Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 25 June 2026
Revised 09 Aug 2026
Accepted 22 Aug 2026

Natural Resources for Human Health 2026, Vol. 6 (18s): 410–418

KEYWORDS:
Metabolic Syndrome, Hearing Loss, Pure-Tone Audiometry

Analysis of Metabolic Risk Factors Associated with the Severity of Noise-Induced Hearing Loss among Cement Factory Workers at PT Semen Tonasa

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ABSTRACT: Noise exposure is a risk factor for hearing impairment in the workplace. Metabolic risk factors may exacerbate noise-induced hearing impairment. This study aims to analyze metabolic risk factors associated with the degree of noise-induced hearing impairment based on Pure Tone Audiometry (PTA) results. This cross-sectional study involved 98 workers from PT Semen Tonasa in Pangkep Regency who met the study criteria. Metabolic risk factors included waist circumference, fasting blood glucose (FBG), triglycerides, high-density lipoprotein (HDL), and systolic (SBP) and diastolic (DBP) blood pressure. Metabolic syndrome was defined according to the National Cholesterol Education Program-Adult Treatment Panel III (NCEP-ATP III) criteria. Hearing function was assessed via PTA, with the degree of hearing impairment categorized according to International Organization for Standardization (ISO) standards. Significant differences were observed regarding waist circumference (left ear p=0.036, right ear p=0.034) and SBP (left ear p=0.047, right ear p=0.045) in relation to the degree of hearing impairment based on PTA results. Based on NCEP-ATP III criteria, an association was also found between metabolic syndrome and the degree of hearing impairment in the left ear (p=0.016, OR=2.865) and right ear (p=0.011). However, after adjusting for age and duration of employment in the multivariate analysis, none of the metabolic syndrome components (waist circumference, FBG, triglycerides, HDL, SBP, DBP) were significant independent risk factors for the degree of hearing impairment (p>0.05). Metabolic risk factors are not the sole factors influencing the degree of hearing impairment.

1. INTRODUCTION

Workplace noise exposure has emerged as a significant global health concern. The World Health Organization (WHO) estimates that around 16% of adult hearing impairment is attributable to noise exposure in the workplace. The National Institute for Occupational Safety and Health (NIOSH) indicates that around one-third of the global workforce encounters dangerous noise levels that can lead to Noise-Induced Hearing Loss (NIHL). Sound levels over 85 decibels (dB) can inflict lasting harm on cochlear hair cells, leading to irreversible noise-induced hearing loss (NIHL); thus, mitigating and managing noise exposure is essential.[1–3]

Metabolic syndrome is a major health concern in Indonesia, with a high prevalence among the adult population. Consequently, it is important to consider its potential to cause hearing loss in labourers.[4] Chronic systemic inflammation is one of the mechanisms that connect metabolic syndrome to hearing loss. Individuals with metabolic syndrome have elevated levels of inflammation, which can inflict damage on cochlear hair cells and inner ear structures.[5,6] A better understanding of the relationship between these two conditions is expected to help develop more effective prevention and intervention strategies.

The correlation between metabolic syndrome and hearing loss has been the subject of numerous prior investigations. Rim et al. (2021) discovered that metabolic syndrome is linked to an elevated risk of sensorineural hearing loss.[6] According to Zand et

al. (2023), metabolic syndrome is linked to a worse prognosis in sensorineural hearing loss and increased hearing thresholds.[7] Amiri et al. (2026) discovered a correlation between noise-induced hearing loss (NIHL) and metabolic syndrome, including its components, in a particular group of workers exposed to noise, through an examination of cross-frequency hearing thresholds among petrochemical industry employees.[8] However, most of these studies have examined noise and metabolic factors separately; there is limited research simultaneously investigating both factors alongside audiometric evaluation by pure tone audiometry (PTA) among cement industry workers in developing countries. This study aims to analyze metabolic risk factors for noise-induced hearing loss (NIHL) by evaluating the severity of hearing impairment in relation to metabolic syndrome among cement factory workers at PT Semen Tonasa

2. MATERIALS AND METHODS

2.1 Study Design

This research is an observational analysis characterised by a cross-sectional framework. The study took place at PT Semen Tonasa in Pangkep Regency from April to June 2026. All participants underwent anthropometric evaluations, which included measurements of body weight, height, body mass index (BMI), and waist circumference, in addition to blood pressure readings and laboratory analyses for fasting blood glucose (FBG), triglycerides, and high-density lipoprotein (HDL). Following this, all participants completed PTA. An evaluation was conducted to investigate the correlation between metabolic risk variables and the extent of auditory deficiency.

