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Cardiometabolic diseases according to the type and degree of hearing loss in noise-exposed workers

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ABSTRACT

Background: This study aimed to determine the association between cardiometabolic diseases, including metabolic syndrome, hypertension, and diabetes, and the type and degree of hearing loss in noise-exposed workers.
Methods: A total of 237,028 workers underwent air conduction pure tone audiometry in 2015 to assess their health and diagnose cardiometabolic diseases. The study defined metabolic syndrome, hypertension, and diabetes using blood pressure, fasting blood sugar, cholesterol, and triglyceride levels. Mid-frequency hearing loss was defined as ≥ 30 dB at 2,000 Hz, whereas high-frequency hearing loss was ≥ 40 dB at 4,000 Hz. The average air conduction hearing thresholds at these frequencies were used to determine hearing loss degrees.
Results: The odds ratio (OR) of combined exposure to noise and night-shift work in all cardiometabolic diseases was higher than that of noise exposure alone. The risk of cardiometabolic diseases was dose-response, with higher hearing loss causing higher ORs. The ORs of hypertension compared with the normal group were 1.147 (1.098–1.198), 1.196 (1.127–1.270), and 1.212 (1.124–1.306), and those of diabetes were 1.177 (1.119–1.239), 1.234 (1.154–1.319), and 1.346 (1.241–1.459) for mild, moderate, and moderate-severe hearing loss, respectively.
Conclusions: Workers who are exposed to noise tend to demonstrate high risks of hearing loss and cardiometabolic diseases; thus, bio-monitoring of cardiometabolic diseases, as well as auditory observation, is necessary.

Keywords: Cardiometabolic disease; Hearing loss; Noise exposure

BACKGROUND

Noise is a major hazard to Korean workers in workplaces. Based on special health examinations, noise-induced hearing loss is currently the most prevalent among Korean workers who have diseases, and 10%–20% of the examinees of the special health examination on noise are determined to require noise-induced hearing loss observation. Noise-exposed environments have improved in Korea; however, the excess rate of exposure limits remains at approximately 15%, and more than half of the workers are exposed to noise of ≥ 85 dBA.[1] Noise exposure affects the daily lives of 2,539,890 people working in 291,793 workplaces across industries, affecting 15.7% of workplaces and 16.0% of workers.[2] Hearing loss is a

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high-occurrence disease, along with hypertension and diabetes, and tends to increase with aging. Besides ear diseases, the causes of hearing loss include general systemic diseases such as infectious, cardiovascular, kidney, immune-mediated, and endocrine metabolic diseases. Histopathological, physiological, and biochemical changes in the cochlea, auditory nerves, and central nervous system are used to determine the effects of these disorders on hearing.[3]

The risk factors for cardiometabolic diseases, such as hypertension, diabetes, and dyslipidemia, are similar to those for hearing loss. These risk factors include general factors such as male gender, older age, smoking, and occupational noise exposure. Recent studies have revealed a strong association between these diseases and hearing loss.[4] Cardiovascular disorders demonstrate dose-response connections with male gender and advancing age and are related to hearing loss at both low and high frequencies, depending on the specific type of disease.[5] A synergistic effect on hearing impairment may have occurred when chronic diseases, such as hypertension and diabetes, coexist.[6] Hence, due consideration, close monitoring, and prompt intervention in cases of hearing impairment resulting from or affecting the auditory system associated with these cardiovascular conditions.

This study used the data from special health examination of noise-exposed workers to identify the association between cardiometabolic diseases and personal factors, such as sex and age; occupational factors, such as industrial types of workplaces, duration of occupational noise exposure, and business scale; combined exposure to noise and night shifts and hearing loss. Additionally, this study attempted to determine the relationship between cardiometabolic diseases and hearing loss, i.e., hearing loss at specific mid- and high-frequency and the degree of hearing loss.

METHODS

Subjects
This study included 637,842 workers in 28,090 workplaces who underwent a special health examination on noise in 2015. Among these subjects, 489,166 were exposed to noise only, and 148,582 were exposed to noise combined by night-shift work. The night-shift workers perform 8-hour work from 12 PM to 5 AM the next day ≥ 4 times a month or work from 10 PM to 6 AM the next day for an average of 60 hours per month. The final analysis selected 237,028 workers, who underwent clinical test to diagnose metabolic syndrome, hypertension, diabetes, and dyslipidemia as cardiometabolic diseases, among the noise-exposed workers who underwent air conduction audiometry at 2,000 Hz, 3,000 Hz, and 4,000 Hz as the primary special health examination on noise.

