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Risk Assessment of Noise-induced Hearing Loss Among Workers with Occupational Noise Exposure in University Hospitals

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ABSTRACT

OBJECTIVE Occupational noise-induced hearing loss (ONIHL) is prevalent among supporting healthcare workers in a hospital setting. The risk assessment of ONIHL using a risk matrix could be beneficial, particularly in settings with limited resources; however, it has rarely been applied, and no previous studies have evaluated its accuracy compared to audiogram results. This study aimed to develop a system to evaluate the accuracy of a risk matrix score as a screening tool for the risk of ONIHL.

METHODS This retrospective cohort study included hospital workers exposed to high workplace noise levels in Ramathibodi Hospital and Siriraj Hospital between 2016 and 2023. The noise levels were monitored in the workplaces, and workers' annual audiograms were obtained and interpreted. The risk matrix score was developed by multiplying the numerical value of each domain in the risk matrix (probability - P, consequences - C, and exposure time - E), resulting in a score range of 1 to 125. The accuracy of the risk scores for predicting ONIHL was evaluated using the ROC curve. The optimal cut-off value for the risk scores was determined based on sensitivity and specificity, and the scores were classified into five risk levels (R).

RESULTS A total of 239 workers were included in the study (45.6% male and 54.4% female), 38.5% of whom were diagnosed with ONIHL. For noise exposure level (P), most workers (70.7%) were exposed to occupational noise levels less than 80 dBA as an 8-hour time-weighted average (level 1). Regarding Consequences (C), the majority (38.5%) experienced moderate health effects from noise exposure (level 3). For exposure time (E), most workers (32.2%) had a job duration of 20 years or more (level 5). In terms of risk categories (R), most workers (40.2%) were in the moderate risk category (level 3), followed by 26.8% in the acceptable risk category (level 1), 20.5% in the low-risk category (level 2) and 12.6% in the high-risk category (level 4). The area under the curve (AUC) of the risk score for predicting ONIHL was 0.667. At a score of 8, the sensitivity and specificity for ONIHL were 65.2% and 55.1%, respectively.

CONCLUSIONS The risk matrix can moderately predict ONIHL. It should be employed to screen and prioritize high-risk workers for audiometry in settings with limited resources to promote early detection of ONIHL and further noise control.

KEYWORDS occupational noise-induced hearing loss, risk matrix, risk assessment, screening test, healthcare worker

INTRODUCTION

Occupational noise-induced hearing loss (ONIHL) is one of the most common occupational diseases globally. The global prevalence of ONIHL in 2019 ranged from 11.2 to 58.0% and was generally higher in developing countries (1). The cause is prolonged exposure to loud noise, typically over a period of 10 years, resulting in permanent injury to hair cells within the cochlea of the inner ear. ONIHL is sensorineural hearing loss (1). The gold standard for diagnosis of ONIHL is pure tone audiometry (PTA) (2). ONIHL has characteristic audiogram signatures: a notch presentation of hearing threshold at high frequencies, 3,000, 4,000, or 6,000 Hz, with a recovery observed at 8,000 Hz. ONIHL differs from presbycusis in that it shows a recovery pattern at 8,000 Hz, whereas presbycusis does not (3).

Presently, there are no ways to cure ONIHL (4). The catastrophic consequences of hearing loss are associated with poor health status, high unemployment rates, depression, dementia, and high mortality rates (5). ONIHL in workers also significantly increases the risk of work-related injuries (6, 7). The impact of ONIHL results in both a financial and disease burden at individual and country levels (8). In hospitals, workers in certain departments, such as laundry, nutrition, and engineering service units, may be exposed to loud noise. However, hearing conservation programs in many hospitals in Thailand are often overlooked and inadequately implemented.

