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Comparison of the risk of noise-induced hearing loss between male police officers and male non-police officers: a nationwide cohort study using propensity score matching in South Korea

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Abstract

Background Police officers are at a high risk of noise-induced hearing loss (NIHL) owing to the nature of their work. Therefore, this study aimed to compare the risk of NIHL in police officers and controls.

Methods This study used the National Health Insurance claims data of workers aged 25–65 years obtained from 2005 to 2015. The case group comprised police officers, while the control group comprised general workers and public officers. The study followed a three-phase cohort design. The standardized incidence ratio (SIR) was calculated using an indirect standardization method based on age. Propensity score matching was performed using the greedy matching method, with a police officer-to-control group ratio of 1:3. Cox regression analysis was performed for each matched control group. Statistical significance was determined by a lower limit of greater than 1, based on the 95% confidence interval (CI).

Results The SIR values for police officers were 1.62 (95% CI: 1.44–1.82) compared with general workers and 1.78 (95% CI: 1.66–1.73) compared with public officers. Police officers exhibited an increased risk of NIHL compared with general workers (hazard ratio (HR): 1.71, 95% CI: 1.49–1.98) and public officers (HR: 2.19, 95% CI: 1.88–2.56).

Conclusions It is necessary to prevent NIHL by reducing occupational noise exposure through measures such as wearing earplugs, improving shooting training methods, and improving the shift work system.

Keywords Police officers, Noise-induced hearing loss, Propensity score matching, Cox regression, Average treatment effect of treated

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Background

Noise exposure frequently reduces work efficiency and causes adverse health effects, such as increased blood pressure, stress, and noise-induced hearing loss (NIHL) [1]. NIHL is a well-known occupational disease caused by noise exposure [1, 2] and has non-auditory health effects, such as sleep and cognitive disorders, thus reducing the quality of life [3]. Worldwide, approximately 16% of hearing impairment cases are attributed to occupational noise exposure [1, 4], with more than 250 million people experiencing NIHL [3].

In South Korea, workers in industries exposed to health hazards, such as noise and dust, undergo special health examinations [5]. In 2020, special health examinations were conducted in approximately 2.21 million people, revealing 164,214 patients with abnormal findings and suspected of having occupational disease. Notably, NIHL accounts for approximately 90% of these cases (Supplementary Table 1) [6]. As of 2020, 2,711 persons with NIHL were recognized as having work-related illnesses according to the Industrial Accident Compensation Act, with an annual average increase of over 50% in the past 5 years [7].

The diagnosis of occupational NIHL is performed by an occupational and environmental medicine physician [8]. According to the World Health Organization [9], diagnosis is determined through audiometric testing, assessment of exposure history, and consideration of other potential risk factors. Audiometric testing involves determining hearing thresholds through pure-tone audiometry. Hearing loss is typically characterized by a notch in the hearing threshold at 3, 4, or 6 kHz, with recovery at 8 kHz. This pattern is known as the "noise notch." The assessment of exposure history involves the review of records related to occupational noise exposure, specifically those involving noise levels exceeding 85 dB (A) over an 8-hour time-weighted average. Potential causes such as age-related hearing loss must be excluded.

Police officers are at an increased risk of developing NIHL [10–14]. Due to the nature of their work, they are frequently exposed to various sources of noise, including car horns, gunshots, barking police dogs, and traffic noise [15]. Although many studies have investigated the relationship between NIHL and police officers, most have focused only on traffic police officers [10–18].

Comparative studies on all police officers in the country, including traffic officers and those from other branches, have not yet been conducted. Therefore, this study aimed to compare the risk of NIHL between police officers and control groups, using propensity score matching (PSM) to minimize potential biases.

Methods

Data and participants

This study used the National Health Insurance (NHI) claims data for analysis. The NHI claims data are representative data that include all medical records of outpatients, inpatients, and emergency services provided to the entire population in South Korea [19].

In this study, we analyzed the data from 2005 to 2015. The data obtained in 2005 was used only as a washout period, and the research observations started in 2006. Of the 49,760,223 participants, only workers aged 25–64 years were included in the study. Police officers exhibited a greater gender imbalance compared with other industries (Supplementary Table 2). Furthermore, due to the high proportion of women working in office jobs [20], they were excluded from the study to reduce gender bias. Those diagnosed with NIHL in 2005 were also excluded. For age-standardized incidence ratio (SIR) calculations, 97,695 police officers, 6,168,572 general workers, and 468,905 public officers were used. Subsequently, 97,365 police officers, 292,085 general workers, and 272,233 public officers were included in the final study, excluding those who were not matched through PSM. The participants were then divided into general worker and public officer cohort groups (Fig. 1).