Methods
Based on the data of the primary special health examination on noise, ≥ 30 dB at 2,000 Hz was defined as mid-frequency hearing loss and ≥ 40 dB at 4,000 Hz as high-frequency hearing loss. The special health examination on noise revealed that a worker who demonstrated any hearing loss of ≥ 30 dB at 2,000 Hz, ≥ 40 dB at 3,000 Hz, or ≥ 40 dB at 4,000 Hz should undergo a secondary hearing test. The air conduction pure tone audiometry average of thresholds at 2,000 Hz, 3,000 Hz, and 4,000 Hz defined ≤ 25 dB, 26–40 dB, 41–55 dB, and ≥ 56 dB as normal hearing and mild, moderate, and moderate-severe hearing loss, respectively. Hearing thresholds were based on those of worse ear.

Age groups were categorized according to age into <30, 30–39, 40–49, and ≥ 50 years. Work duration was classified into < 5 years, 5–9 years, 10–19 years, and ≥ 20 years. According to the large categories of the standard industry codes, types of industries were divided into mining, manufacturing, construction, and noise-exposed other industries. According to the number of individual workers, the workplace (business) scales were classified into < 50, 50–299, 300–999, and ≥ 1,000. Noise exposure was classified into daytime (noise only) and night-shift exposures (combined exposure).

Metabolic syndrome, hypertension, and diabetes were selected as cardiometabolic diseases of noise-exposed workers. The relevant major clinical and blood tests were used, including blood pressure, serum total cholesterol, low-density lipoprotein-cholesterol (LDL-C), high-density lipoprotein-cholesterol (HDL-C), triglycerides, and fasting blood sugar. A subject was diagnosed to have metabolic syndrome when the person had three or more of the following five items: 1) for central obesity, the waist is ≥ 90 cm for males or ≥ 85 cm for females; 2) for hypertriglyceridemia, the triglyceride level is ≥ 150 mg/dL; 3) the HDL-C is low (< 40 mg/dL for males and < 50 mg/dL for females); 4) the fasting blood sugar is ≥100 mg/dL; and 5) for hypertension, a systolic blood pressure is ≥ 130 mmHg or a diastolic blood pressure is ≥ 85 mmHg. Hypertension was defined as a systolic blood pressure of 140 mmHg or a diastolic blood pressure of ≥ 90 mmHg. Diabetes was defined as a fasting blood glucose level of ≥ 126 mg/dL.

Statistical analyses

A Pearson test was performed when both the dependent and the separated variables were discrete. A model was fitted with logistic regression when each of cardiometabolic diseases (hypertension, diabetes, and metabolic syndrome) was a dependent variable. These models were used to estimate the effects of factors influencing cardiometabolic diseases. A multivariate analysis was performed to simultaneously test all factors in the logistic regression models, and the effects of each factor were presented as odds ratios (ORs), 95% confidence interval (CI), and p-values. R version 3.3.2 (R Foundation for Statistical Computing; Vienna, Austria) was used for all analyses.

Ethics statement

The present study protocol was reviewed and approved by the Institutional Review Board (IRB) of Seoul Medical Center (IRB No. 2017-02-006).

RESULTS

Prevalence of cardiometabolic diseases

The prevalence of metabolic syndrome in male workers was 18.9%, which is slightly over twice that of female workers (9.3%). The prevalence was significantly higher with aging (22.8%, 20.7%, 16.8%, and 8.4% for ages ≥ 50, 40–49, 30–39, and < 30 years, respectively) and increasing work duration (15.1%, 17.6%, 20.9%, and 23.3% for < 5, 5–9, 10–19, and ≥ 20 years, respectively). In terms of industry types, the prevalence of metabolic syndrome was 28.9%, 24.6%, 17.9%, and 16.9% in mining, construction, manufacturing, and other industries, respectively. In terms of business scales, the prevalence was 18.6%, 17.9%, 17.9%, and 17.4% for < 50, 50–299, ≥ 1,000, and 300–999 workers, respectively. The prevalence of metabolic syndrome in workers exposed to noise only and to noise combined with night-shift work was 18.2% and 17.8%, respectively (**Table 1**).