2.2 Participants

The research subjects were workers at PT Semen Tonasa who met the study's inclusion and exclusion criteria. The inclusion criteria were as follows: 1) exposure to noise levels ≥85 dB; 2) working hours of ≥8 hours/day; 3) employment duration of ≥10 years; and 4) age between 30 and 50 years. The exclusion criteria were as follows: 1) history of congenital hearing impairment; 2) history of acute acoustic trauma; 3) presence of a tumor in the ear, nose, or throat; or 4) use of ototoxic medications. A purposive sampling technique was employed.

2.3 Ethical Clearance

This research has obtained authorisation and ethical clearance from the Health Research Ethics Committee at the Faculty of Medicine, Hasanuddin University. All participants were apprised of the study's aims and methodologies. All participants consented to take part in the study and signed the informed consent

2.4 Operational Definition

Metabolic Syndrome

Metabolic syndrome is identified based on the National Cholesterol Education Program-Adult Treatment Panel III (NCEP-ATP III) criteria when three or more of the following five factors are present: abdominal obesity (waist circumference of at least 102 cm in men or 80 cm in women), elevated triglycerides (150 mg/dL or higher, or ongoing triglyceride-lowering treatment), diminished HDL-C (below 40 mg/dL in men or below 50 mg/dL in women), hypertension (systolic pressure of 130 mmHg or higher and/or diastolic pressure of 85 mmHg or higher, or current antihypertensive medication use), and hyperglycemia (fasting plasma glucose of 100 mg/dL or higher, or current diabetes mellitus treatment).

Degree of hearing loss based on PTA examination

The degree of hearing impairment is determined based on the average hearing threshold across four frequencies (500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz), calculated by summing the values and dividing by four. The classification of the degree of hearing impairment follows the criteria of the International Organization for Standardization:

a) <25 dB = Normal
b) 26 – 40 dB = Mild hearing loss
c) 41 – 55 dB = Moderate hearing loss
d) 56 – 70 dB = Moderate-severe hearing loss
e) 71 – 90 dB = Severe hearing loss
f) > 90 dB = Very Severe hearing loss

Noise Intensity

The noise intensity in the work environment of PT Semen Tonasa was measured using a Smart Sensor mini digital sound level meter (SLM). The measurement range of the device is 30–130 dB. The results of the measurement are digitally displayed on the monitor and recorded in decibels (dB).

2.5 Data analysis

The data analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 29.0. The means and standard deviations of subject characteristics, including age, duration of employment, waist circumference, fasting blood glucose (FBG), triglycerides, HDL, and systolic and diastolic blood pressure, are presented. The graphic representation of the degree of Noise-Induced Hearing Loss (NIHL) in both ears is provided. The Shapiro-Wilk test was employed to conduct normality testing on numerical variables, including age, duration of employment, waist circumference, FBG, triglycerides, HDL, and systolic and diastolic blood pressure. The Mann-Whitney test was employed to analyse the risk factors associated with the degree of hearing impairment in the left ear, as determined by the PTA results. The Kruskal-Wallis test was employed for the analysis of the right ear. The Chi-square test was employed to analyse the relationship between metabolic syndrome and the degree of hearing impairment in the left ear, while the Fisher's exact test was employed in the right ear. Logistic regression was implemented to execute multivariate analysis. A 95% confidence level was implemented, and p-values less than 0.05 were regarded as statistically significant.

3. RESULTS AND DISCUSSION

3.1 Subject Characteristics

A total of 98 workers from the PT Semen Tonasa were involved in this investigation. The baseline characteristics of the study subjects are summarised in **Table 1.** The subjects' average age was 47.98 years. The majority of the subjects had been employed for a significant period, as evidenced by the mean duration of employment of 25.6 years.

Table 1. Baseline Characteristics of Study Subjects

Characteristics	**Mean (SD)**
Age (years)	47.98 (4.4)
Length of Work (years)	25.6 (7.6)
Waist circumference (cm)	100.8 (7.1)
FBG (mg/dL)	90.1 (19.5)
Triglycerides (mg/dL)	166.4 (100.7)
HDL (mg/dL)	41.3 (11.4)
Systole (mmHg)	132.4 (16.0)
Diastole (mmHg)	84.8 (11.4)

3.2 Noise Intensity at the Research Site

Noise intensity measurements suggest that the average noise level in the entire work area is 83.6 dBA, which is on the cusp of the 85 dBA Threshold Limit Value (TLV) for an 8-hour workday exposure. In the Makassar Packing Plant workshop, the noise intensity was the lowest at 55.8 dBA, while the highest was recorded at Kiln Area 4 (100.9 dBA).