Variables

Outcome measure

The outcome measure of this study was NIHL. In South Korea, NIHL is primarily diagnosed by performing a Workers' Health Examination. During this examination, pure-tone audiometry and noise exposure assessment by job history are conducted [21]. The incidence of NIHL was determined based on the status of medical service utilization with the International Classification of Disease, Tenth version (ICD-10) code H83.3 as the primary diagnosis.

Independent variable

The participants were classified as police officers, general workers, and public officers according to their occupation in 2006 at baseline. General workers included all industrial workers, except those who were self-employed. To compare the risk of developing NIHL among police officers with that among other workers, general workers were selected as the control group. Public officers, including national general officers and public educational officers, who are generally considered in good health and exposed to low levels of occupational noise, were used as the control group [14, 22]. Consequently, police officers were classified as the case group, while general workers and public officers were classified as the control group.

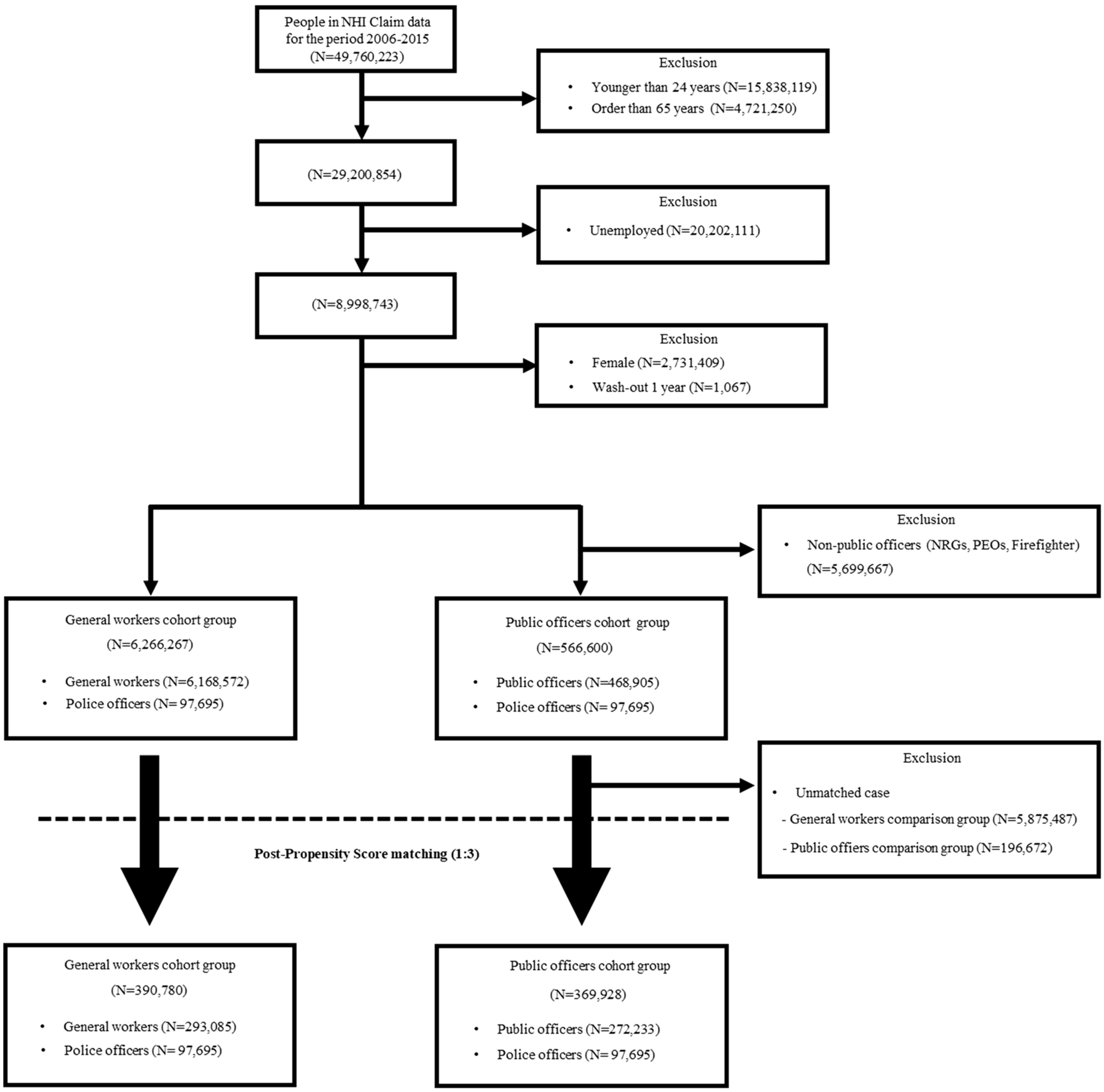

Fig. 1 Flow chart of the patient selection process

Covariates

The covariates included age, income, region, disability, Charlson Comorbidity Index (CCI), and admission in 2005. The participants were divided into the following age groups: 25–34, 35–44, 45–54, and 55–64 years. Income was stratified into four categories according to the NHI premium standards: ≤70%, 71–80%, 81–90%, and 91–100%. Based on region, the participants were grouped into those belonging to Seoul, Gyeonggi, metropolitan, and rural areas. According to disability status, they were divided into disabled people according to the disability registration system and non-disabled people [23]. Based on the CCI calculated according to Quan's criteria [24], the participants were classified as those with 0, 1, and 2 or more points.

Statistical analysis

This study included two cohorts, with general and public officers serving as the control groups. The study was conducted in three phases, each aligned with the construction of the cohort. The SIR was calculated using an indirect standardization method, with age divided into

10-year increments ranging from 25 to 64 years. The age-specific disease incidence rates were initially determined for each control group. The expected incidence was then calculated by multiplying the person-years of police officers by the incidence rates of the control groups. The SIR was derived by dividing the actual number of cases among police officers by the expected number of cases in the control group. Person-years were calculated per calendar year. The results were considered significant when the lower limit of the 95% confidence interval (CI) was greater than 1.