Table 1. Baseline characteristics of study participants according to cardiometabolic diseases

Variables	No. of participants	Metabolic syndrome	Hypertension	Diabetes
Sex				
Female	23,359 (9.9)	2,172 (9.3)***	1,121 (4.8)***	719 (3.1)***
Male	213,669 (90.1)	40,324 (18.9)	15,329 (7.2)	10,360 (4.8)
Age (years)				
< 30	38,120 (16.1)	3,198 (8.4)***	1,061 (2.8)***	358 (0.9)***
30–39	76,002 (32.1)	12,738 (16.8)	4,186 (5.5)	1,989 (2.6)
40–49	70,870 (29.9)	14,700 (20.7)	5,730 (8.1)	3,915 (5.5)
≥ 50	52,036 (22.0)	11,860 (22.8)	5,473 (10.5)	4,817 (9.3)
Work duration (years)				
< 5	115,990 (48.9)	17,480 (15.1)***	6,606 (5.7)***	4,169 (3.6)***
5–9	37,519 (15.8)	6,590 (17.6)	2,683 (7.2)	1,559 (4.2)
10–19	43,589 (18.4)	9,130 (20.9)	3,666 (8.4)	2,198 (5.0)
≥ 20	39,930 (16.8)	9,296 (23.3)	3,495 (8.8)	3,153 (7.9)
Business scale (persons)				
≥ 1,000	44,611 (18.8)	7,987 (17.9)***	2,559 (5.7)***	1,837 (4.1)***
300–999	39,993 (16.9)	6,972 (17.4)	2,803 (7.0)	1,802 (4.5)
50–299	119,226 (50.3)	21,360 (17.9)	8,345 (7.0)	5,642 (4.7)
< 50	33,198 (14.0)	6,177 (18.6)	2,743 (8.3)	1,798 (5.4)
Type of Industry				
Other industries	36,630 (15.5)	6,205 (16.9)***	2,371 (6.5)***	1,661 (4.5)***
Manufacturing	195,119 (82.3)	34,988 (17.9)	13,524 (6.9)	8,907 (4.6)
Construction	5,127 (2.2)	1,259 (24.6)	539 (10.5)	497 (9.7)
Mining	152 (1.0)	44 (28.9)	16 (10.5)	14 (9.2)
Noise exposure work type				
Daytime exposure	88,913 (37.5)	16,161 (18.2)*	6,096 (6.9)	4,280 (4.8)*
Night-shift exposure	148,115 (62.5)	26,335 (17.8)	10,354 (7.0)	6,799 (4.6)
Total	237,028 (100)	42,496 (17.9)	16,450 (6.9)	11,079 (4.7)

Values are numbers (%).
^aHypertension was defined as systolic blood pressure ≥ 140 mmHg, or diastolic blood pressure ≥ 90 mm Hg. ^bDiabetes was defined as fasting glucose ≥ 126 mg/dL.
*$p < 0.05$; ***$p < 0.001$.

The prevalence of hypertension in male workers was 7.2%, which was significantly higher than that of in female workers (4.8%). The prevalence was significantly higher with aging (10.5%, 8.1%, 5.5%, and 2.8% for ages ≥ 50, 40–49, 30–39, and <30 years, respectively) and increasing work duration (5.7%, 7.2%, 8.4%, and 8.8% for < 5, 5–9, 10–19, ≥ 20 years, respectively). In terms of industry types, the prevalence of hypertension was 10.5%, 10.5%, 6.9%, and 6.5% in mining, construction, manufacturing, and other industries, respectively, indicating that the smaller the scales, the higher the prevalence. The prevalence of hypertension in workers exposed to noise only and to noise combined with night-shift work was 6.9% and 7.0%, respectively, with no significant difference (**Table 1**).

