

Association between serum iron levels and low-frequency hearing loss in Korean females

Running title: Iron deficiency and hearing

Inho Jung¹, Seunghyeon Cho², Sunjin Jung¹, JiHwan Kim¹, Won-Ju Park^{1*}

¹Department of Occupational and Environmental Medicine, Chonnam National University Medical School and Chonnam National University Hwasun Hospital, Hwasun, Korea

²Department of Occupational and Environmental Medicine, Chonnam National University Hospital, Gwangju, Korea

*Corresponding authors:

Won-Ju Park

Department of Occupational and Environmental Medicine, Chonnam National University Medical School and Chonnam National University Hwasun Hospital, 322 Seoyang-ro, Hwasun 58128, Korea

E-mail: wonjupark@jnu.ac.kr

Competing interests

Prof. Won-Ju Park has been a member of the editorial board of the Annals of Occupational and Environmental Medicine since 2021. He was not involved in the review process.

Otherwise, no potential conflict of interest relevant to this article was reported.

Acknowledgements

This study was financially supported by Chonnam National University (Grant number: 2024-0443). The purpose was to support the research activities of newly hired professors within Chonnam National University.

Author contributions

Conceptualization: Jung I; Data curation: Jung S; Investigation: Kim J; Methodology: Cho S; Writing - original draft: Jung I, Park WJ; Writing - review & editing: Cho S, Jung S, Kim J, Park WJ.

Ethics statement

This study was conducted through a retrospective review of participants' medical records. All participant data were anonymized and stored in the Chonnam National University Hospital Clinical Data Warehouse. Data were used for research purposes in compliance with the Personal Information Protection Act. Informed consent for the collection and uses of personal information was obtained before the checkup. The protocol was approved in advance by the Institutional Review Board of Chonnam National University Hwasun Hospital (CNUHH-2016-150).

ORCID iDs

Inho Jung <https://orcid.org/0000-0001-9381-5353>

Seunghyeon Cho <https://orcid.org/0000-0001-5314-2078>

Sunjin Jung <https://orcid.org/0000-0001-5297-3435>

Jihwan Kim <https://orcid.org/0009-0006-6950-1235>

Won-Ju Park <https://orcid.org/0000-0002-1081-9840>

Epub ahead of print

Association between serum iron levels and low-frequency hearing loss in Korean females

ABSTRACT

Background: This study investigates the association between serum iron levels and frequency-specific hearing loss in Korean female population, a topic previously unexplored in auditory health research.

Methods: This study enrolled Korean female participants from the general population. Serum iron levels and hearing thresholds at low (1 kHz) and high (4 kHz) frequencies were assessed, adjusting for potential confounders. Participants were stratified into quartiles based on serum iron levels.

Results: The mean age of the study population was 51.1 ± 10.1 years. Among the 2,987 participants, 344 (11.5%) had abnormal low-frequency hearing thresholds, and 719 (24.1%) had abnormal high-frequency thresholds. Multiple linear regression analysis demonstrated a significant negative association between serum iron levels and low-frequency hearing thresholds ($\beta = -0.012$, $p = 0.017$), whereas no significant association was observed with high-frequency thresholds ($\beta = -0.006$, $p = 0.352$). In a stratified analysis using 50 years (the average menopausal age) as a cutoff, no statistically significant association was identified in participants younger than 50 years. However, in those aged 50 years and older, the negative association between serum iron levels and low-frequency hearing thresholds remained statistically significant.

Conclusions: This study is the first to identify an association between serum iron levels and low-frequency hearing loss in females aged 50 years and older, underscoring the potential role of iron in auditory function. These findings highlight the importance of further research in diverse populations to elucidate the underlying mechanisms and broader clinical implications.

Keywords: Anemia; Auditory threshold; Diet; Malnutrition; Menopause

BACKGROUND

Hearing loss is a prevalent condition that can significantly impact quality of life. In a study conducted as part of the Korea National Health and Nutrition Examination Survey, the prevalence of unilateral and bilateral hearing loss was reported as 9.31% and 13.42%, respectively.¹ Hearing impairment has substantial consequences, as it affects speech perception, contributes to communication difficulties, and can lead to social isolation and reduced quality of life.

