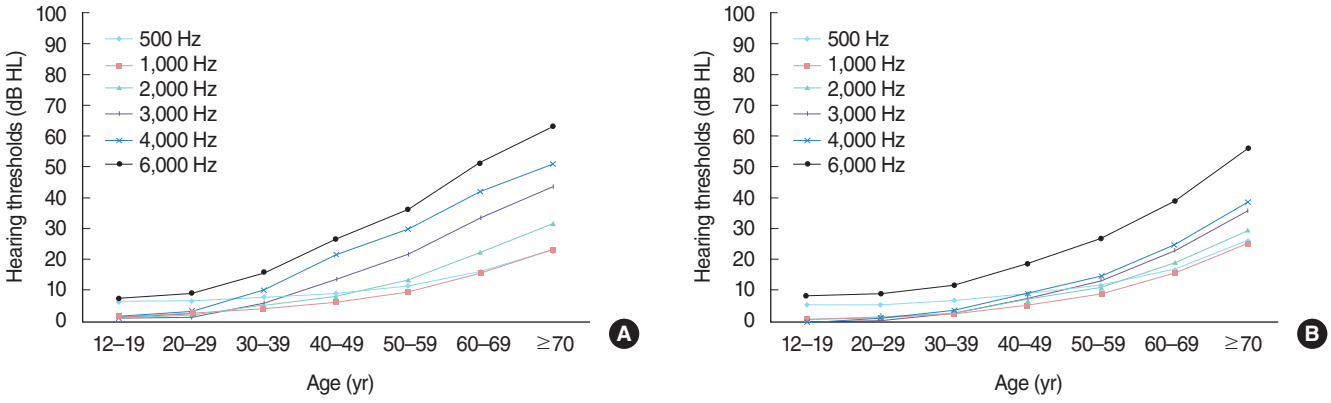

Fig. 1. Mean hearing threshold levels at each frequency in Korean men (A) and women (B).

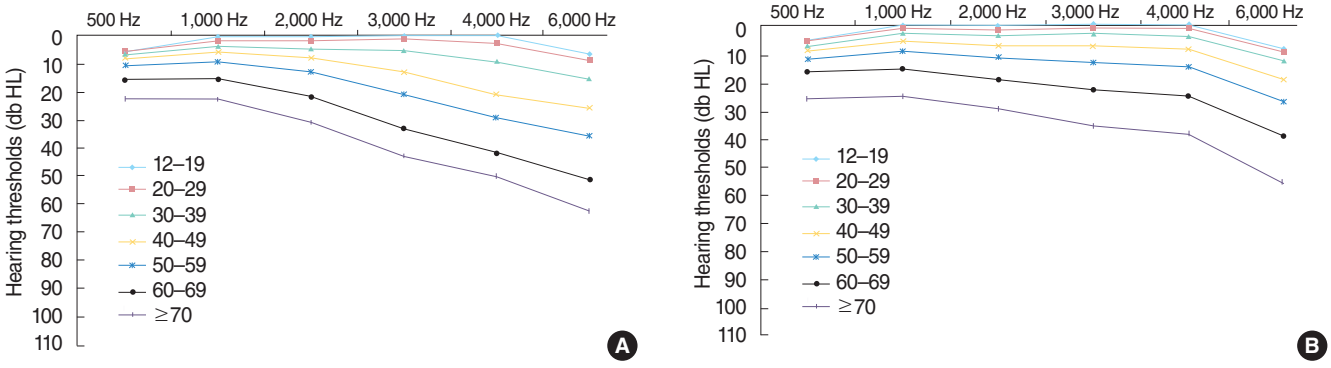

Fig. 2. Changes of mean hearing levels with ages in Korean men (A) and women (B). In men, there was no significant difference in hearing levels in between the 10's and 20's in all frequencies except 4 kHz and hearing thresholds increased with ages beyond the 20's at all frequencies ($P<0.001$). Women showed no significant difference in hearing levels in between the 10's and 20's in all frequencies and hearing thresholds increased with ages beyond the 20's at all frequencies ($P<0.001$).