The study by Pinosova et al. (9) used a three-dimensional risk matrix to assess the risk of ONIHL by using risk scores. The dimensions were Probability, Consequence, and Exposure time. The noise level in the workplaces increases the risk of ONIHL; therefore, it is defined as Probability. The Consequences include auditory effects, non-auditory effects, and injuries from noise exposure. The Exposure time is measured in years worked in high noise level units. The risk matrix can prioritize hazard management according to the risk scores. However, a study by Pinosova et al. (9) did not test the accuracy of the risk matrix scores by comparing them with the audiograms of the workers. To our knowledge, no previous studies have compared risk matrix scores with diagnosed ONIHL from audiograms, and there is no published evidence of a risk matrix of occupational noise exposure in Thailand. Such a matrix could help prioritize workers who should receive PTA testing to detect hearing damage and to suggest further preventive measures early. Moreover, such a risk assessment could serve as an educational tool to motivate employers and workers to comply with hearing conservation programs.

Ramathibodi and Siriraj Hospital, Mahidol University are among the largest tertiary care hospitals in Thailand. Both facilities have various working areas where hospital workers are exposed to high noise levels. At those institutions, hearing and noise monitoring data have been collected regularly. This study aimed to develop a risk matrix score and to assess its accuracy as a screening tool of ONIHL which could identify high-risk workers. Early detection of ONIHL would help protect the workers against more severe hearing damage and encourage organizations to manage the risk of noise hazards through a hierarchy of controls.

METHODS

This retrospective cohort study aimed to construct a three-dimensional risk matrix for use as a screening tool for ONIHL. The data sources were questionnaire interviews, annual audiometry records, and measurements of noise levels in the work environment.

Study population

The study population was all workers exposed to loud noise who were included in the hearing monitoring program. There were a total of 308 workers: 168 and 140 from Ramathibodi and Siriraj Hospitals, respectively. The departments included Laundry, Nutrition, Prosthetics and Orthotics, Engineering Service, Central Sterile Supply, OR OB-GYN, Printing, and Medical Gas System.

Sample characteristics

The inclusion criteria were: 1) workers who underwent PTA due to workplace noise exposure between 1 January 2016 and 30 September 2023, and 2) workers' departments which had annual noise monitoring data. Individuals were excluded who: 1) had retired or resigned, or 2) had permanent hearing loss from other causes, e.g., ototoxic drugs/chemicals, trauma, uncurable or congenital or genetic ear diseases, history of non-occupational acoustic trauma, etc.

After data collection, a total of 239 participants were identified from a group of 308 workers, or 77.6%, which was considered an acceptable response rate (10).

Power of the study

This study used all available data. The power of the retrospective cohort study was calculated using OpenEpi (11). The exposed group was defined as individuals who had a regular noise exposure level of 80 dBA and above, a level at which long-term exposure would increase the risk of ONIHL (2). The non-exposed group was defined as individuals having a noise exposure level of less than 80 dBA. The power of the study was 0.7 (70.0%), an acceptable statistical power.

Data collection

Questionnaire: The authors collected data through face-to-face interviews using an electronic questionnaire. The questionnaire content included demographics, auditory symptoms (e.g., tinnitus, communication problems), non-auditory symptoms (e.g., dizziness, headache), and injuries related to noise exposure in the workplace (e.g., slipping, falling, and amputation). Three occupational medicine physicians verified the validity of the questionnaire using the content validity index (CVI). Then a pilot study was done after which the questionnaire was adapted and used for data collection. The participants provided written permission to use their PTA results.

Noise exposure: Data on annual noise monitoring of the workers' departments were obtained. Industrial hygienists in each hospital measured noise levels using a sound level meter, then calculated the noise level as an 8-hour time weight average (TWA).

Hearing status: The annual hearing monitoring of hospital staff using PTA tested hearing at 500, 1,000, 2,000, 3,000, 4,000, 6,000, and 8,000 Hertz in both ears followed the ACOEM guidance statement 2018 (3). Audiograms made between 2016 and 2023 were obtained from both occupational health units. The latest audiogram was used to diagnose ONIHL.