Iron plays a critical role in oxygen transport and cellular processes essential for maintaining the health of the cochlea and auditory nerve.² Evidence suggests that iron deficiency may impair auditory nerve maturation, highlighting its importance in auditory function.³ Recent studies have reported that iron deficiency anemia (IDA) —a clinical manifestation of low iron status—, are associated with an increased risk of hearing loss. For

example, several case-control and cohort studies have identified significant associations between IDA and various forms of hearing loss, such as sudden sensorineural and mixed hearing loss.⁴⁻⁶ In Korean adolescents, low transferrin saturation was found to be associated with an increased incidence of hearing loss, particularly at high frequencies.⁷

While several studies have examined the relationship between IDA and hearing loss, research specifically investigating differences in hearing impairment across various frequency ranges remain limited. The present study aims to investigate the association between serum iron levels and hearing loss in a Korean female population, with a particular focus on potential differences in hearing loss across frequency ranges.

METHODS

Study participants

This cross-sectional study analyzed a subset of adult female participants who voluntarily underwent medical examinations at a university hospital in Korea between January 2007 and December 2014. Of the 5,046 individuals who completed health assessments, 3,136 underwent serum iron level testing. A total of 149 participants were excluded due to missing audiometric data, occupational noise exposure, or a history of ear disease or head trauma. Consequently, 2,987 participants were included in the final analysis.

Audiometric measurement

Audiometric evaluations were conducted using pure tone audiometry at 1 kHz and 4 kHz after a minimum of 14 hours of noise avoidance. Testing was performed by a technician certified by the Korea Occupational Safety and Health Agency (KOSHA). A Madsen Itera II audiometer (Otometrics, Denmark) equipped with TDH-39P (Telephonics, USA) headphones was utilized, with hearing thresholds recorded between -10 dB and 120 dB. The audiometric device underwent annual calibration in accordance with KOSHA guidelines and successfully met KOSHA's biannual quality control inspections.⁸ The American Speech-Language-Hearing Association (ASHA) recommends a screening threshold of 25 dB as the pass/fail criterion.⁹ In this study, low-frequency hearing loss was defined as a hearing threshold exceeding 25 dB at 1 kHz in the worse ear, and high-frequency hearing loss was defined as a threshold exceeding 25 dB at 4 kHz. The hearing threshold of the worse ear was used for all analyses.

Covariates

Trained occupational and environmental medicine physicians conducted structured interviews to collect medical history and comorbidity data. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m²). Blood pressure was measured in the left arm using a calibrated electronic sphygmomanometer following a minimum of five minutes of rest. Venous blood samples were obtained after a 12-hour fast and analyzed for serum iron, creatinine, total cholesterol, low-density lipoprotein (LDL) cholesterol, and fasting blood glucose using a Hitachi 7600 analyzer (Hitachi, Tokyo, Japan). HbA1c level was measured

using an XE-2100 analyzer (Sysmex Corporation, Kobe, Japan). Hypertension was defined as a prior diagnosis of hypertension, systolic blood pressure ≥ 140 mmHg, or diastolic blood pressure ≥ 90 mmHg. Diabetes mellitus was defined as a prior diagnosis, fasting blood glucose ≥ 126 mg/dL, or HbA1c $\geq 6.5\%$. Dyslipidemia was defined as a prior diagnosis, total cholesterol ≥ 240 mg/dL, or LDL cholesterol ≥ 160 mg/dL.

Statistical analyses

Serum iron levels were categorized into quartiles: Q1 (< 77 $\mu\text{g/dL}$), Q2 ($77\text{--}98$ $\mu\text{g/dL}$), Q3 ($99\text{--}121$ $\mu\text{g/dL}$), and Q4 (≥ 122 $\mu\text{g/dL}$). Group differences in baseline characteristics were assessed using analysis of variance (ANOVA) and Pearson's χ^2 test. Post hoc comparisons were performed using Tukey-Kramer methods following ANOVA. The association between serum iron levels and both low- and high-frequency pure tone thresholds was examined using multiple linear regression analysis. The regression models were adjusted as follows: Model 1 included age; Model 2 included age, and BMI; and Model 3 included age, BMI, hypertension, diabetes mellitus, and dyslipidemia. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 29.0 (IBM Corp., Armonk, NY, USA), with statistical significance set at $p < 0.05$.

Ethics statement

This study was conducted through a retrospective review of participants' medical records. All participant data were anonymized and securely stored in the OOOO University Hospital

Clinical Data Warehouse. Data utilization complied with the Personal Information Protection Act. Informed consent for data collection and use was obtained prior to the medical checkup. The study protocol was approved by the Institutional Review Board of OOOO University Hospital (OOOO-2000-150).