PSM was performed to reduce potential bias. The propensity scores were calculated using logistic regression and included age, region, income, disability, CCI score, and admission in 2005 as covariates. Matching was performed using the greedy matching method with a police officer-to-control group ratio of 1:3. The suitability of matching was confirmed if the standardized difference value was less than the absolute value of 0.1.

After PSM, Cox regression analysis was performed for each matched control group. The proportional hazards assumption was validated using a log-rank test. The multivariable Cox regression analysis was adjusted for all covariates (including age, region, income, disability, CCI score, and hospital admission in 2005). By adjusting the covariates twice through PSM and Cox regression, we were able to obtain doubly robust estimated analysis results [25]. Statistical significance was considered significant when the lower limit was greater than 1, based on the 95% CI. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).

Results

Supplementary Table 3 confirms that the case to control ratio was 1:3 across cohorts, with a standardized difference absolute value of 0.1 or less, indicating effective matching.

Of the total 390,780 study participants in the general workers cohort group, 814 (0.2%) were diagnosed with NIHL. In the public officers cohort group, 672 (0.2%) out of 369,928 participants were diagnosed with NIHL (Supplementary Table 4). Specifically, 814 (0.2%) general workers, 376 (0.1%) public officers, and 296 (0.3%) police officers were diagnosed with NIHL, with police officers exhibiting the highest proportion. Considering age, income, region, disability, CCI score, and admission in 2005, the NIHL incidence for each category ranged from 0.1 to 0.3% (Table 1).

The results of the age-SIR analysis, conducted to explore the association between occupations (police officers versus non-police officers) and NIHL, are presented in Table 2. When general workers were used as the control group, the expected number of NIHL cases was 182.7. When public officers were used as the control group, the expected number of NIHL cases was 166.7. The SIR values for police officers were 1.62 (95% CI: 1.44–1.82) compared with general workers and 1.78 (95% CI: 1.66–1.73) compared with public officers (Table 2).

After the PSM of each cohort, Cox regression analysis was performed. The results of the multivariate Cox regression analysis, conducted to explore the association between occupations (police officers versus non-police officers) and NIHL, are presented in Table 3. Police officers exhibited an increased risk of NIHL compared with general workers (hazard ratio (HR): 1.71, 95% CI: 1.49–1.98) and public officers (HR: 2.19, 95% CI: 1.88–2.56). A log-rank test confirmed that the proportional hazards assumption was met ($p < 0.001$) (Table 3).