Twenty-eight (53.8%) of the 52 measurement points exceeded the TLV, while 24 (46.2%) remained below it. Points that exceeded the TLV were predominantly situated in production areas, including the limestone and clay crushers, coal mill, kiln, raw mill, and finish mill, which are considered sources of high-intensity machinery noise. In contrast, the quality control laboratory, offices, and workshops were typically located in areas with noise levels that were below the TLV. These results suggest that over 50% of the measurement sites are located in high-risk zones, where prolonged noise exposure could potentially result in hearing impairment if proper personal protective equipment is not utilised.

3.3 Degree of NIHL among PT Semen Tonasa Workers Based on PTA Examination

Figure 1 showed that the majority of respondents demonstrated moderate and moderate-to-severe NIHL in both ears, as indicated by PTA results of 98 workers. In the left ear, 50 workers (51.0%) had moderate NIHL, while 48 workers (49.0%) had moderate-to-severe NIHL. No workers presented with mild or severe NIHL. Concurrently, 48 workers (49.0%) exhibited

moderate-to-severe NIHL in the right ear, 46 workers (46.9%) exhibited moderate NIHL, and 4 workers (4.1%) exhibited mild NIHL.

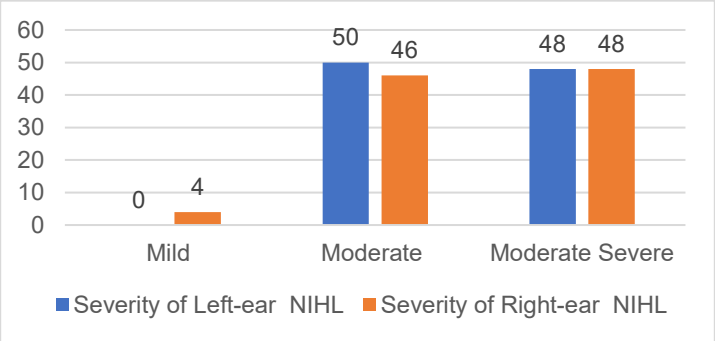


Figure 1. Degree of NIHL in 98 PT Semen Tonasa workers based on PTA examination.

3.4 Analysis of Risk Factors Associated with the Severity of Noise-Induced Hearing Impairment Based on PTA

Table 2 illustrates substantial disparities in numerous risk factors between workers who have moderate and moderate-severe NIHL in the left ear. The mean age of the moderate-severe NIHL group was significantly higher than that of the moderate group (49.7 ± 1.5 vs. 46.0 ± 5.4 years; $p < 0.001$). The moderate-severe group had a longer mean duration of employment than the moderate group (30.0 ± 2.7 vs. 20.9 ± 7.8 years; $p < 0.001$). The mean waist circumference was also significantly higher in the moderate-severe group (102.5 ± 7.5 cm) than in the moderate group (99.2 ± 6.5 cm; $p = 0.036$). Additionally, the moderate-severe group reported a higher mean systolic blood pressure than the moderate group (135.4 ± 14.4 vs. 129.4 ± 17.0 mmHg; $p = 0.047$). In contrast, there were no significant differences between the two groups in terms of FBG ($p = 0.657$), triglycerides ($p = 0.443$), HDL ($p = 0.413$), or DBP ($p = 0.202$).

Additionally, **Table 2** demonstrates substantial disparities in the duration of employment and age among the various NIHL severity grades in the right ear. The mean age of the mild, moderate, and moderate-severe groups indicated an increasing trend as the severity of NIHL increased: 43.5 ± 5.1 years, 46.0 ± 5.5 years, and 50.0 ± 0.0 years, respectively ($p < 0.001$). The mean length of work increased in accordance with the severity of NIHL: 17.0 ± 9.4 years in the mild group, 21.0 ± 7.7 years in the moderate group, and 30.7 ± 2.0 years in the moderate-to-severe group ($p < 0.001$). More severe NIHL was associated with a significant increase in waist circumference ($p = 0.034$) (99.2 ± 7.3 cm, 98.8 ± 6.2 cm, and 102.9 ± 7.5 cm). Systolic blood pressure also exhibited a substantial increase ($p = 0.045$) as the severity of NIHL increased (133.0 ± 30.0 mmHg, 128.4 ± 15.3 mmHg, and 136.1 ± 14.8 mmHg). Furthermore, there were no statistically significant differences between the NIHL severity groups in terms of FBG ($p = 0.776$), triglycerides ($p = 0.614$), HDL ($p = 0.299$), and DBP ($p = 0.064$).