Table 1. Hearing thresholds (dB HL) of Korean men and women at each frequency with ages

Frequency	Centile	Men (yr)							Women (yr)						
		12–19	20–29	30–39	40–49	50–59	60–69	≥70	12–19	20–29	30–39	40–49	50–59	60–69	≥70
500	5	–7.25	–6.97	–5.35	–5.17	–3.80	–1.14	2.03	–7.00	–6.17	–4.72	–3.87	–3.21	–0.43	5.33
	10	–4.43	–4.30	–3.63	–3.32	–1.17	1.15	5.22	–4.43	–4.17	–3.37	–1.29	0.16	2.01	7.79
	25	–0.53	–0.44	0.41	0.96	2.97	5.56	9.88	–0.77	–0.85	0.40	2.17	3.81	6.84	12.92
	Median	3.27	3.48	4.32	5.39	7.76	11.23	17.45	3.13	3.09	4.30	6.32	8.56	12.59	20.39
	75	7.74	7.76	9.15	10.16	13.15	18.64	26.73	7.40	7.36	8.77	10.25	13.63	19.31	30.86
	90	12.16	11.65	13.99	16.62	19.05	27.86	38.38	11.18	10.98	13.52	14.68	19.55	28.73	43.46
	95	14.60	14.45	17.28	19.56	23.13	34.12	48.09	13.93	13.95	16.45	18.54	24.62	35.89	53.29
1,000	5	–9.61	–9.04	–8.24	–6.87	–4.94	–2.91	0.33	–9.60	–9.49	–8.26	–7.36	–4.71	–2.55	1.61
	10	–8.38	–7.50	–5.82	–4.48	–3.37	0.12	3.17	–8.36	–8.12	–6.15	–4.74	–3.08	0.43	5.22
	25	–4.85	–4.03	–2.98	–1.31	0.82	4.16	9.08	–4.84	–4.56	–3.38	–1.49	0.96	4.43	10.74
	Median	–1.75	–0.47	0.82	2.79	5.62	9.99	18.11	–2.07	–1.47	–0.09	2.69	5.38	11.28	20.53
	75	2.01	3.28	4.65	7.44	11.46	19.20	28.40	1.37	2.40	3.64	7.20	11.55	19.67	32.18
	90	4.77	6.82	9.56	12.47	18.13	28.69	40.15	4.60	5.48	7.83	11.89	18.70	29.58	43.65
	95	8.41	9.32	13.18	15.88	22.82	37.54	47.49	7.60	8.61	10.62	14.97	23.69	37.34	51.78
2,000	5	–10.00	–9.58	–7.79	–6.54	–4.65	–0.12	3.93	–10.00	–9.70	–8.53	–6.70	–4.57	–0.75	5.19
	10	–9.14	–8.18	–4.98	–4.18	–2.35	2.05	8.04	–8.87	–8.36	–6.53	–4.20	–2.35	2.00	8.19
	25	–6.21	–4.53	–2.52	–0.36	2.41	7.58	15.73	–5.46	–4.63	–3.17	–0.43	1.94	7.77	15.93
	Median	–2.32	–1.34	1.54	4.14	8.40	16.03	25.85	–1.91	–0.88	0.88	3.91	7.22	15.14	25.67
	75	2.07	2.94	6.01	9.46	15.80	27.82	39.65	2.17	3.58	4.77	9.27	14.40	24.22	36.98
	90	6.54	7.57	11.14	15.32	24.59	42.65	54.02	5.57	7.84	9.45	14.75	21.83	34.15	48.33