Diagnosis of ONIHL from pure tone audiograms

ONIHL was diagnosed from annual audiograms according to the ACOEM ONIHL guidance statement 2018 (3) and Cole et al. (12), then verified by three occupational physicians. The diagnostic criteria were: 1) a notch at frequencies 3,000, 4,000, or 6,000 Hz of 10 dB or more compared with that at 1,000 or 2,000 Hz, and 2) a notch at frequencies 3,000, 4,000, or 6,000 Hz of 10 dB or more compared with that at 6,000 or 8,000 Hz.

Risk matrix

The individual risk matrix consisted of the following three parameters. The probability of risk occurrence (P) was the central value (median) of all annual workplace noise levels as an 8-hour TWA. The probability was divided into five levels according to the noise level (1 = 'less than 80 dBA', 2 = '80-84 dBA', 3 = '85-89 dBA', 4 = '90-94 dBA', and 5 = 'more than 94 dBA') (details in Supplement Table S1).

The risk of developing ONIHL increases with prolonged exposure to noise levels above 80 dBA as an eight-hour TWA, and the risk significantly increases when exposure exceeds 85 dBA (3). According to National Institute for Occupational Safety and Health (NIOSH) Occupational Noise Exposure Revised Criteria 1998, the estimated risk of significant hearing impairment after 40 years of work is 1.0% at 80 dBA with eight-hour TWA, 8.0% at 85 dBA, and 25.0% at 90 dBA (13).

The consequences or the severity of the risk (C) were the most severe health effects or injuries as obtained from the questionnaire. The consequences were divided into five levels according to the severity (1 = 'insignificant effects', 2 = 'minor effects', 3 = 'moderate effects', 4 = 'major effects', and 5 = 'catastrophic effects') (details in Supplement Table S2)

The exposure time (E) was the job-years of exposure to loud noise in the workplace. The exposure time was divided into five levels according to the duration (1 = less than 5 years, 2 = 5-9 years, 3 = 10-14 years, 4 = 15-19 years, and 5 = 20 years and above). (details in Supplement Table S3.)

The risk of ONIHL from prolonged noise exposure starts at 5 years (14). ONIHL progresses most rapidly during the first 10 to 15 years, after which the rate of hearing loss slows. This differs from age-related hearing loss, which speeds up as time progresses (3).

Finally, the risk scores were calculated: Risk score = P x C x E.

Statistical analyses

Receiver operating characteristic (ROC) analysis of the risk matrix scores. The accuracy of the risk matrix scores as a screening tool for ONIHL was tested using ROC analysis. The area under the curve (AUC), sensitivity, and specificity were calculated. The optimal cut-off for the risk matrix tool was determined based on sensitivity, specificity, and clinical significance.

New risk categories (R) in risk matrix development. After determining the cut-off point of ONIHL from risk scores, simple logistic regression was used to find the association between risk scores and the diagnosis of ONIHL. The odd ratios, 95% confidence interval, probability (odds/(1+odds)), and *p*-values were used to classify risk scores into five risk categories (R). A *p*-value less than 0.05 was considered statistically significant. The hazard management for each risk category was developed based on the studies of Piňosová et al. (9), Chaiklieng et al. (15), and Kadir et al. (16).

All data were analyzed using STATA software version 17.

Ethical approval

The research was approved by the human ethics committee of the Faculty of Medicine, Ramathibodi Hospital and the Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand (COA No. MURA2023/783).

RESULTS

Demographic data, Proportion of ONIHL, and noise level

The participants were 239 workers: 130 (54.4%) from Ramathibodi and 109 (45.6%) from Siriraj Hospital. There were 109 male workers (45.6%) and 130 female (54.4%). The age ranged from 22 to 59 years old, with a mean (SD) of 41.4 (10.2). The average noise levels in work areas varied from 55.6 to 87.2 dBA, with a median (Q1, Q3) of 78 (72.4, 80.8). Years on the job ranged from 0 to 40, with a median (Q1, Q3) of 11 (6, 22). The participants by department are shown in Table 1. The proportion of workers with ONIHL was 38.5% (29.2% in Ramathibodi and 49.5% in Siriraj Hospital).