Table 2. Analysis of Risk Factors Associated with the Degree of Noise-Induced Hearing Impairment Based on PTA

Risk Factor	Left Ear			Right Ear			
	NIHL			NIHL			
	Moderate (n=50)	Moderate-Severe (n=48)	P-value*	Mild (n=4)	Moderate (n=46)	Moderate-Severe (n=48)	p-value**
Age (years), Mean (SD)	46.0 (5.4)	49.7 (1.5)	**<0.001**	43.5 (5.1)	46.0 (5.5)	50.0 (0.0)	**<0.001**
Length of work (years), Mean (SD)	20.9 (7.8)	30.0 (2.7)	**<0.001**	17.0 (9.4)	21.0 (7.7)	30.7 (2.0)	**<0.001**
Waist circumference	99.2 (6.5)	102.5 (7.5)	**0.036**	99.2 (7.3)	98.8 (6.2)	102.9 (7.5)	**0.034**

(cm), Mean (SD)							
FBG (mg/dL), Mean (SD)	89.2 (19.4)	91.0 (19.7)	0.657	92.0 (9.2)	90.5 (18.9)	89.5 (21.0)	0.776
Triglyceride (mg/dL), Mean (SD)	154.2 (68.9)	179.1 (125.1)	0.443	222.0 (207.1)	148.2 (43.2)	179.2 (125.1)	0.614
HDL (mg/dL), Mean (SD)	42.1 (11.2)	40.5 (11.6)	0.413	45.0 (11.3)	43.0 (12.2)	39.3 (10.5)	0.299
Systole (mmHg), Mean (SD)	129.4 (17.0)	135.4 (14.4)	**0.047**	133.0 (30.0)	128.4 (15.3)	136.1 (14.8)	**0.045**
Diastole (mmHg), Mean (SD)	83.6 (10.1)	86.0 (12.6)	0.202	86.2 (13.6)	82.3 (10.0)	87.1 (12.2)	0.064

*Mann-whitney **Kruskal-wallis

The severity of left-ear NIHL is significantly correlated with metabolic syndrome (p = 0.016), as demonstrated in **Table 3**. The moderate-to-severe NIHL group had a slightly higher proportion of workers with metabolic syndrome than the moderate NIHL group: 77.1% (37/48) versus 54.0% (27/50). In contrast, the moderate NIHL group had a higher proportion of workers without metabolic syndrome than the moderate-to-severe group (46.0% vs. 22.9%). Workers with metabolic syndrome had 2.865 times the likelihood of experiencing moderate-to-severe NIHL compared to those without metabolic syndrome, as indicated by an Odds Ratio (OR) of 2.865. The analysis also demonstrated a substantial correlation between the severity of right-ear NIHL and metabolic syndrome (p = 0.011). As the severity of NIHL increased, the proportion of workers with metabolic syndrome also increased: 50.0% in the modest group, 52.2% in the moderate group, and 79.2% in the moderate-to-severe group. In contrast, the proportion of workers without metabolic syndrome decreased as the severity of NIHL increased, with values of 50.0%, 47.8%, and 20.8% for the respective groups. These findings suggest that metabolic syndrome is linked to an elevated severity of NIHL among workers of PT Semen Tonasa.

Table 3. Analysis of the Relationship between Metabolic Syndrome and the Degree of Noise-Induced Hearing Impairment Based on PTA

Metabolic Syndrome	Left Ear				Right Ear			
	NIHL		p-value*	OR	NIHL			p-value**
	Moderate (n=50)	Moderate-Severe (n=48)			Mild (n=4)	Moderate (n=46)	Moderate-Severe (n=48)	
Yes, n (%)	27 (54.0)	37 (77.1)	0.016	2,865	2 (50.0)	24 (52.2)	38 (79.2)	0.011
No, n (%)	23 (46.0)	11 (22.9)			2 (50.0)	22 (47.8)	10 (20.8)	

*Chi-square **Fisher exact

3.5 Multivariate Analysis of Risk Factors Associated with the Severity of Noise-Induced Hearing Impairment Based on PTA

Table 4 illustrates that the severity of NIHL in the left ear was only independently correlated with age and duration of employment. After adjusting for other variables in the model, the age variable had an adjusted odds ratio (aOR) of 0.652 (95%