	95	9.38	10.69	14.67	19.75	34.40	53.16	61.10	8.91	9.75	12.95	19.56	27.54	40.04	55.61
3,000	5	–10.00	–10.00	–9.10	–5.37	–2.09	2.82	10.83	–10.00	–10.00	–9.53	–7.60	–3.84	0.51	8.74
	10	–9.06	–8.94	–7.24	–3.38	1.00	6.70	14.67	–9.88	–9.43	–7.87	–4.86	–1.30	4.02	12.17
	25	–6.02	–5.76	–3.36	1.25	6.11	15.01	25.45	–6.98	–6.51	–4.04	–1.13	3.21	10.20	20.54
	Median	–2.23	–2.12	1.30	7.29	14.49	25.88	39.84	–2.63	–2.42	–0.22	3.90	9.27	18.26	31.92
	75	2.03	2.25	7.01	15.74	27.42	46.49	55.25	1.99	2.09	4.15	9.68	16.26	28.58	44.53
	90	6.21	7.17	13.57	29.97	45.38	61.05	67.98	6.08	6.53	8.98	16.18	24.48	40.66	55.52
	95	9.27	10.18	18.76	44.25	57.25	67.83	74.79	8.73	9.31	12.68	19.84	33.10	49.46	62.44
4,000	5	–10.00	–10.00	–7.95	–4.07	1.18	8.05	14.54	–10.00	–10.00	–9.66	–8.17	–4.20	0.21	9.09
	10	–10.00	–9.54	–4.77	0.15	5.45	12.70	21.81	–10.00	–9.54	–7.94	–5.15	–1.20	5.15	13.14
	25	–6.94	–5.25	–0.27	6.41	12.29	22.54	35.79	–7.21	–6.23	–3.79	–0.59	4.50	10.55	22.23
	Median	–2.64	–0.19	4.66	14.20	23.13	37.88	48.87	–2.71	–1.25	0.92	5.03	10.53	20.29	36.01
	75	1.86	5.28	11.65	27.70	40.16	56.31	61.38	2.01	3.38	5.97	11.35	18.27	32.50	48.51
	90	6.60	11.51	21.16	46.93	56.17	67.89	73.01	6.47	7.81	10.36	17.92	28.85	44.57	59.40
	95	9.62	15.49	29.64	59.14	64.17	75.09	79.91	9.31	10.40	13.99	22.69	36.69	51.44	67.09
6,000	5	–8.21	–8.07	–4.26	0.49	6.52	15.49	26.03	–8.06	–6.71	–4.49	0.44	4.62	10.51	20.66
	10	–5.37	–4.93	–1.09	4.95	11.30	21.06	33.44	–4.74	–3.90	–1.53	3.03	8.52	14.49	27.44
	25	–1.47	–0.04	4.35	10.06	19.01	32.99	46.80	0.48	0.68	3.29	8.19	15.34	23.38	40.14
	Median	3.43	4.83	10.75	19.78	29.01	48.69	60.84	5.96	5.81	8.84	15.22	22.27	34.51	54.88
	75	9.48	11.03	18.52	33.27	45.36	63.92	75.36	11.52	12.10	14.76	23.26	31.71	48.42	67.42
	90	14.39	18.97	28.84	51.80	63.52	76.51	87.17	17.68	18.15	21.11	31.71	44.01	61.85	78.66
	95	18.41	24.11	39.08	64.30	73.79	85.62	95.27	21.00	22.08	26.07	37.56	52.38	71.92	85.36