Discussion

The key findings of this study indicate that police officers are at a higher risk of NIHL compared with general workers and public officers. These results align with those of a previous study, which reported a higher incidence of NIHL among police officers (activities, non-motorcyclists, and motorcyclists) compared with general public officers [14].

Police officers are often exposed to noise from shootings, rallies, sirens, and traffic. In South Korea, police officers typically fire shots more than twice a year, with field officers firing more than six times annually during training, averaging over 30 shots per session [26]. A previous study found that the maximum vibration during shooting was 4,580 Hz, with maximum noise levels of 113.1 dB for pistols and 116.8 dB for revolvers [27]. Police officers wore earplugs and were provided hearing protection to reduce noise exposure during shooting. However, a previous study investigating the effects of dual hearing protection confirmed that long-term exposure to gunshot impact sound could impair hearing [28]. Given the nature of their work, police officers are required to shoot regularly, making it crucial to implement measures that minimize noise exposure without compromising their shooting proficiency. To reduce noise exposure, police officers should limit the number of live ammunition shots per session. Additionally, incorporating alternative training methods, such as survival shooting and virtual reality shooting, could help maintain combat readiness while reducing reliance on live ammunition.

In a previous study, some protesters attempted to weaponize sound using megaphones, speakers, and other devices [29]. In South Korea, the number of rallies and demonstrations over the past 5 years has steadily increased from 8,855 in 2018 to 55,091 in 2022 [30]. This increase has led to a corresponding rise in the noise exposure of police officers. According to the South

Table 1 Baseline characteristics of the participants with and without disease after propensity score matching

Variable	General workers cohort group			Public officers cohort group		
	NIHL patient (*N*=814) N (%)	Non-patient (*N*=389,966) N (%)	Chi-square	NIHL patient (*N*=672) N (%)	Non-patient (*N*=369,256) N (%)	Chi-square
Occupation						
Non-police officers	518 (0.2)	292,567 (99.8)	<.001***	376 (0.1)	271,857 (99.9)	<.001***
Police officers	296 (0.3)	97,399 (99.7)		296 (0.3)	97,399 (99.7)	
Age						
25 to 34	113 (0.1)	87,997 (99.9)	<.001***	135 (0.2)	79,947 (99.8)	.006**
35 to 44	350 (0.2)	178,652 (99.8)		277 (0.2)	167,967 (99.8)	
45 to 54	312 (0.3)	107,512 (99.7)		235 (0.2)	106,266 (99.8)	
55 to 64	39 (0.2)	15,805 (99.8)		25 (0.2)	15,076 (99.8)	
Income						
70% or less	86 (0.1)	63,402 (99.9)	<.001***	114 (0.2)	64,068 (99.8)	0.88
71% to 80%	225 (0.2)	119,137 (99.8)		189 (0.2)	99,832 (99.8)	
81% to 90%	434 (0.2)	178,800 (99.8)		321 (0.2)	176,704 (99.8)	
91% to 100%	69 (0.2)	28,627 (99.8)		48 (0.2)	28,652 (99.8)	
Region						
Seoul	99 (0.1)	75,921 (99.9)	<.001***	101 (0.1)	69,759 (99.9)	<.001***
Gyeonggi	107 (0.2)	70,613 (99.8)		96 (0.1)	70,994 (99.9)	
Metropolitan	273 (0.2)	109,051 (99.8)		176 (0.2)	99,487 (99.8)	
Rural	335 (0.2)	134,381 (99.8)		299 (0.2)	129,016 (99.8)	
Disability						
Non-disabled	796 (0.2)	384,696 (99.8)	0.03*	662 (0.2)	364,037 (99.8)	0.87
Disabled	18 (0.3)	5,270 (99.7)		10 (0.2)	5,219 (99.8)	
CCI score						
0	680 (0.2)	335,586 (99.8)	0.11	554 (0.2)	319,269 (99.8)	.005**
1	69 (0.2)	28,715 (99.8)		67 (0.3)	26,161 (99.7)	
≥2	65 (0.3)	25,665 (99.7)		51 (0.2)	23,826 (99.8)	
Admission in 2005						
No	745 (0.2)	363,249 (99.8)	0.07	608 (0.2)	346,631 (99.8)	<.001***
Yes	69 (0.3)	26,717 (99.7)		64 (0.3)	22,625 (99.7)	