CI: 0.449–0.945; p = 0.024). This ratio indicates that a 34.8% reduction in the risk of developing moderate-to-severe NIHL was associated with each one-year increase in age, compared to moderate NIHL. In contrast, the duration of employment was a significant risk factor, with an aOR of 1.774 (95% CI: 1.329–2.369; p < 0.001). This suggests that the risk of developing moderate-to-severe NIHL increased by 77.4% with each additional year of employment. Meanwhile, waist circumference (aOR = 0.998; 95% CI: 0.916–1.088; p = 0.968), FBG (aOR = 1.006; 95% CI: 0.972–1.040; p = 0.737), triglycerides (aOR = 1.002; 95% CI: 0.994–1.010; p = 0.585), HDL (aOR = 1.003; 95% CI: 0.942–1.067; p = 0.925), systolic blood pressure (aOR = 0.997; 95% CI: 0.932–1.066; p = 0.921), and DBP (aOR = 0.974; 95% CI: 0.894–1.060; p = 0.539) did not show a statistically significant association with the severity of NIHL after adjustment for other variables in the model.

The analysis also demonstrated that the severity of NIHL in the right ear was independently correlated with the duration of employment. After taking into account the other variables in the model, the duration of employment variable had an aOR of 1.456 (95% CI: 0.205–0.548; p < 0.001). This suggests that the risk of experiencing a more severe degree of NIHL increased by 45.6% with each additional year of employment. In contrast, the degree of NIHL was not statistically associated with age (p = 0.331), waist circumference (p = 0.653), FBG (p = 0.666), triglycerides (p = 0.777), HDL (p = 0.520), SBP (p = 0.422), and DBP (p = 0.755) after adjusting for other variables in the model.

Table 4. Multivariate Analysis of Risk Factors Affecting Hearing Impairment Due to Noise Exposure Based on PTA

Risk Factor	Left Ear			Right Ear		
	aOR	95%CI (Lower-Upper)	p-value	aOR	95% (Lower-Upper)	p-value
Age	0.652	0.559-0.945	**0.024**	0.893	-0.340-0.115	0,331
Length of Work	1.774	1.329-2.369	**<0.001**	1.456	0.205-0.548	**<0.001**
Waist circumference	0.998	0.916-1.088	0.968	1.017	-0.057-0.091	0.653
FBG	1.006	0.972-1.040	0.737	0.994	-0.031-0.020	0.666
Triglycerides	1.002	0.994-1.010	0.585	0.999	-0.006-0.005	0.777
HDL	1.003	0.942-1.067	0.925	0.984	-0.067-0.034	0.520
Systole	0.997	0.932-1.066	0.921	0.978	-0.077-0.032	0.422
Diastole	0.974	0.894-1.060	0.539	1.011	-0.060-0.083	0.755

Note: Binary logistic regression analysis; aOR = adjusted odds ratio; CI = confidence interval; bold values are statistically significant (p<0.05).

3.5 Discussion

The length of work is the factor that is most consistently associated with the severity of NIHL in both ears, as indicated by the findings of this study. This discovery is consistent with a variety of recent investigations. Mutthumanickam et al. (2024) conducted research on palm oil mill workers in Malaysia and discovered that the risk of NIHL was increased by a tenure of 10 years or more (adjusted odds ratio [aOR] 2.41; 95% CI: 1.14–5.07) and a history of workplace noise exposure at previous jobs (aOR 5.89; 95% CI: 2.38–14.53). However, the use of hearing protection was protective (aOR 0.36; 95% CI: 0.16–0.83). A study conducted by Elshaer et al. (2023) on steel industry workers in Egypt also indicated a correlation between hazardous noise exposure and elevated hearing thresholds across all frequencies.2 Kim et al. (2024) conducted research on 237,028 noise-exposed labourers in South Korea, which demonstrated that the prevalence of cardiometabolic disease increased with the duration of employment. Specifically, the prevalence was 15.1%, 17.6%, 20.9%, and 23.3% for tenures of <5, 5–9, 10–19, and ≥20 years, respectively.[10]