RESULTS

Table 1 summarizes the general characteristics of the study participants stratified by serum iron level quartiles. The mean age of the study population was 51.1 ± 10.1 years, with higher serum iron quartiles associated with younger age ($p < 0.001$). BMI showed a statistically significant difference among the quartiles, with the highest mean BMI observed in the second and third quartiles ($p < 0.001$). Pure tone thresholds in the worse ear demonstrated a significant association with serum iron levels, wherein participants in higher serum iron quartiles exhibited lower pure tone thresholds at both low and high frequencies ($p < 0.001$). The prevalence of hypertension was significantly lower in participants with higher serum iron levels ($p < 0.001$), whereas no significant differences were observed for diabetes mellitus ($p = 0.069$) or dyslipidemia ($p = 0.268$). Regarding hearing impairment, participants with higher serum iron levels exhibited a lower prevalence of abnormal pure tone thresholds at both low and high frequencies ($p = 0.001$) (**Table 1**).

[Table 1 Here]

129

130 Table 2 presents the linear regression coefficients for the association between serum iron
131 levels and pure tone thresholds in the worse ear. In Model 1, adjusted for age, higher serum
132 iron levels were significantly associated with lower pure tone thresholds at low frequencies (β
133 = -0.011, $p = 0.022$), whereas no significant association was observed at high frequencies. In
134 Model 2, which included additional adjustments for BMI, the association between serum iron
135 levels and low-frequency pure tone thresholds remained significant ($\beta = -0.012$, $p = 0.013$),
136 while the association at high frequencies remained non-significant. In Model 3, which was
137 further adjusted for hypertension, diabetes mellitus, and dyslipidemia, the negative
138 association between serum iron levels and low-frequency thresholds persisted ($\beta = -0.012$, p
139 = 0.017), with no significant association at high frequencies. These findings suggest that
140 higher serum iron levels are independently associated with better low-frequency hearing, but
141 not with high-frequency hearing.

142

143 [Table 2 Here]

144

145 Table 3 presents the regression coefficients for the association between serum iron
146 quartiles and pure tone thresholds of the worse ear. In Model 1, adjusted for age, participants
147 in the highest serum iron quartile (Q4) exhibited significantly lower pure tone thresholds at
148 low frequencies compared to those in the lowest quartile (Q1) ($\beta = -1.871$, $p = 0.001$). A
149 similar trend was observed at high frequencies, though the association was marginally
150 significant ($\beta = -1.355$, $p = 0.050$). The p -value for trend across quartiles was significant for

both frequency ranges ($p < 0.001$). In Model 2, which included additional adjustments for BMI, the negative association between serum iron levels and low-frequency thresholds remained significant for Q4 vs. Q1 ($\beta = -1.870$, $p < 0.001$). The association at high frequencies did not reach statistical significance ($\beta = -1.354$, $p = 0.050$), although the p -value for trend remained significant ($p < 0.001$). In Model 3, further adjustments were made for hypertension, diabetes mellitus, and dyslipidemia. The association between higher serum iron levels and lower pure tone thresholds at low frequencies persisted (Q4 vs. Q1: $\beta = -1.835$, $p < 0.001$), whereas the association at high frequencies remained non-significant. Overall, a significant dose-response relationship was observed between serum iron levels and low-frequency hearing thresholds across all models (p for trend < 0.001), suggesting that higher serum iron levels are independently associated with better low-frequency auditory function.

[Table 3 Here]

Table 4 presents the linear regression coefficients for the association between serum iron levels and pure tone thresholds of the worse ear, stratified by age groups. As a sensitivity analysis, participants were categorized into two age groups based on the average menopausal age of 50 years, given that previous reports indicate an average menopausal age of 49.9 years among Korean females.¹⁰ Among participants younger than 50 years, no significant associations were observed between serum iron levels and pure tone thresholds at either low or high frequencies across all models. In contrast, among participants aged 50 years or older, higher serum iron levels were significantly associated with lower pure tone thresholds at low

frequencies across all models. In Model 1, adjusted for age, serum iron levels exhibited a significant negative association with low-frequency thresholds ($\beta = -0.029$, $p = 0.002$). This association remained statistically significant after additional adjustments in Model 2 ($\beta = -0.029$, $p = 0.002$) and Model 3 ($\beta = -0.029$, $p = 0.002$). However, a significant association between serum iron levels and high-frequency thresholds in this age group was observed only in model 2, while no significant results were found in the other models. These findings suggest that the relationship between higher serum iron levels and better low-frequency hearing is significant only among individuals aged 50 years or older, whereas no significant associations were observed in younger participants or at high frequencies.