The annual noise monitoring levels from the different departments had medians of 65.6 to 86.7 dBA. The loudest areas were in the Engineering Service Department. Comparisons between the hospitals showed most departments had similar median noise levels, e.g., the Nutrition and the Central Sterile Supply Department. However, in the Prosthetics and Orthotics Unit, the noise levels were much higher in Siriraj Hospital (Table 2).

Characteristics of the risk matrix and risk scores

Regarding the probability (P), most participants were exposed to occupational noise levels less than 80 dBA (70.7%), followed by 80-84 dBA (24.3%) and 85-89 dBA (5.0%). Concerning consequences (C) or self-reported health effects and injuries from noise exposure, most workers (38.5%)

Table 1. Participants by departments of Ramathibodi and Siriraj Hospitals (N = 239)

Department	Participant number (%)		Total (n = 239)
	Ramathibodi Hospital (n = 130)	Siriraj Hospital (n = 109)	
Engineering Service	12 (9.2)	-	12
Nutrition	20 (15.4)	8 (7.3)	28
Central Sterile Supply	23 (17.7)	63 (57.8)	86
OR OB-GYN*	23 (17.7)	-	23
Prosthetics and Orthotics Unit	2 (1.5)	22 (20.2)	24
Laundry	50 (38.5)	2 (1.8)	52
Publishing	-	8 (7.3)	8
Medical Gas System Division	-	6 (5.5)	6
Total	130 (100.0)	109 (100.0)	

*Obstetrics and Gynecology operating room

Table 2. Medians of annual noise level (dBA) in work areas (8-hours TWA) of Ramathibodi and Siriraj Hospital between 2016 and 2023

Work areas	Noise level (dBA)	
	Ramathibodi Hospital	Siriraj Hospital
1. Engineering Service Department		
Grinding room	70.2	-
Vacuum generator room	86.7	-
Chiller room	85.6	-
Boiler room	79.6	-
2. Nutrition Department		
Steam rice area	77.1	-
Dish washing area	80.4	78.6
Blenderized diet room	76.6	-
3. Central Sterile Supply Department		
Washing room	81.7	84.5
Oven room	78.6	-
After washing process area	75.1	75.5
4. OR OB-GYN*		
Instrument cleaning room	74.9	-
5. Prosthetics and Orthotics Unit	65.6	81.5
6. Laundry Department		
Washing area	78.8	81.3
Drying machine area	-	80.0
Cloth sewing unit	78.8	-
7. Publishing Unit		
Printing room	-	83.0
8. Medical Gas System Division	-	77.0