The bivariate analysis found only significant differences in waist circumference and systolic blood pressure among the five metabolic syndrome components that were examined. In the moderate-to-severe group, the left ear had a greater waist circumference, whereas the right ear exhibited a trend of increasing values with the degree of severity, attaining statistical significance. The left ear exhibited a higher systolic blood pressure in the moderate-to-severe group, while the right ear exhibited a trend of increasing values that corresponded to the severity. Conversely, there were no substantial contrasts in the fasting

blood glucose, triglycerides, HDL, and diastolic blood pressure of either ear. Central adiposity and hearing loss are associated with a robust pathophysiological foundation. Yang et al. (2020) conducted a systematic review and meta-analysis that revealed a positive correlation between the risk of hearing loss and both body mass index and waist circumference.[11] The underlying mechanisms are characterised by a chronic pro-inflammatory state that is the result of excess adipose tissue, which induces hypoxia and ischaemic injury, as well as increased oxidative stress and vascular dysfunction.[12] Cochlear blood flow can be reduced by obesity-related vascular damage, which is characterised by the stiffening and constriction of the internal auditory artery. This can result in capillary constriction in the stria vascularis, cell mortality, and reduced auditory sensitivity. Given that the cochlea is an organ with high metabolic demands that is dependent on a terminal artery that lacks collateral circulation, even minor reductions in perfusion can exacerbate the damage already caused by acoustic trauma.[13–15]

This study also illustrates that the degree of hearing loss in both ears is correlated with systolic blood pressure, but diastolic blood pressure is not. This is consistent with the research conducted by Kim et al. (2024) on 237,028 noise-exposed workers in South Korea. The study demonstrated a clear dose-response relationship between the degree of hearing loss and hypertension, with adjusted odds ratios of 1.147 (95% CI: 1.098–1.198), 1.196 (95% CI: 1.127–1.270), and 1.212 (95% CI: 1.124–1.306) for mild, moderate, and moderate-severe degrees, respectively, in comparison to the normal group.[10] From a mechanistic perspective, noise functions as a psychosocial stressor that activates the hypothalamic-pituitary-adrenal axis and the sympathetic nervous system, resulting in an increase in the levels of adrenaline, noradrenaline, and cortisol. These hormones are all involved in the regulation of blood pressure. The role of blood-labyrinth barrier disruption as a common link between hypertension and noise-induced hearing loss (NIHL) has been highlighted in recent reviews. This is due to the fact that endothelial dysfunction in the cochlear microcirculation increases the susceptibility to acoustic trauma.[16,17] Consequently, the bidirectional nature of the relationship between blood pressure and NIHL renders it impossible to ascertain the direction of causality in our cross-sectional study.

The absence of statistical significance in this study with respect to triglyceride, HDL, and fasting blood glucose levels is in accordance with certain existing literature. The most pronounced effect was observed in the increase of triglyceride levels, although the effect of NIHL on the reduction of HDL levels was not statistically significant, according to a study conducted by Amiri et al. (2026) that involved 1,142 petrochemical industry workers.[8] In contrast, a study conducted by Dehagho et al. (2023) on oil and gas industry workers identified hypertriglyceridemia as a component associated with NIHL, with an odds ratio of 1.255.[18] The non-significant results concerning lipid components may be attributed to a variety of factors. Initially, the triglyceride levels exhibited significant variability, with a standard deviation of 100.7 mg/dL across all subjects and 125.1 mg/dL in the moderate-to-severe left-ear group. This highly skewed distribution diminished the statistical power to detect differences. Secondly, the analysis regarded these levels as continuous variables, whereas metabolic syndrome criteria are categorical and based on specific cut-off points. Consequently, potential threshold effects may have been overlooked. Third, the mean HDL level (41.3 mg/dL) was exceedingly near to the 40 mg/dL cut-off for men, which resulted in the majority of subjects clustering around this threshold and minimal contrast between groups. A re-analysis that involves the categorisation of each component in accordance with the NCEP-ATP III criteria is necessary.[8,18]

An important discovery of this investigation is that despite the absence of a significant association between the severity of NIHL in both ears and the majority of individual components of metabolic syndrome, metabolic syndrome as a unified diagnosis was significantly correlated with NIHL. The proportion of workers with metabolic syndrome in the moderate-to-severe group was 77.1%, while the proportion in the moderate group was 54.0%. This resulted in an odds ratio of 2.865 for the left ear. For the right ear, the proportion increased gradually: 50.0% in the mild group, 52.2% in the moderate group, and 79.2% in the moderate-to-severe group. The hypothesis of a cumulative or clustering effect is substantiated by this gradient pattern, which posits that the simultaneous accumulation of multiple metabolic disorder components has a greater impact on cochlear function than the contribution of each component in isolation. This hypothesis is corroborated by research conducted on noise-exposed workers in South Korea, which demonstrated that the prevalence of metabolic syndrome increased in proportion to the severity of hearing loss: 16.6% in the normal group, 21.7% in the mild group, 22.4% in the moderate group, and 23.2% in the moderate-to-severe group.[10] Research by Amiri et al. (2026) concluded that frequency-specific NIHL patterns are associated with an increased likelihood of metabolic syndrome.[8] The microvascular endothelium is damaged by the synergistic action of insulin resistance, atherogenic dyslipidaemia, hypertension, and low-grade chronic inflammation from a pathophysiological perspective. The cochlea is highly susceptible to microcirculatory disturbances, which significantly impact its tolerance threshold to trauma, as it depends on the stria vascularis to sustain the endocochlear potential.[12,16,19]