[Table 4 Here]

DISCUSSION

This study investigated the association between serum iron levels and frequency-specific hearing loss in a Korean female population. A significant correlation was identified between lower serum iron levels and an increased prevalence of low-frequency hearing loss in individuals over 50 years of age, even after adjusting for potential confounders. Notably, no significant relationship was observed between serum iron levels and high-frequency hearing loss. Furthermore, no significant association was detected between serum iron levels and low-frequency hearing loss in individuals under 50 years old.

Several studies have examined the relationship between IDA and hearing loss, proposing various underlying mechanisms. One hypothesis suggests that the cochlea is particularly susceptible to ischemic damage, while another implicates IDA in reactive thrombocytosis.⁵ Additionally, an animal study demonstrated a reduction in cochlear ribbon synapses—essential for the rapid and precise transmission of auditory signals—in rats with induced iron deficiency.¹¹ This finding suggests a potential mechanistic link between iron deficiency and auditory impairment. In postmenopausal females, inadequate dietary intake, chronic illnesses, and gastrointestinal bleeding contribute to an increased susceptibility to iron deficiency.¹² A cohort study reported an elevated risk of hearing loss among females who underwent menopause after the age of 50.¹³ Decreased estrogen levels have been postulated to influence inner ear function and central auditory processing, while aging and chronic diseases may further exacerbate auditory decline.¹³ Nevertheless, the precise mechanism by which postmenopausal females exhibit heightened sensitivity to iron deficiency-related hearing loss remains unclear.

Several previous studies have investigated relationships between IDA and hearing loss using populations defined by clinical or diagnostic criteria for anemia. For example, a case-control study in Taiwan and a large cohort study in the United States both identified statistically significant associations between IDA and various subtypes of hearing loss.^{4,5} Improvement of hearing after IDA treatment has also been observed.^{6,14} Nonetheless, it is important to note that IDA represents only the most severe end of iron deficiency. In the present study, we analyzed participants according to serum iron levels, regardless of IDA diagnosis, thereby capturing a broader range of iron status. This approach allows for assessment of the impact of iron deficiency—even in the absence of overt anemia—on hearing function.

218 This study has several strengths. First, it is the first to examine the relationship between
219 serum iron levels and hearing loss in the Korean female population. By stratifying
220 participants based on the average menopausal age of 50 years, the analysis identified a
221 significant association between serum iron levels and hearing loss in females aged 50 years or
222 older, a relationship that was not observed in those under 50. Second, the use of multiple
223 linear regression analysis, along with adjustments for multiple confounders, enhances the
224 robustness of the findings.

225 However, several limitations should be acknowledged. First, hearing was assessed only at
226 1 kHz and 4 kHz, which may not fully capture the entire range of auditory frequencies.
227 Second, the cross-sectional design precludes the determination of causal relationships
228 between serum iron levels and hearing loss. Third, although individuals with self-reported
229 occupational noise exposure were excluded, the precise levels of occupational and
230 environmental noise exposure were not quantitatively measured. Fourth, menopause status
231 was not directly confirmed; instead, females aged 50 years or older were assumed to be
232 postmenopausal, which introduces potential variability in the classification of menopausal
233 status. Finally, given the study's focus on the Korean female population and the use of data
234 from a single university hospital, the generalizability of the findings to other populations,
235 including males, may be limited.

238 CONCLUSIONS

239 This study demonstrates a significant association between lower serum iron levels and
240 increased low-frequency hearing loss in Korean females aged 50 years and older, even after

adjusting for potential confounders. However, no significant relationship was observed between serum iron levels and high-frequency hearing loss, nor was an association detected for low-frequency hearing loss in individuals younger than 50 years. By examining the relationship between serum iron levels and hearing loss across different frequency ranges, this study addresses a gap in the literature and underscores the distinct patterns observed before and after the average menopausal age of 50 years.

NOTES

Abbreviations

BMI: body mass index; IDA: iron deficiency anemia; Korea Occupational Safety and Health Agency: KOSHA; LDL: low-density lipoprotein.