HL, hearing loss.

Table 2. Comparison of the mean hearing thresholds in men and women at different age groups

Age (yr)	500 Hz			1,000 Hz			2,000 Hz			3,000 Hz			4,000 Hz			6,000 Hz		
	Men	Women	*P*-value	Men	Women	*P*-value	Men	Women	*P*-value	Men	Women	*P*-value	Men	Women	*P*-value	Men	Women	*P*-value
12–19	6.1	5.9	1.000	1.2	0.8	1.000	0.9	1.0	1.000	1.0	0.3	1.000	0.6	0.3	1.000	7.0	8.8	0.021
20–29	6.2	5.9	1.000	2.3	1.5	0.806	2.0	2.1	1.000	1.3	0.7	1.000	3.2	1.7	0.055	9.0	9.4	1.000
30–39	7.5	7.3	1.000	4.0	3.1	0.076	4.9	3.8	0.008	5.4	3.0	<0.001	9.8	4.1	<0.001	15.6	12.2	<0.001
40–49	8.6	9.4	0.781	6.1	6.0	1.000	7.9	7.6	1.000	13.4	7.6	<0.001	21.5	8.6	<0.001	26.5	19.2	<0.001
50–59	11.1	12.0	1.000	9.4	9.6	1.000	13.1	11.5	0.214	21.5	13.6	<0.001	29.8	15.1	<0.001	36.1	27.2	<0.001
60–69	15.7	16.9	1.000	15.5	16.0	1.000	22.1	19.7	0.080	33.4	23.2	<0.001	42.0	25.1	<0.001	51.3	39.2	<0.001
≥70	22.5	26.2	0.001	23.0	25.6	0.109	31.4	30.0	1.000	43.5	35.9	<0.001	50.9	38.9	<0.001	63.1	56.2	<0.001
Total	9.4	10.5	<0.001	6.6	7.2	0.007	8.7	8.8	1.000	12.7	9.5	<0.001	18.0	10.7	<0.001	24.4	21.3	<0.001

Table 3. Prevalence (%, 95% CI) of hearing loss and nonserviceable hearing according to the age

Age (yr)	Total				Men				Women			
	No.	Weighted no.	%	95% CI	No.	Weighted no.	%	95% CI	No.	Weighted no.	%	95% CI
Unilateral or bilateral HL: PTA >25 dB HL in either ear												
12–19	48	107,918	2.4	1.36–3.43	27	72,750	3.1	1.27–4.92	21	35,168	1.6	0.79–2.47
20–29	53	180,318	3.0	1.99–4.06	16	63,427	2.0	0.94–3.11	37	116,891	4.1	2.50–5.78
30–39	106	275,835	4.0	2.81–5.18	46	149,167	4.3	2.78–5.73	60	126,669	3.7	2.33–5.13
40–49	242	687,784	9.6	8.12–11.14	127	425,594	11.8	9.46–14.09	115	262,190	7.4	5.80–9.06
50–59	610	1,272,227	22.2	20.19–24.20	308	771,663	27.1	24.06–30.08	302	500,564	17.4	14.97–19.78
60–69	1,164	1,552,201	48.7	46.22–51.13	599	849,617	55.5	51.72–59.27	565	702,584	42.4	39.13–45.62
≥70	1,501	1,858,674	75.4	73.27–77.61	678	752,893	76.8	73.30–80.38	823	1,105,781	74.5	71.52–77.51
Total	3,724	5,934,957	16.5	15.64–17.42	1,801	3,085,111	17.2	16.03–18.31	1,923	2,849,846	15.9	14.83–16.96
Bilateral HL: PTA >25 dB HL in both ears												
12–19	6	12,082	0.3	0.03–0.51	3	7,275	0.3	0–0.69	3	4,808	0.2	0–0.50
20–29	5	18,435	0.3	0.03–0.59	2	6,606	0.2	0–0.51	3	11,829	0.4	0–0.92
30–39	16	44,283	0.6	0.26–1.03	10	32,984	0.9	0.25–1.63	6	11,299	0.3	0.02–0.65
40–49	64	199,512	2.8	2.00–3.59	39	138,454	3.8	2.46–5.20	25	61,058	1.7	0.96–2.50
50–59	243	533,210	9.3	7.98–10.63	137	347,111	12.2	9.96–14.40	106	186,099	6.5	4.98–7.94
60–69	710	940,988	29.5	27.28–31.73	385	545,219	35.6	32.25–38.98	325	395,769	23.9	20.81–26.92
≥70	1,143	1,452,757	59.0	56.42–61.51	520	583,464	59.6	55.36–63.73	623	869,293	58.6	55.25–61.91
Total	2,187	3,201,267	8.9	8.37–9.47	1,096	1,661,113	9.2	8.51–9.98	1,091	1,540,155	8.6	7.89–9.29
Unilateral or bilateral nonserviceable hearing: PTA >40 dB HL in either ear												
12–19	23	45,513	1.0	0.47–1.55	14	32,625	1.4	0.51–2.26	9	12,888	0.6	0.09–1.10
20–29	25	87,841	1.5	0.81–2.14	9	37,481	1.2	0.34–2.05	16	50,360	1.8	0.73–2.84
30–39	47	119,599	1.7	1.01–2.46	21	69,480	2.0	0.99–2.97	26	50,119	1.5	0.65–2.30
40–49	82	213,984	3.0	2.14–3.85	39	120,062	3.3	2.03–4.61	43	93,922	2.7	1.64–3.68
50–59	215	425,532	7.4	6.14–8.71	102	252,929	8.9	6.78–10.97	113	172,603	6.0	4.65–7.33
60–69	449	624,903	19.6	17.48–21.71	256	376,398	24.6	21.20–27.98	193	248,505	15.0	12.51–17.46