The length of work was the sole factor consistently and independently associated with the degree of NIHL in both ears, as determined by multivariate analysis. In terms of clinical implications, this suggests that the cumulative noise dose over the course of employment is the primary determinant of NIHL severity, surpassing the contributions of all analysed metabolic components. These results are consistent with the research conducted by Mutthumanickam et al. (2024) on palm oil mill labourers, which also identified duration of employment as an independent predictor of NIHL after adjustment.[9] In contrast, the multivariate analysis results for the age variable in relation to the left ear necessitate a very circumspect interpretation. The results are clear: a one-year increase in age reduces the likelihood of experiencing moderate-to-severe impairment by 34.8%. The direction of this association is in direct opposition to the bivariate analysis results from the same study, which indicated that the moderate-to-severe group had higher ages. Additionally, it is inconsistent with the existing literature, which consistently identifies age as a risk factor for hearing impairment.[10,20] Therefore, these findings cannot be interpreted as a biological protective effect of age. Another point to consider is that the multivariate model in this study included metabolic syndrome components only as separate continuous variables, rather than including metabolic syndrome as a dichotomous composite variable. The lack of statistical significance for the individual metabolic components in the multivariate analysis does not imply that metabolic syndrome plays no role; instead, it suggests that the metabolic effects in this population are cumulative and go undetected when the components are analyzed in isolation.

There are numerous constraints associated with this investigation. Initially, the cross-sectional design is limited to the identification of associations and is unable to determine the direction of causality, particularly in the context of the theoretically bidirectional relationship between metabolic syndrome and NIHL. Secondly, the absence of a comparison group of workers who were not exposed to noise prevented the direct quantification of the extent to which noise exposure contributes to hearing impairment. Third, the model's capacity to differentiate the effects of presbycusis from those of cumulative noise exposure was restricted by the narrow age range of the subjects and the strong collinearity between age and duration of employment. Fourth, the Kruskal-Wallis and Fisher test results for the "mild" (n = 4) and "severe" (n = 1) groups for the right ear were not precise due to the small number of subjects in these strata. Consequently, these findings should be interpreted as trends rather than stable estimates. Fifth, noise measurements were conducted using a sound level meter within an area rather than based on personal dosimetry. Consequently, the actual individual exposure dosages, which included the impact of worker mobility between areas, could not be accurately estimated. Sixth, the study did not examine a number of potential confounding variables that are known to impact hearing function. These variables include the level of compliance with and quality of hearing protection device (HPD) usage, the history of noise exposure in previous jobs (a known strong predictor), smoking habits, the history of ototoxic medication use, the history of head trauma, the history of ear infections, and combined noise and dust exposure, which is prevalent in the cement industry. Seventh, the analysis of metabolic components regarded levels as continuous variables, which could have resulted in the undetected assessment of threshold effects that correspond to metabolic syndrome diagnostic criteria. Eighth, the notch characteristic at 4000 Hz, which is a defining feature of NIHL, and the quantitative correction of presbycusis were not possible due to the absence of audiometric data by frequency (500–8000 Hz) and age-related hearing threshold corrections in accordance with ISO 7029.

4. CONCLUSION

Waist circumference and systolic blood pressure are risk factors influencing the degree of hearing loss in both ears. However, after adjusting for several variables, waist circumference and systolic blood pressure are not independent risk factors affecting the degree of hearing loss.