*Obstetrics and Gynecology operating room

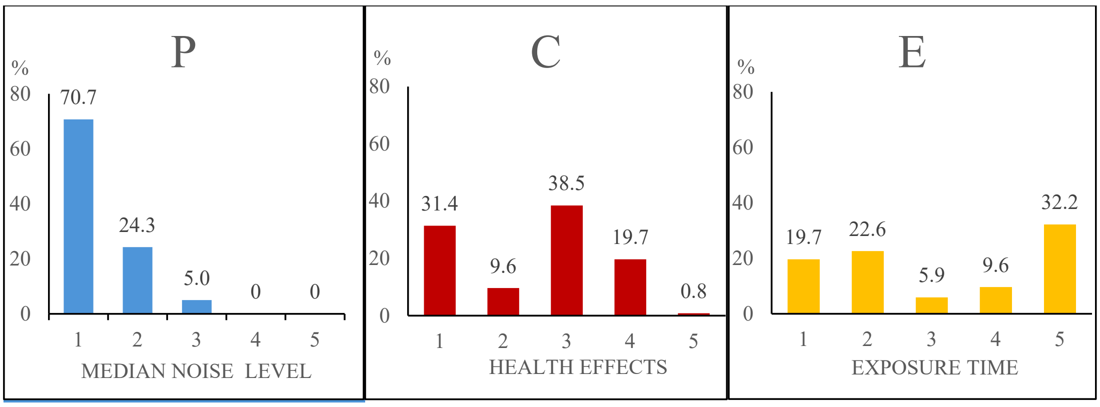

Figure 1. Percentages of workers by dimension and level in the Risk Matrix Model
Probability of risk occurrence (P): 1, 'less than 80 dBA'; 2, '80-84 dBA'; 3, '85-89 dBA'; 4, '90-94 dBA'; and 5, 'more than 94 dBA'. The consequence (C) or health effects and injuries from noise exposure: 1, 'insignificant effects'; 2, 'minor effects'; 3, 'moderate effects'; 4, 'major effects'; and 5, 'catastrophic effects'. The exposure time (E) or job years: (1, '<5 years'; 2, '5-9 years'; 3, '10-14 years'; 4, '15-19 years'; and 5, '≥20 years')

were classified as moderate (level 3), followed by insignificant (level 1) (31.4%). Finally, regarding exposure time (E), most participants had 20 or more years of on the job exposure (32.2%), followed by 5-9 years (22.6%) (Figure 1).

The calculated individual risk scores ranged from 1 to 60. The median score (Q1, Q3) was 8 (4, 15). The median risk scores by department are shown in Figure 2. The highest departmental risk scores were in the Laundry (Siriraj), the Engineering

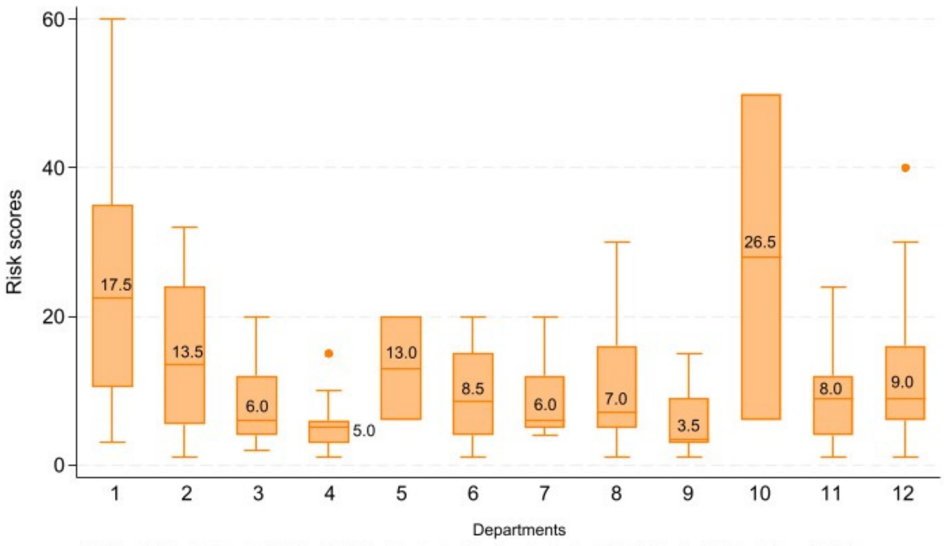

Figure 2. Median risk scores by department
Ramathibodi Hospital: 1, Engineering Service; 2, Nutrition; 3, Central Sterile Supply; 4, Obstetrics and Gynecology operating room; 5, Prosthetics and Orthotics; 6, Laundry
Siriraj Hospital : 7, Nutrition; 8, Publishing; 9, Medical Gas System; 10, Laundry; 11, Central Sterile Supply; 12, Prosthetics and Orthotics