The prevalence of diabetes in male workers was 4.8%, which was significantly higher than that in female workers (3.1%). The prevalence was significantly higher with aging (9.3%, 5.5%, 2.6%, and 0.9% for ages ≥ 50, 40–49, 30–39, and < 30 years, respectively) and increasing work duration (3.6%, 4.2%, 5.0%, and 7.9% for < 5, 5–9, 10–19, and ≥ 20 years, respectively). In terms of industry types, the prevalence of diabetes was 9.7%, 9.2%, 4.6%, and 4.5% in construction, mining, manufacturing, and other industries, respectively. In terms of business scales, the prevalence was 5.4%, 4.7%, 4.5%, and 4.1% for <50, 50–299, 300–999, and ≥1,000, respectively, indicating that the smaller the scales, the higher the prevalence. The prevalence of diabetes in workers exposed to noise only and to noise combined with night-shift work was 4.8% and 4.6%, respectively (**Table 1**).

The comparison of cardiometabolic diseases prevalence between the hearing loss group at mid-frequency (2,000 Hz) and the normal group revealed metabolic syndrome in 22.3% and 17.5%, hypertension in 10.6% and 6.6%, and diabetes in 8.8% and 4.3%, respectively, indicating that the mid-frequency hearing loss group demonstrated a higher prevalence of cardiometabolic diseases. The comparison of cardiometabolic diseases prevalence between the hearing loss group at high-frequency (4,000 Hz) and the normal group revealed metabolic syndrome was 22.4% and 16.8%, hypertension in 10.0% and 6.1%, and diabetes in 7.8% and 3.8%, respectively, indicating that the high-frequency hearing loss group exhibited a higher prevalence of cardiometabolic diseases. The comparison of cardiometabolic diseases prevalence between the normal group and the groups divided by the degrees of hearing loss revealed metabolic syndrome in 16.6%, 21.7%, 22.4%, and 23.2% for the normal, mild, moderate, and moderate-severe hearing loss group, respectively. Additionally, hypertension was reported in 6.0%, 9.3%, 10.4%, and 10.6%, and diabetes in 3.7%, 7.1%, 8.4%, and 9.4%, respectively. These results indicated that cardiometabolic diseases prevalence was significantly higher as the degrees of hearing loss increased (**Table 2**).

Health factors influencing cardiometabolic diseases

Multivariate logistic regression analysis using metabolic syndrome as a dependent variable revealed that the ORs were significantly different based on the risk factors of sex, age, work duration, business scale, industry type, noise exposure work type, and hearing loss. The OR of metabolic syndrome was significantly higher in males than females; older workers; longer work durations; smaller business scales; manufacturing, mining, and construction than other industries; combined exposure to noise and night-shift work than exposure to daytime noise only; and in the hearing loss groups. Mid-frequency and high-frequency hearing loss demonstrated ORs of 1.030 (0.993–1.069) and 1.041 (1.013–1.069), respectively (**Tables 3** and **4**).

The analyses of hypertension and diabetes were consistent with those of the metabolic syndrome in terms of risk factors. The OR of hypertension was 1.185 (1.126–1.247) and 1.169 (1.125–1.215), respectively, and that of diabetes was 1.240 (1.173–1.311) and 1.171 (1.120–1.225) at mid-frequency and high-frequency hearing loss, respectively (**Tables 3** and **4**).

Table 2. Type and degree of hearing loss in patients with cardiometabolic diseases

Variables	No. of participants	Metabolic syndrome	Hypertension	Diabetes
Mid-freq HL				
No	216,925 (91.5)	38,013 (17.5)***	14,325 (6.6)***	9,302 (4.3)***
Yes	20,098 (8.5)	4,483 (22.3)	2,125 (10.6)	1,777 (8.8)
High-freq HL				
No	187,919 (79.3)	31,484 (16.8)***	11,551 (6.1)***	7,232 (3.8)***
Yes	49,106 (20.7)	11,012 (22.4)	4,899 (10.0)	3,847 (7.8)
Hearing loss				
Normal	179.023 (75.5)	29,670 (16.6)***	10,784 (6.0)***	6,575 (3.7)***
Mild	34,820 (14.7)	7,563 (21.7)	3,231 (9.3)	2,472 (7.1)
Moderate	14,757 (6.2)	3,311 (22.4)	1,538 (10.4)	1,243 (8.4)
Moderate-severe	8,428 (3.6)	1,952 (23.2)	897 (10.6)	789 (9.4)
Total	237,028 (100)	42,496 (17.9)	16,450 (6.9)	11,079 (4.7)