ACKNOWLEDGEMENTS

None

AUTHOR CONTRIBUTIONS

AMA, RD, and AA designed the research concept. AMA conducted the research, collected and analyzed the data, and drafted the manuscript. RD, AA, FH, MAA, and AQP provided supervision. All authors have approved the changes made to the research and the manuscript

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

DATA AVAILABILITY STATEMENT

Data supporting the findings of this study are not available

REFERENCES

[1] Nurrokhmawati Y, Nataliningrum DM, Anggraeny D. Original Article Noise induced hearing loss among furniture factory workers PT Chitose Cimahi. 2022;1(6):10–8.
[2] Elshaer N, Meleis D, Mohamed A. Prevalence and correlates of occupational noise - induced hearing loss among workers in the steel industry. J Egypt Public Health Assoc. 2023.
[3] Salih H, Zmnako S, Chalabi Y. The prevalence of occupational noise-induced hearing loss among workers in metal industries in the Sulaimani governorate. J Med Pharm Chem Res. 2024;6(2):887–97.
[4] Herningtyas EH. Prevalence and distribution of metabolic syndrome and its components among provinces and ethnic groups in Indonesia. 2019;1–12.
[5] Kalinec GM, Lomberk G, Urrutia RA, Kalinec F. Resolution of Cochlear Inflammation : Novel Target for Preventing or Ameliorating Drug- , Noise- and Age-related Hearing Loss. 2017;11(7):1–24.
[6] Rim H sung, Kim M gu, Park D choon, Kim S soo, Kang D woong, Kim S hoon, et al. Association of Metabolic Syndrome with Sensorineural Hearing Loss. 2021.
[7] Zand V, Dadgarnia M, Baradaranfar M, Meybodian M. The association between metabolic syndrome and the prognosis of idiopathic sudden sensorineural hearing loss. Eur Arch Oto-Rhino-Laryngology. 2022.
[8] Amiri A, Soltani E, Khavanin A, Rashnoudi P. Assessment of noise-induced hearing loss based on frequency analysis and its association with metabolic syndrome : a case study in a petrochemical industry. 2026.
[9] Mutthumanickam G, Supramanian RK, Lim YC. Prevalence and Factors Associated With Occupational Noise-Induced Hearing Loss Among Palm Oil Mill Workers in Selangor , Malaysia. 2024.
[10] Kim CH su, Lauritsen KL, Nguyen SA, Meyer TA, Cumpston EC, Pelic J, et al. Characteristics of Hearing Loss in Type 2 Diabetes Mellitus: A Systematic Review and Meta-Analysis. Otolaryngol Head Nect Surg. 2024;173(6):1317–21.
[11] Yang J rong, Hidayat K, Chen C long, Li Y hong, Xu J ying, Qin L qiang. Body mass index , waist circumference , and risk of hearing loss : a meta-analysis and systematic review of observational study. 2020;9:1–9.
[12] Terreros G, Tapia A, Alvarez F. Obesity and hearing loss: mechanisms and future challenges. Obes Rev. 2025.
[13] Zhang H, Fang Q, Li M, Yang L, Lai X, Wang H, et al. Hearing loss increases all - cause and cardiovascular mortality in middle - aged and older Chinese adults : the Dongfeng - Tongji Cohort Study. Environ Sci Pollut Res. 2023;30(32):78394–407.
[14] Lalusu RGY, Pontoh I, Wijayanti A, Yani A. Literature Review on the Relationship Between Hearing Impairment and Obesity. 2025;8(4).
[15] Jung W, Kim J, Cho IY, Jeon KH, Song YM. Association between Serum Lipid Levels and Sensorineural Hearing Loss in Korean Adult Population. Korean J Fam Med. 2022;43(5):334–43.
[16] Förster CY, Stavrakis S, Scheper V, Lenarz T. Interplay between noise-induced sensorineural hearing loss and hypertension : pathophysiological mechanisms and therapeutic prospects. 2025;(4):1–13.
[17] Miao L, Zhang J, Yin L, Pu Y. Hearing loss and hypertension among noise- exposed workers : a pilot study based on baseline data. Int J Environ Health Res.2022;00(00):1–13.
[18] Dehaghi BF, Mohammadi A. Investigation of the Relationship Between Noise - Induced Hearing Loss and Metabolic Syndrome in One of the Oil Industries in the South of Iran. Indian J Otolaryngol Head Neck Surg.2023;75(s1):43–9.
[19] Madhan S, Bambore R, Rao S, Parameshwarappa A. Evaluation of the Effects of Dyslipidemia on Hearing in Patients with Type 2 Diabetes Mellitus. Indian J Otolaryngol Head Neck Surg [Internet]. 2023;75(s1):541–7.
[20] Ramalingam A, Davis P, Ganesan P, Velayutham P. Prevalence of Noise-Induced Hearing Loss Among Construction Workers in Puducherry , India. 2024;16(10).