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Table 3. Continued

Age (yr)	Total				Men				Women			
	No.	Weighted no.	%	95% CI	No.	Weighted no.	%	95% CI	No.	Weighted no.	%	95% CI
≥70	757	937,237	38.0	35.25–40.83	364	411,263	42.0	37.91–46.04	393	525,974	35.4	31.94–38.95
Total	1,598	2,454,610	6.8	6.29–7.39	805	1,300,238	7.2	6.50–7.97	793	1,154,372	6.4	5.79–7.09
Bilateral nonserviceable hearing: PTA >40 dB HL in both ears												
12–19	3	8,848	0.2	0–0.42	2	6,205	0.3	0–0.64	1	2,643	0.1	0–0.36
20–29	2	6,606	0.1	0–0.27	2	6,606	0.2	0–0.51	0	-	-	-
30–39	5	10,948	0.2	0–0.32	2	5,366	0.2	0–0.37	3	5,582	0.2	0–0.40
40–49	11	35,060	0.5	0.15–0.83	6	23,301	0.6	0.11–1.18	5	11,760	0.3	0–0.69
50–59	40	97,142	1.7	1.05–2.34	20	61,538	2.2	1.03–3.28	20	35,605	1.2	0.60–1.87
60–69	179	238,078	7.5	6.22–8.71	109	154,784	10.1	7.91–12.31	70	83,294	5.0	3.68–6.36
≥70	395	496,986	20.2	17.88–22.47	192	207,093	21.1	18.05–24.22	203	289,893	19.5	16.50–22.57
Total	635	893,669	2.5	2.23–2.75	333	464,893	2.6	2.22–2.96	302	428,776	2.4	2.04–2.74

CI, confidence interval; HL, hearing loss; PTA, pure tone average.

of hearing loss (pure tone average [PTA] >25 dB hearing level) in either ear of participants was 16.5% (estimates of 5.9 million) (Table 3). In the youngest age group (12–19 years), 2.4% exhibited hearing loss, and the prevalence rate increased with age up to 75.4% in oldest group (70 years and older). The prevalence rate showed an age-related increase at all frequencies ($P<0.001$ by logistic regression analysis). The prevalence of bilateral HL was 8.9% (estimates of 3.2 million). In the youngest age group (12–19 years), 0.3% exhibited bilateral HL, and the prevalence rate increased with age up to 59.0% in oldest group (70 years and older).

The prevalence of nonserviceable hearing (PTA >40 dB hearing level) in either ear of participants was 6.8% (estimates of 2.5 million). In the youngest age group (12–19 years), 1.0% exhibited hearing loss of >40 dB, and the prevalence rate increased with age up to 38.0% in oldest group (70 years and older). The prevalence rate showed an age-related increase at all frequencies ($P<0.001$ by logistic regression analysis). The prevalence of bilateral nonserviceable hearing was 2.5% (estimates of 0.9 million). In the youngest age group (12–19 years), 0.2% exhibited bilateral hearing loss of >40 dB, and the prevalence rate increased with age up to 20.2% in oldest group ($P<0.001$ by logistic regression analysis).

DISCUSSION

To our knowledge, there has been no report about normative values of hearing thresholds in Asian populations through a national survey, though there have been several reports from regional survey [7-11]. Table 1 displays the statistical distribution of thresholds of the Korean men and women by age. The hearing threshold values presented in this survey provide the expected values of hearing thresholds for Koreans with normal tympanic membranes. This information may be useful for clinical counseling with younger individuals presenting for audiological assessment.