NIHL Noise-induced hearing loss, *CCI* Charlson Comorbidity Index

$p<0.001^{***}$, $p<0.01^{**}$, $p<0.05^{*}$

Table 2 Age-standardized incidence ratio of male police officers compared with male general workers and male public officers

Control group	Cases/at risk (Police officer)	Expected case	SIR	95% CI
General worker	296/97,695	182.7	1.62	(1.44–1.82)
Public officers	296/97,695	166.7	1.78	(1.66–1.73)

SIR Standardized incidence ratio, *CI* Confidence interval

Korean regulations, the noise level at gatherings is measured based on equivalent noise (Leq) and maximum noise (Lmax) [31]. In residential areas, the Leq is set at 65 dB, and the Lmax is set at 85 dB [31]. If the Leq exceeded the standard once over a 10-minute average or if the Lmax exceeded the standard three or more times within an hour, the noise standard was considered to have been violated [31]. In 2022, out of 55,091 rallies and demonstrations, 2,673 cases (4.9%) violated the noise standards. The rate of noise standard violations has been gradually decreasing over the past 5 years [30]. Despite this, the level of noise exposure for police officers can vary depending on the location of rallies and demonstrations. However, some police officers are still exposed to noise generated during these events. Therefore, measures such as shortening shift times to avoid prolonged exposure to noise during demonstrations are necessary.

The NIHL in police officers due to traffic noise has been extensively investigated [10–18]. Traffic police,

Table 3 Results of the multivariable Cox regression analysis on the association between occupation and the incidence of noise-induced hearing loss in male police officers compared with male general workers and male public officers

Variable	General workers cohort group			Public officers cohort group		
	Cases/at risk	HR	95% CI/ *p*-value	Cases/Exposure	HR	95% CI/ *p*-value
Occupation						
Non-police officers	518/293,085	1.00		376/272,233	1.00	
Police officers	296/97,695	1.71	(1.49–1.98)	296/97,695	2.19	(1.88–2.56)
Age						
25–34	113/88,110	1.00		135/80,082	1.00	
35–44	350/179,002	1.41	(1.09–1.83)	277/168,244	1.11	(0.86–1.45)
45–54	312/107,824	1.94	(1.29–2.90)	235/106,501	1.20	(0.75–1.90)
55–64	39/15.844	2.24	(1.66–3.04)	25/15,101	1.74	(1.27–2.39)
Income						
70% or less	86/63,488	1.00		114/64,182	1.00	
71% to 80%	225/119,362	1.15	(0.87–1.52)	189/100,021	0.93	(0.71–1.23)
81% to 90%	434/179,234	1.07	(0.79–1.46)	321/177,025	0.73	(0.54–0.99)
91% to 100%	69/28,696	0.94	(0.64–1.38)	48/28,700	0.61	(0.40–0.92)
Region						
Seoul	99/76,020	1.00		101/69,860	1.00	
Gyeonggi	107/70,720	1.21	(0.92–1.60)	96/71,090	0.97	(0.73–1.28)
Metropolitan	273/109,324	1.94	(1.54–2.45)	176/99,663	1.22	(0.95–1.55)
Rural	335/134,716	1.96	(1.56–2.45)	299/129,315	1.61	(1.28–2.01)
Disability						
Non-disabled	796/385,492	1.00		662/364,699	1.00	
Disabled	18/5,288	1.45	(0.90–2.32)	10/5,229	0.95	(0.50–1.77)
CCI score						
0	680/336,266	1.00		554/319,823	1.00	
1	69/28,784	1.09	(0.85–1.40)	67/26,228	1.40	(1.09–1.81)
≥2	65/25,730	1.13	(0.88–1.46)	51/23,877	1.16	(0.87–1.55)
Admission in 2005						
No	745/363,994	1.00		608/347,239	1.00	
Yes	69/26,786	1.20	(0.93–1.53)	64/22,689	1.51	(1.16–1.95)
Log-rank test			**<.001*****			**<.001*****

HR Hazard ratio, *CI* Confidence interval, *CCI* Charlson Comorbidity Index

$p<0.001^{***}$

especially those controlling traffic at intersections, are regularly exposed to high levels of vehicular noise [10, 11]. A previous study on traffic police in the Dhaka district reported maximum noise levels ranging from 112.4 dB to 123.7 dB, depending on the area [18]. In a previous study in India, 61% of traffic police reported work-related tinnitus or ear fullness, the early symptoms of NIHL [11]. Chronic exposure to traffic noise can lead to significant occupational NIHL [14]. To mitigate this risk, traffic police officers are required to wear hearing protection equipment (such as earplugs) and minimize noise exposure while on duty.