REFERENCES

1. Jun HJ, Hwang SY, Lee SH, Lee JE, Song JJ, Chae S. The prevalence of hearing loss in South Korea: data from a population-based study. *Laryngoscope* 2015;125(3):690-4.
2. Teh MR, Armitage AE, Drakesmith H. Why cells need iron: a compendium of iron utilisation. *Trends Endocrinol Metab* 2024;35(12):1026-49.
3. Lee DL, Strathmann FG, Gelein R, Walton J, Mayer-Pröschel M. Iron deficiency disrupts axon maturation of the developing auditory nerve. *J Neurosci* 2012;32(14):5010-5.
4. Chung SD, Chen PY, Lin HC, Hung SH. Sudden sensorineural hearing loss associated with iron-deficiency anemia: a population-based study. *JAMA Otolaryngol Head Neck Surg* 2014;140(5):417-22.
5. Schieffer KM, Chuang CH, Connor J, Pawelczyk JA, Sekhar DL. Association of iron deficiency anemia with hearing loss in US adults. *JAMA Otolaryngol Head Neck Surg* 2017;143(4):350-4.
6. Taki M, Hasegawa T, Ninoyu Y, Mohri H, Hirano S. Low-frequency sensorineural hearing loss associated with iron-deficiency anemia. *J Int Adv Otol* 2021;17(5):465-7.
7. Han SY, Kim YH. Microalbuminuria and functional iron deficiency are risk factors for hearing loss in adolescents. *Laryngoscope* 2024;134(7):3329-34.
8. Korea Occupational Safety and Health Agency (KOSHA): Standards for pure-tone audiometric testing KOSHA code H-56-2023.
<https://www.kosha.or.kr/kosha/data/guidanceH.do>. Updated 2023. Accessed March 12, 2025.
9. Guidelines for screening for hearing impairment and middle-ear disorders. Working Group on Acoustic Immittance Measurements and the Committee on Audiologic Evaluation. American Speech-Language-Hearing Association. *ASHA Suppl* 1990;(2):17-

24.

10. Kim, SJ, Park, SS. The relationship between natural menopausal age and prevalence of obesity, hypertension, diabetes, and dyslipidemia [in Korean]. Korean Journal of Public Health Research 2021;47(1): 1-9.
11. Schieffer KM, Connor JR, Pawelczyk JA, Sekhar DL. The relationship between iron deficiency anemia and sensorineural hearing loss in the pediatric and adolescent population. Am J Audiol 2017;26(2):155-62.
12. Pasricha SR, Tye-Dins J, Muckenthaler MU, Swinkels DW. Iron deficiency. Lancet 2021;397(10270):233-48.
13. Curhan SG, Eliassen AH, Eavey RD, Wang M, Lin BM, Curhan GC. Menopause and postmenopausal hormone therapy and risk of hearing loss. Menopause 2017;24(9):1049-56.
14. Grampurohit A, Sandeep S, Ashok P, Shilpa C, Thanzeemunissa. Study of association of sensory neural hearing loss with iron deficiency anaemia. Indian J Otolaryngol Head Neck Surg 2022;74(Suppl 3):3800-5.

Table 1. General characteristics of the participants according to quartiles of serum iron level