Values are numbers (%).
Mid-freq HL: hearing loss at mid-frequency (pure-tone threshold of ≥ 30 dB at 2 kHz in worse ear), High-freq HL: hearing loss at high frequency (pure-tone threshold of ≥ 40 dB at 4 kHz in worse ear), Hearing loss: In the pure-tone average of thresholds at 2,000 Hz, 3,000 Hz, 4000 Hz, ≤ 25 dB was defined as normal, 26–40 dB as mild HL, 41–55 dB as moderate HL, and ≥ 56 dB was moderate-severe HL.
[a]Hypertension was defined as systolic blood pressure ≥ 140 mmHg, or diastolic blood pressure ≥ 90 mm Hg.
[b]Diabetes was defined as fasting glucose ≥ 126 mg/dL.
***$p < 0.001$.

Table 3. Adjusted ORs (95% CIs) for metabolic syndrome, hypertension, and diabetes among mid-frequency hearing loss

Variables	Metabolic syndrome		Hypertension		Diabetes	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Sex						
Female	1.000	0.000	1.000	0.000	1.000	0.000
Male	2.445 (2.333–2.562)		1.822 (1.708–1.943)		2.018 (1.864–2.185)	
Age (years)						
< 30	1.000	0.000	1.000	0.000	1.000	0.000
30–39	2.067 (1.982–2.155)	0.000	1.894 (1.766–2.031)	0.000	2.781 (2.480–3.118)	0.000
40–49	2.716 (2.600–2.838)	0.000	2.943 (2.741–3.159)	0.000	6.169 (5.512–6.904)	0.000
≥ 50	3.122 (2.978–3.273)	0.000	4.072 (3.782–4.385)	0.000	10.500 (9.367–11.770)	0.000
Work duration (years)						
< 5	1.000	0.000	1.000	0.000	1.000	0.000
5–9	1.038 (1.005–1.072)	0.023	1.126 (1.074–1.181)	0.000	0.971 (0.914–1.032)	0.348
10–19	1.151 (1.116–1.187)	0.000	1.180 (1.127–1.235)	0.000	0.966 (0.912–1.022)	0.229
≥ 20	1.129 (1.088–1.171)	0.000	0.990 (0.938–1.045)	0.712	1.092 (1.029–1.160)	0.004
Business scale (persons)						
≥ 1,000	1.000	0.000	1.000	0.000	1.000	0.000
300–999	1.053 (1.015–1.093)	0.006	1.338 (1.263–1.418)	0.000	1.297 (1.210–1.391)	0.000
50–299	1.137 (1.102–1.174)	0.000	1.363 (1.296–1.433)	0.000	1.449 (1.364–1.539)	0.000
< 50	1.208 (1.160–1.259)	0.000	1.636 (1.538–1.740)	0.000	1.568 (1.454–1.691)	0.000
Type of industry						
Other industries	1.000	0.000	1.000	0.000	1.000	0.000
Manufacturing	1.053 (1.022–1.086)	0.001	1.083 (1.034–1.134)	0.001	0.980 (0.927–1.036)	0.471
Construction	1.363 (1.270–1.463)	0.000	1.369 (1.238–1.513)	0.000	1.650 (1.481–1.838)	0.000
Mining	1.635 (1.146–2.332)	0.007	1.224 (0.725–2.065)	0.449	1.424 (0.814–2.489)	0.215
Noise exposure work type						
Daytime exposure	1.000	0.000	1.000	0.000	1.000	0.000
Night-shift exposure	1.061 (1.037–1.085)		1.097 (1.060–1.136)		1.083 (1.039–1.129)	
Mid-freq HL						
No	1.000	0.116	1.000	0.000	1.000	0.000
Yes	1.030 (0.993–1.069)		1.185 (1.126–1.247)		1.240 (1.173–1.311)	

Hearing loss: pure-tone threshold of ≥ 30 dB at 2 kHz in worse ear (mid-freq HL).
OR: odds ratio; CI: confidence interval; Mid-freq HL: hearing loss at middle frequency.