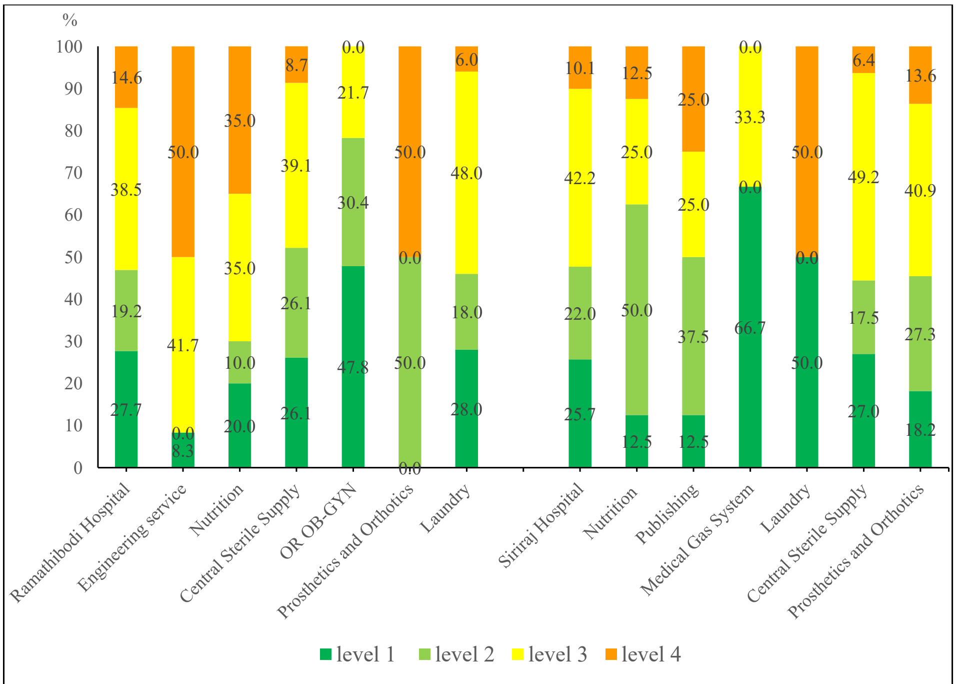

Figure 3. Proportion of individual risk level by department

Service (Ramathibodi), and the Nutrition Department (Ramathibodi). Regarding individual risk levels, most of the workers were at level 3 (moderate risk). The Engineering Service Department (Ramathibodi) had the highest proportion of workers at level 4 (high risk), followed by the Nutrition Department (Ramathibodi) (Figure 3).

Accuracy of the risk scores as a screening tool for ONIHL

The AUC of the ROC curve for predicting ONIHL was 0.667 (95%CI: 0.60-0.74). The optimal cut-off value of risk scores to discriminate between the ONIHL group and the non-ONIHL was selected at eight, with a sensitivity of 65.2% and a specificity of 55.1%. Another candidate cut-off value was a score of nine, with a sensitivity of 62.0% and a

Table 3. Association between risk categories and proportion of participants with ONIHL by simple logistic regression

Risk score	Risk level	Odds ratio (95%CI)	*p*-value	Probability	Frequency (%) (N = 239)
1-4	1	-	-	-	64 (26.8)
5-7	2	1.74 (0.76-3.96)	0.190	0.50	49 (20.5)
8-17	3	2.14 (1.05-4.35)	0.035*	0.67	96 (40.2)
18-64	4	8.98 (3.32-24.29)	< 0.001*	0.89	30 (12.6)

*Statistically significant ($p < 0.05$)

specificity of 63.9% (Supplement Table S4). However, the value of 8 is more suitable for practical use because a screening tool should have a sensitivity higher than its specificity to effectively identify high-risk workers for PTA. Early detection of ONIHL is important for the prevention of permanent hearing damage (1).