Variables	Quartiles of serum iron level (µg/dL)				Total (N = 2,987)	p-value ^a	Post hoc ^b
	Q1 (< 77)	Q2 (77–98)	Q3 (99–121)	Q4 (≥ 122)			
	(n = 751)	(n = 748)	(n = 747)	(n = 741)			
Age (years)	51.1 ± 10.8	52.8 ± 9.8	52.1 ± 9.9	48.6 ± 9.4	51.1 ± 10.1	< 0.001	Q2 > Q1 > Q4, Q3 > Q4
BMI (kg/m ²)	23.2 ± 2.9	23.6 ± 3.0	23.5 ± 3.1	23.0 ± 2.8	23.3 ± 3.0	< 0.001	Q2, Q3 > Q4
Pure tone threshold of the worse ear							
Low-frequency (dB)	17.8 ± 12.6	17.8 ± 11.2	17.6 ± 12.0	15.1 ± 9.0	17.1 ± 11.4	< 0.001	Q1, Q2, Q3 > Q4
High-frequency (dB)	22.5 ± 15.0	23.3 ± 16.0	22.7 ± 15.0	19.5 ± 13.7	22.0 ± 15.0	< 0.001	Q1, Q2, Q3 > Q4
Serum iron level (µg/dL)	54.8 ± 18.3	87.9 ± 6.3	109.4 ± 6.6	149.7 ± 29.2	100.3 ± 38.8	< 0.001	Q4 > Q3 > Q2 > Q1
Creatinine (mg/dL)	0.8 ± 0.1	0.8 ± 0.1	0.8 ± 0.1	0.8 ± 0.1	0.8 ± 0.1	0.491	
Hypertension	156 (20.8)	141 (18.9)	146 (19.5)	88 (11.9)	531 (17.8)	< 0.001	
Diabetes mellitus	76 (10.1)	70 (9.4)	62 (8.3)	48 (6.5)	256 (8.6)	0.069	
Dyslipidemia	139 (18.5)	157 (21.0)	157 (21.0)	132 (17.8)	585 (19.6)	0.268	
Abnormal hearing threshold							
Low-frequency	90 (12.0)	103 (13.8)	90 (12.0)	61 (8.2)	344 (11.5)	0.008	
High-frequency	189 (25.2)	197 (26.3)	196 (26.2)	137 (18.5)	719 (24.1)	0.001	

Values are presented as number (%), arithmetic mean ± standard deviation, or p-value.

BMI: body mass index.

^aComparison using analysis of variance or the Pearson's χ^2 test.

^bComparison using Tukey-Kramer test.

Table 2. Linear regression coefficient between serum iron level and pure tone threshold of worse ear

Variables	Model 1		Model 2		Model 3	
	β	<i>p</i> -value	β	<i>p</i> -value	β	<i>p</i> -value
Pure tone threshold						
Low-frequency (1 kHz)	-0.011	0.022	-0.012	0.013	-0.012	0.017
High-frequency (4 kHz)	-0.005	0.428	-0.007	0.287	-0.006	0.352

Model 1 adjusts for age. Model 2 adjusts for age, and body mass index. Model 3 adjusts for age, body mass index, hypertension, diabetes mellitus, and dyslipidemia.

Table 3. Regression coefficients of the quartiles of serum iron level with pure tone threshold of worse ear

Variables		Low-frequency (1 kHz)		High-frequency (4 kHz)	
		β	<i>p</i> -value	β	<i>p</i> -value
Model 1	Q2 vs Q1	-0.859	0.122	-0.603	0.383
	Q3 vs Q1	-0.914	0.100	-0.961	0.164
	Q4 vs Q1	-1.871	0.001	-1.355	0.050
	<i>p</i> for trend		< 0.001		< 0.001
Model 2	Q2 vs Q1	-0.892	0.109	-0.644	0.351
	Q3 vs Q1	-0.943	0.090	-0.998	0.149
	Q4 vs Q1	-1.870	< 0.001	-1.354	0.050
	<i>p</i> for trend		< 0.001		< 0.001
Model 3	Q2 vs Q1	-0.886	0.111	-0.590	0.394
	Q3 vs Q1	-0.933	0.094	-0.959	0.166
	Q4 vs Q1	-1.835	< 0.001	-1.264	0.068
	<i>p</i> for trend		< 0.001		< 0.001

Model 1 adjusts for age. Model 2 adjusts for age, and body mass index (BMI). Model 3 adjusts for age, BMI, hypertension, diabetes mellitus, and dyslipidemia.

Table 4. Linear regression coefficient between serum iron level and pure tone threshold of worse ear stratified by age groups

Variables	Model 1		Model 2		Model 3	
	β	<i>p</i> -value	β	<i>p</i> value	β	<i>p</i> -value
Age < 50 (n = 1,254)						
Pure tone threshold						
Low-frequency (1 kHz)	-0.001	0.860	0.000	0.960	0.000	0.968
High-frequency (4 kHz)	0.006	0.390	0.007	0.311	0.006	0.331
Age $\geq$ 50 (n = 1,733)						
Pure tone threshold						
Low-frequency (1 kHz)	-0.029	0.002	-0.029	0.002	-0.029	0.002
High-frequency (4 kHz)	-0.022	0.053	-0.022	0.046	-0.021	0.055

Model 1 adjusts for age. Model 2 adjusts for age, and body mass index (BMI). Model 3 adjusts for age, BMI, hypertension, diabetes mellitus, and dyslipidemia.