The OR of all the cardiometabolic diseases in this study was higher when the subjects were exposed to noise combined with night-shift work than to noise only (1.061, 1.097, and 1.083 for metabolic syndrome, hypertension, and diabetes, respectively), indicating the risk of exposure to night-shift work as well as noise. The OR for hearing loss was highest for diabetes, followed by hypertension and metabolic syndrome. Metabolic syndrome demonstrated statistically significant hearing loss in high-frequency, whereas hypertension and diabetes exhibited statistically significant hearing loss in mid- and high-frequency (**Tables 3** and **4**).

As for the risks of cardiometabolic diseases based on average hearing thresholds, the ORs were higher as hearing loss increased, indicating dose-response relationships. The ORs of the hearing loss group for metabolic syndrome compared with the normal group in model III, in which all variables were adjusted, were 1.062 (1.030–1.094), 1.027 (0.984–1.072), and 1.065 (1.008–1.124) at mild, moderate, and moderate-severe hearing loss, respectively; those for hypertension were 1.147 (1.098–1.198), 1.196 (1.127–1.270), and 1.212 (1.124–1.306), respectively; and those for diabetes were 1.177 (1.119–1.239), 1.234 (1.154–1.319), and 1.346 (1.241–1.459), respectively (**Table 5**).

Table 4. Adjusted ORs (95% CIs) for metabolic syndrome, hypertension, and diabetes among high-frequency hearing loss

Variables	Metabolic syndrome		Hypertension		Diabetes	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Sex						
Female	1.000	0.000	1.000	0.000	1.000	0.000
Male	2.427 (2.315–2.545)		1.773 (1.662–1.892)		1.966 (1.814–2.130)	
Age (years)						
< 30	1.000	0.000	1.000	0.000	1.000	0.000
30–39	2.063 (1.978–2.152)	0.000	1.882 (1.754–2.018)	0.000	2.765 (2.466–3.100)	0.000
40–49	2.699 (2.582–2.821)	0.000	2.879 (2.680–3.092)	0.000	6.054 (5.407–6.778)	0.000
≥ 50	3.086 (2.942–3.238)	0.000	3.944 (3.658–4.252)	0.000	10.276 (9.158–11.532)	0.000
Work duration (years)						
< 5	1.000	0.000	1.000	0.000	1.000	0.001
5–9	1.038 (1.005–1.072)	0.024	1.125 (1.073–1.180)	0.000	0.970 (0.913–1.031)	0.329
10–19	1.150 (1.115–1.187)	0.000	1.178 (1.125–1.233)	0.000	0.963 (0.910–1.020)	0.198
≥ 20	1.127 (1.087–1.169)	0.000	0.985 (0.933–1.039)	0.569	1.087 (1.023–1.154)	0.007
Business scale (persons)						
≥ 1,000	1.000	0.000	1.000	0.000	1.000	0.000
300–999	1.053 (1.014–1.093)	0.007	1.334 (1.259–1.413)	0.000	1.290 (1.204–1.383)	0.000
50–299	1.136 (1.100–1.173)	0.000	1.357 (1.291–1.428)	0.000	1.442 (1.357–1.532)	0.000
< 50	1.206 (1.158–1.256)	0.000	1.626 (1.528–1.729)	0.000	1.559 (1.445–1.680)	0.000
Type of industry						
Other industries	1.000	0.000	1.000	0.000	1.000	0.000
Manufacturing	1.053 (1.021–1.085)	0.001	1.080 (1.031–1.131)	0.001	0.977 (0.925–1.033)	0.418
Construction	1.363 (1.270–1.463)	0.000	1.370 (1.239–1.515)	0.000	1.652 (1.483–1.840)	0.000
Mining	1.632 (1.144–2.329)	0.000	1.221 (0.724–2.061)	0.454	1.426 (0.815–2.492)	0.214
Noise exposure work type						
Daytime exposure	1.000	0.000	1.000	0.000	1.000	0.000
Night-shift exposure	1.061 (1.037–1.085)		1.097 (1.060–1.136)		1.083 (1.039–1.128)	
High-freq HL						
No	1.000	0.004	1.000	0.000	1.000	0.000
Yes	1.041 (1.013–1.069)		1.169 (1.125–1.215)		1.171 (1.120–1.225)	

Hearing loss: pure-tone threshold of ≥ 40 dB at 4 kHz in worse ear (high-freq HL).
OR: odds ratio; CI: confidence interval; High-freq HL: hearing loss at high frequency.