Risk score categorization (R) in the risk matrix model

The new Risk categorization (R) or Risk level was developed (Supplement Table S5) based on simple logistic regression analysis and on previous studies (9, 15, 16). Most participants were at risk level 3 (40.2%), followed by risk level 1 (26.8%). No participants were at risk level 5 (Table 3).

DISCUSSION

This study is the first to use a risk matrix and risk scores as the screening tool for the risk of ONIHL. The AUC was 0.667, which implies satisfactory performance (17, 18). At the cut-point score of eight, the sensitivity and specificity in predicting ONIHL were moderate and could be used to prioritize high-risk workers who should undergo PTA. The screening process is relatively low cost and requires no special skill set, making it suitable for limited resource settings. Another benefit is as a warning to workers who have refused to attend PTA. However, this risk matrix model should be used together with the laws or recommendations of each country regarding hearing conservation programs, e.g., NIOSH revised noise exposure criteria (13), and Occupational Safety and Health Administration (OSHA) Standard Number 1910.95 (Occupational noise exposure) (19).

The risk scores in this study were significantly lower than in another study at a metal cutting and welding center (9). In that study, risk scores ranged from 1 to 60, with a median (Q1, Q3) of 8 (4, 15). In contrast to the present study, most metal workers had unacceptable risk scores (risk scores more than 75), with median risk scores in the welding and the cutting center of 28 and 76, respectively. The difference could be a result of the lower noise level in the work environment and shorter exposure time due to shorter median job duration in the cutting and welding center (11 years compared to 18 years at the hospitals). Nevertheless, half the participants in this study (53.1% of Ramathibodi and 52.3% of Siriraj participants) were at risk levels 3 and 4, considered moderate and high risk, respectively. The hospital workplaces in those institutions need to implement further preventive measures following the hierarchy of controls as soon as possible, especially for workers at high risk. Their existing hearing conservation programs should be revised and improved. The recommendations for risk level 3 and above are similar to the study by Piňosová et al. (9), and are also applicable to other types of occupational hazards, e.g., chemical hazards in a study by Chaiklieng et al. (15).

It was noted that most workers with hearing loss (70 workers, or 76.2%) had been exposed to noise for 10 years or more and were classified as level 3 or higher for Exposure Time (E). This assigned risk category aligns with the fact that ONIHL development mostly occurred after 10 years of noise exposure (3, 14).

This study had some limitations. First, the retrospective nature of the study resulted in several issues. For example, recall biases could occur among participants with abnormal audiograms. Some workers could also have forgotten about the health effects of occupational noise exposure in the past which could have led to underreporting of symptoms. Moreover, most participants lacked baseline audiograms; therefore, excluding hearing loss from non-occupational causes was problematical. Second, work arrangements could differ from regular eight-hour shifts during the study period. For example, some participants could have to work overtime or rotate to other worksites. Therefore, the occupational noise exposure level could deviate from the estimated value. For workers who worked more than eight hours per day, the risk assessment might underestimate the risk, while those who worked less than the average might overestimate the risk category. Additionally, this study used ambient noise monitoring in the workplace for exposure assessment which might not accurately represent individual exposure. Using personal noise dosimeter data in future studies could improve the exposure assessment. Third, some workers didn't have confirmation audiograms after abnormal results, which could have led to overdiagnosis. However, the like lihood of a temporary threshold shift, the main cause of ONIHL misdiagnosis, was quite low because most workers were not exposed to loud noise for at least 12 hours before undergoing PTA (20).

Finally, some departments in this study, such as the Laundry Department at Siriraj and the Prosthetics and Orthotics Units at Ramathibodi, had small sample sizes, which might not accurately represent their actual risk. To improve the accuracy of the risk matrix screening tool, further studies should include a larger sample size and validate other settings.