The hearing thresholds in 10's and 20's (audiological reference population) obtained in this survey are around 0–6 dB HL from 500 Hz to 4,000 Hz. Theoretically, the expected value, according to the international standard, is supposed to be 0 dB HL (ISO 7029). There are several factors related to the testing procedures. The ambient noise in the test area and the use of a 5-dB step size in test signal presentation compared to smaller 2-dB steps as used in other studies may contribute to this discrepancy [12]. However, taking into account the negligible difference (≤1 dB) between the thresholds in this study and 0 dB HL especially at 1, 2, and 3 kHz (Table 1), our audiologic data may represent the reference data base for the distribution of normal Korean population. It was reported that the median hearing threshold levels of any group of 18–20 years olds, are not zero, but on the order of +5 dB for most frequencies of 0.25–8 kHz in audio-

metric surveys [13].

There have been several reports about the prevalence of hearing loss. The present prevalence estimate of 16.5% (based on participants aged 12 years or older) is lower than those (20.3%–26.1%) derived from different countries including United Kingdom, Australia, and United States [7,14-16]. This difference can be explained partially by the fact that we excluded any participants with abnormal tympanic membrane in this study. A recent KHANES study of the same period showed that the prevalence of hearing loss in Korean population was 22.7%, when tympanic membrane abnormalities were included [17]. Similarly, recent work has demonstrated that 20.3% of Americans 12 years and older have hearing loss (NHANES 2001–2008) [16]. Though the prevalence rates from national estimates may be variable according to the differences in age groups and ethnic distributions of the surveyed population, nation-wide epidemiological studies that are conducted by government organizations can provide powerful data for investigating the national prevalence of disease conditions. The representative estimates of the Korean civilian population suffering from hearing loss by using the power of sample weight may facilitate the proper and predictable allocation of public health resources aimed at hearing rehabilitation.

Our data clearly show that the prevalence of hearing loss increased with age. Age-related hearing loss may affect neural fibers, stria vascularis, and inner and outer hair cells causing progressive hearing impairment [18,19]. In the youngest age group (12–18 years), 2.4% exhibited hearing loss in either ear, and the prevalence rate increased with age up to 75.4% in oldest group (70 years and older), which is similar to previous reports from other countries [7,14-16]. An estimate of 3.2 million (a prevalence of 8.9%) had bilateral hearing loss in South Korea and 2.5 million (a prevalence of 6.8%) had nonserviceable hearing. There is a strong relationship between hearing loss in the elderly and psychosocial status, which can lead to social isolation, cognitive decline and the loss of independence [20,21]. The most common audiologic rehabilitation approach to address adult-onset hearing impairment is the provision of hearing aids, which is well-known to improve individual quality of life [22,23]. Due to the increase in life expectancy, hearing rehabilitation should be considered for an ageing population with hearing loss.

There are several limitations to this study. We tried to exclude conductive hearing losses by excluding any participants with abnormal tympanic membrane. As only air-conduction threshold was evaluated and bone-conduction pure tone testing was not performed in this survey, conductive hearing losses could not be entirely excluded. Also, we did not subcategorized hearing losses by specific etiologies. Particularly, the history of exposure to noise was not an exclusion criterion, given that noise is well known to induce hearing loss [24].

In conclusions, hearing loss aggravated from the 30's at all frequencies and men showed higher hearing thresholds than women at high frequencies. Hearing loss was a common condition and the prevalence of nonserviceable hearing in either ear, which needs hearing rehabilitation to help social communication, was 6.8%. Normative pure tone thresholds at each frequency can be used as referent values when counseling patients complaining of hearing loss.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGMENTS

We appreciate Korean Society of Otorhinolaryngology-Head and Neck Surgery and members of the Division of Chronic Disease Surveillance in Korea Centers for Disease Control & Prevention for participating in this survey and the dedicated work they provided.

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