Table 5. Adjusted ORs (95% CIs) for metabolic syndrome, hypertension, and diabetes by degree of hearing loss.

	Model I[a]		Model II[b]		Model III[c]	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Metabolic syndrome						
Hearing loss						
Normal (≤ 25 dB)	1.000	0.000	1.000	0.000	1.000	0.000
Mild (26–40 dB)	1.070 (1.038–1.103)	0.000	1.063 (1.032–1.096)	0.000	1.062 (1.030–1.094)	0.000
Moderate (41–55 dB)	1.035 (0.992–1.080)	0.115	1.028 (0.985–1.073)	0.209	1.027 (0.984–1.072)	0.216
Moderate-severe (≥ 56 dB)	1.071 (1.014–1.131)	0.014	1.065 (1.009–1.125)	0.023	1.065 (1.008–1.124)	0.024
Hypertension						
Hearing loss						
Normal (≤ 25 dB)	1.000	0.000	1.000	0.000	1.000	0.000
Mild (26–40 dB)	1.162 (1.112–1.213)	0.000	1.149 (1.100–1.201)	0.000	1.147 (1.098–1.198)	0.000
Moderate (41–55 dB)	1.213 (1.143–1.288)	0.000	1.197 (1.128–1.271)	0.000	1.196 (1.127–1.270)	0.000
Moderate-severe (≥ 56 dB)	1.218 (1.130–1.313)	0.000	1.212 (1.124–1.307)	0.000	1.212 (1.124–1.306)	0.000
Diabetes						
Hearing loss						
Normal (≤ 25 dB)	1.000	0.000	1.000	0.000	1.000	0.000
Mild (26–40 dB)	1.194 (1.135–1.256)	0.000	1.179 (1.121–1.240)	0.000	1.177 (1.119–1.239)	0.000
Moderate (41–55 dB)	1.253 (1.173–1.340)	0.000	1.235 (1.155–1.320)	0.000	1.234 (1.154–1.319)	0.000
Moderate-severe (≥ 56 dB)	1.355 (1.250–1.469)	0.000	1.345 (1.241–1.459)	0.000	1.346 (1.241–1.459)	0.000

Hearing loss: In the pure-tone average of thresholds at 2,000 Hz, 3,000 Hz, 4000 Hz, ≤25 dB was defined as normal, 26–40 dB as mild HL, 41–55 dB as moderate HL, and ≥56 dB was moderate-severe HL.
OR: odds ratio; CI: confidence interval.
[a]Model I: Adjusted for sex and age.
[b]Model II: Further adjusted for work duration, business scale and industry type.
[c]Model III: Further adjusted for day and night-shifts.

DISCUSSION

The study investigated the association between cardiometabolic diseases (metabolic syndrome, hypertension, and diabetes) and socio-demographic, occupational, night shift work, and hearing loss in noise-exposed workers. Metabolic syndrome, a cluster of conditions, including abdominal obesity, hypertension, dyslipidemia, and impaired fasting glucose, increases the risk of cardiovascular diseases and type 2 diabetes mellitus. All three cardiometabolic diseases demonstrated significantly higher ORs when exposed to noise combined with night-shift work. However, metabolic syndrome exhibited a higher OR for high-frequency hearing loss, whereas hypertension and diabetes had higher ORs at mid- and high-frequency hearing loss. The study concluded that noise-exposed workers demonstrated a high risk of hearing loss and cardiometabolic diseases, indicating the need for biomonitoring and auditory observation.

Hearing loss can arise from genetics, ear diseases, aging, and noise exposure and is related to various health conditions. A previous study revealed that 58.85% of those > 60 years old had a hearing loss of ≥ 25 dB, with a correlation with ear diseases, diabetes, hypertension, noise exposure, and ototoxic drugs. The largest effects were found for ear diseases and noise exposure (OR: 2.83 [95% CI: 2.43–3.29]; OR: 2.59 [95% CI: 1.80–3.72]).[4] The Rotterdam Study linked hearing loss to age, blood pressure, diabetes, and lifestyle factors, with gender-specific differences noted.[7,8]