CONCLUSIONS

The risk matrix to assess the risk of ONIHL was developed from three dimensional factors: probability, exposure, and concentration. The risk matrix can predict the risk of hearing loss with moderate accuracy and could help warn workers exposed to loud noise in the workplace. It should be used to screen and prioritize high-risk workers who should undergo pure tone audiometry in settings with limited resources as a means of promoting early detection of ONIHL and further noise control.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

ADDITIONAL INFORMATION

Supplementary materials

The following supporting information can be downloaded at: Supplementary materials

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Supplementary materials

P (probability of risk occurrence): the central value (median) of all annual noise levels as 8-hour TWA in the workplaces (Table S1.)

Table S1. Probability of risk occurrence (P)

Probability	Value	Noise level (dBA)	Description of probability
Rare	1	< 80	The likelihood of risk occurrence is nearly eliminated.
Unlike	2	80-84	Risk occurrence is improbable but feasible.
Possible	3	85-89	Risk occurrence is likely (occurs intermittently).
Likely	4	90-94	Risk occurrence is highly likely.
Almost certain	5	> 94	The danger of risk occurrence is highly likely.

C (consequence or severity of the risk): the most severe health effects and injuries from occupational noise exposure, obtaining from the questionnaire (Table S2)

Table S2. Consequence or severity of the risk (C)

Level	Value	Description of health effects and injuries
Insignificant	1	No compliant the impact of loud noise
Minor	2	Mild concentration difficulties, palpitation, fatigue, mild to moderate distress during work
Moderate	3	Headache, dizziness, temporary hearing loss, severe distress during work, severe concentration difficulties, mild muscle pain/spasm, tinnitus, mild to moderate communication problems
Major	4	Serious communication problems, severe sleeping disturbances, moderate to severe muscle pain/ spasm, injury at noisy work with day off < 3 days
Catastrophic	5	Injury at noisy work with day off ≥ 3 days

E (exposure time): job years in the current work areas (Table S3)

Table S3. Exposure time (E)

Exposure Level	Value	Time [year]
Negligible exposure time	1	0-4
Significant exposure time	2	5-9
High exposure time	3	10-14
Very high exposure time	4	15-19
Excessive exposure time	5	≥ 20

Table S4. Performance of Risk matrix scores (screening tool) through the comparison of cut-off value in identifying workers at risk for ONIHL

Cut-off Value	Sensitivity	Specificity
≥ 1	100%	0%
≥ 2	97.8%	6.1%
≥ 3	95.7%	15.7%
≥ 4	85.9%	24.5%
≥ 5	83.7%	33.3%
≥ 6	73.9%	42.2%
≥ 8	65.2%	55.1%
≥ 9	62.0%	64.0%
≥ 10	58.7%	70.1%
≥ 12	52.2%	72.8%
≥ 15	39.1%	82.3%
≥ 16	28.3%	92.5%
≥ 18	23.9%	94.6%
≥ 20	23.9%	95.2%
≥ 24	16.3%	96.6%

Cut-off Value	Sensitivity	Specificity
≥ 30	10.9%	98.0%
≥ 32	5.4%	99.3%
≥ 40	5.4%	100%
≥ 50	3.3%	100%
≥ 60	2.2%	100%

Table S5. Newly developed Risk score categories (R) in the Risk Matrix model

Risk level	Risk Scores	Risk Category	Action
Acceptable	1-4	1	No action required.
Low	5-7	2	No supplementary controls required. Monitoring required to ensure the maintenance of controls including annual noise level monitoring
Moderate	8-17	3	Necessary to take preventive measures to reduce the risk including annual hearing monitoring
High	18-64	4	Necessary to take preventive measurements very soon to reduce the risk as well as risk level 3

Very high (Unacceptable)	65-125	**5**	The work must be stopped until the elimination of the risk.

Departments with workers with the risk level 2 and above should have annual noise level monitoring. Moreover, departments with workers with risk level 3 and above should have both the preventive measurements and the annual PTA. Nevertheless, the risk matrix should be used together with each country's occupational health and safety laws and regulations.