Previous studies have noted differences in hearing thresholds between the right and left ears [16–18]. In addition, unilateral hearing loss has been observed among active police officers who visited a police hospital in South Korea [32]. Police officers are frequently exposed to high noise levels during traffic and gatherings. They may also use earphones on one side during work to receive and transmit accurate instructions. During shooting training, they may tilt their head toward the hand holding the gun. These factors can contribute to unilateral hearing loss. A previous study showed that the incidence of NIHL was associated with poor quality of life [33]. Therefore, supporting NIHL treatment and promoting the use of hearing aids are essential for improving the quality of life of police officers. However, this study focused solely on NIHL. As this study aimed to explore the association between occupation (police officer versus non-police officer) and NIHL, only the ICD-10 code H83.3 was considered for NIHL Given the high prevalence of unilateral hearing loss among police officers noted in previous studies, the observed difference may be more pronounced if factors such as unilateral conductive hearing loss (ICD-10: H90.1) were included. For this reason, further research should consider conductive hearing loss and involve more comprehensive studies on hearing loss among police officers.

This study has some limitations. First, the extent of noise exposure could not be assessed. In the case of NIHL, the impact of noise exposure is important. However, owing to the nature of the NHI data, information on noise exposure levels were not included. Therefore, future research should incorporate special health examination data to assess workers' exposure to harmful agents. Second, the type of police officers was not considered. Due to the work characteristics of police officers, the effects of noise exposure are likely to vary between office workers and outside workers. To address these limitations, this study focused only on men, who constitute the majority of outdoor workers. In further study, it is necessary to account for the effect of different types of police officers by considering the specific job characteristics of police officers. Third, police officers are likely exposed to noise for a long time as their working period increases; however, owing to data limitations, we did not consider their working period. To overcome this limitation, age was considered as a surrogate variable. The SIRs were calculated using an age-SIR to control for the effects of age.

Despite these limitations, this study provides valuable insights for all police officers, while previous studies have often focused only on specific subgroups, such as the traffic police. In addition, doubly robust results must be obtained by correcting covariates twice with PSM and Cox regression.

Conclusions

The key findings of this study confirmed that the risk of NIHL among police officers was higher than that among general workers and public officers. Due to the work characteristics of police officers' duties, they are regularly exposed to noise that can cause NIHL. Therefore, it is necessary to prevent NIHL by reducing occupational noise exposure through measures such as wearing earplugs, improving shooting training methods, and improving the shift work system.

Abbreviations

NHI	National Health Insurance
NIHL	Noise-induced hearing loss
CI	Confidence interval
SIR	Standardized incidence ratio
PSM	Propensity score matching
ICD-10	International Classification of Disease, Tenth version
CCI	Charlson Comorbidity Index
HR	Hazard ratio

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-19879-8.

Supplementary Material 1: Supplementary Table 1. Classification of disease types of workers diagnosed with occupational disease abnormal findings and suspicious cases of occupational disease from Special Health Examinations in 2020. Statistics of occupational disease abnormal findings and suspicious cases of occupational disease.

Supplementary Material 2: Supplementary Table 2. Occupational proportion by gender. Statistics of occupational proportion by gender in our study.

Supplementary Material 3: Supplementary Table 3. General characteristics. General characteristics by pre and post propensity score matching.

Supplementary Material 4: Supplementary Table 4. General characteristics presented as column percentages.

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None.

Authors' contributions

Conceptulation: W-R Lee, K-T Han, K-B Yoo, J-H Yoon; Data curation: W-R Lee, K-B Yoo; Formal analysis: W-R Lee, K-B Yoo; Methodology: W-R Lee, K-B Yoo, J-H Yoon; Project administration: J-H Yoon; Writing-original draft: W-R Lee; Writing-review and editing: W-R Lee, K-T Han, K-B Yoo, J-H Yoon.

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Availability of data and materials

Data for this study are public secondary data, and they can be accessed through the following NHIS website by submitting an application form and paying a fee: https://nhiss.nhis.or.kr/bd/ay/bdaya001iv.do.

Declarations

Ethics approval and consent to participants

Ethical approval for this study was waived by the Institutional Review Board of the Yonsei University, South Korea (Y-2017-0100), as it used secondary data with anonymized and encrypted personal information. All procedures performed in studies involving human participants were conducted in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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