Korean studies have revelaed that hearing loss correlates with age, smoking, and health conditions such as hypertension and diabetes.[9] This study revealed clear association between hearing loss and cardiometabolic diseases, but not with dyslipidemia, indicating that further research is required. Recent research indicates that metabolic syndrome impacts hearing loss, with increased risks and specific factors such as central obesity and hyperglycemia being influential.[10-19]

Studies since the 1980s have related diabetes to significant hearing loss. Type 1 diabetes is associated with a higher prevalence of hearing impairment.[20,21] Type 2 diabetes also correlates strongly with hearing loss, especially high-frequency hearing impairment, related to hyperglycemia and oxidative stress.[22-25] However, some studies revealed no significant differences in hearing loss between diabetic and non-diabetic groups after accounting for other factors.[26] The impact of hypertension on hearing loss was noted to be significant at certain frequencies, indicating a stronger influence compared to diabetes.[27]

Meanwhile, aging and diabetes were correlated with the prevalence of hearing loss, and no statistically significant association was found between hearing loss and hypertension when age and diabetes were adjusted. Thus, the prevalence of hearing loss increased with age and diabetes, and hearing loss was most observed at high frequency.[28]

Hypertension is a key risk factor in the pathophysiology of cochlear hearing loss, with mechanisms involving potassium recirculation interference and reduced oxygen tension in the cochlea. Evidence indicates that factors, such as age, diabetes, and noise exposure, can confound the association between hypertension and high-frequency sensorineural hearing loss.[29]

Studies have shown a strong association between hypertension and increased hearing thresholds, particularly in grade 2 hypertension patients.[30] Occupational noise exposure

correlates with higher blood pressure and an increased risk of hypertension, showing a dose-response relationship with bilateral high-frequency hearing loss in both genders.[31] A cohort study revealed a higher risk of hypertension in those exposed to occupational noise, with an OR of 1.16 in men and 1.39 in those with bilateral hearing loss.[32] Moreover, current hypertension is related to future hearing loss, as a 25-year longitudinal study revealed a correlation between midlife blood pressure and later hearing loss.[33]

As mentioned above, the results of many studies are consistent with those in this study, indicating an association between hearing loss and cardiometabolic diseases such as metabolic syndrome, hypertension, and diabetes. The study revealed that HDL-C and triglyceride, which are the major components of metabolic syndrome, may not be significantly related to hearing loss. An association of hearing loss with dyslipidemia has not been sufficiently demonstrated and cardiometabolic diseases are generally related to hearing loss at all frequencies, but researchers revealed slight differences. Additionally, the effects of hearing loss seem to have a synergistic effect when there are common chronic diseases along with individual cardiovascular-metabolic diseases.[6] Hearing loss with metabolic syndrome, hypertension, and diabetes have joint effects on the occurrence of coronary heart diseases,[34] thus hearing loss and cardiovascular disease may have common risk factors.

This study revealed that personal factors, such as sex and age, and occupational factors, including noise exposure period and type of industry, appeared to have a significant impact on cardiometabolic diseases. However, the relationship between cardiometabolic diseases and the type or degree of hearing loss can be examined even after adjusting for these factors. Additionally, workers exposed to noise combined with night-shift work have a higher risk of cardiometabolic diseases than those exposed to noise only during daytime work.

This study focuses on the effects of noise exposure on worker health examination results, emphasizing the limited use of work environment measurements and health inspection outcomes in noise-exposure businesses. The research utilized large-scale health reviews from worker health examination subjects to establish associations between hearing loss and cardiometabolic diseases such as metabolic syndrome, hypertension, and diabetes. However, this research has limitations as a cross-sectional study and not a cohort study. The demographic characteristics excluded personal factors, such as education level, socioeconomic status, health behaviors, including smoking and drinking, other underlying diseases, and military exposure history. Additionally, the working period is the current noise exposure working period, which has the limitation of not including the evaluation of past cumulative noise exposure.

The association between hearing loss and cardiometabolic diseases is similar to those of other studies, but the direction of disease occurrence varies. Cardiometabolic diseases appear to induce hearing loss, but hearing loss does not appear to be a risk factor for cardiometabolic diseases. The study reveals that biomonitoring of cardiometabolic diseases and auditory observation may be required for noise-exposed workers.

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