Preplanned Studies

Exploring the Association Between Occupational Noise Exposure and Perimenopausal Syndrome Among Female Workers — Five Provinces, China, 2023–2024

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Summary

What is already known about this topic?

Occupational noise is a multisystem hazard that can damage women's reproductive health.

What is added by this report?

This study revealed a high prevalence (53.3%) (1,205/2,262) of perimenopausal syndrome (PMS) among female workers. Noise exposure and PMS scores were significantly correlated, with both the 8-h equivalent sound level and cumulative noise exposure exhibiting linear dose–response relationships with the PMS scores.

What are the implications for public health practice?

Targeted intervention strategies are necessary to address PMS among noise-exposed female workers, including noise risk management, occupational health education, and psychological support. Incorporating perimenopausal health monitoring into routine occupational physical examinations for female workers is essential.

ABSTRACT

Introduction: The correlation between noise exposure and perimenopausal syndrome (PMS) among female workers is rarely reported. This study aimed to identify the relationship between noise exposure and PMS among female workers, providing a basis for comprehensive occupational health intervention strategies for female workers exposed to noise.

Methods: This cross-sectional survey included 2,262 noise-exposed female workers. Individual noise exposure [e.g., 8-h equivalent sound level ($L_{Aeq,8h}$) and cumulative noise exposure (CNE)] was measured. PMS was evaluated using the modified Kupperman Menopause Index. Binary logistic regression and restricted cubic spline analysis were used to evaluate the association between noise exposure and PMS.

Results: Among participants, 1,205 (53.3%) had symptoms of PMS, including fatigue (59.6%, 1,349/2,262), insomnia (56.3%, 1,273/2,262), and irritability (52.3%, 1,183/2,262). The noise exposure level for 840 (37.14%) people exceeded 85 dB(A). PMS scores were positively correlated with $L_{Aeq,8h}$ (odds ratio 1.631, 95% confidence interval 1.260–2.116) and CNE (1.726, 1.298–2.298) (P<0.01). Both $L_{Aeq,8h}$ and CNE had a dose–response relationship with PMS scores (P<0.01). $L_{Aeq,8h}$ >83 dB(A) and CNE >91 dB(A)·year were action thresholds for increased PMS risk.

Conclusion: Occupational noise exposure significantly increases the risk of PMS among female workers, suggesting a need for targeted preventive strategies in this population.

Perimenopausal syndrome (PMS) usually occurs between the ages of 40 and 55, involving a gradual decline in ovarian function, with fluctuating and decreasing estrogen levels. Patients present with menstrual irregularities, vasomotor symptoms, and neuropsychiatric symptoms (*1*). Because perimenopausal women are more susceptible to health risk factors, their health becomes more vulnerable.

Prolonged workplace noise exposure not only causes hearing damage but also affects multiple systems through mechanisms such as neuroendocrine effects, oxidative stress, and chronic inflammation (*2*). Noise exposure can cause endocrine disruption and alter hormone secretion levels (*3*). No definitive evidence has established a causal relationship between PMS and noise exposure (*4*). There are few reports on the dose–response relationship between noise exposure and PMS. This cross-sectional survey aimed to explore the association between noise exposure and PMS scores and its dose–response relationship, providing scientific evidence for occupational health protection and reproductive health interventions for female industrial workers.

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Female workers currently employed in five typical noise-exposed industries (textiles, food processing, coal mining, automotive manufacturing, and electronics manufacturing) were selected from production workshops or work sections with documented occupational noise exposure across four provinces in China. The inclusion criteria were current employment, age 40–55 years, and ≥1 year of cumulative noise exposure (CNE) duration in the current position. Although the clinical perimenopausal period generally spans from age 40 to 60, the upper age limit in this study was set at 55 years for two reasons. First, the statutory retirement age for female workers in China is 55 years, and the proportion of employed female workers over 55 years of age in the occupational population is extremely low. Second, the age range of 40–55 years fully covers the core stage of the perimenopausal period for employed women and has been adopted in similar epidemiological studies, facilitating horizontal comparisons of study findings. There are no specific gold-standard diagnostic criteria for PMS. The modified Kupperman Menopause Index (KMI) is widely used for the screening and quantitative assessment of PMS in epidemiological investigations and primary healthcare settings. This scale covers core somatic and neuropsychological symptoms characteristic of perimenopausal transition (*5*). For differential clinical diagnosis, serum sex hormone testing was further supplemented to assist in clinical judgment.

The exclusion criteria were as follows: 1) Women with natural menopause lasting >1 year, who were classified as postmenopausal individuals with stable serum hormone levels. Their physiological profiles differ substantially from those in the perimenopausal transition. 2) Patients with malignant tumors of the reproductive system, as both the tumors and corresponding treatments disrupt hormone secretion and trigger symptoms that overlap with manifestations of PMS. 3) Pregnant or lactating women experiencing physiological amenorrhea and dramatic hormonal fluctuations. 4) Women diagnosed with endometriosis, premature ovarian failure, or other gynecological disorders that markedly impair ovarian function and endocrine homeostasis. Finally, 2,262 participants were included (Supplementary Figure S1, available at https://weekly.chinacdc.cn). The study protocol was approved by the Ethics Committee of the National Institute of Occupational Health and Poison Control, Chinese Center for Disease Control and Prevention (NIOHP202324).

Individual noise exposure (8-h normalized A-weighted equivalent continuous sound level [$L_{Aeq,8h}$]) was measured throughout the shift using an individual noise meter (ASV5910-R, Hangzhou Aihua Instruments Co., Ltd., Hangzhou, China) for each participant, according to the Chinese occupational standard, Measurement of Physical Factors in the Workplace-Part 8: Noise (GBZ/T 189.8-2007). CNE was calculated as follows:

$$CNE = L_{Aeq,8h} + 10 \cdot \lg(T),$$

where T is the actual years of exposure

The "Female Workers' Reproductive Health Survey Questionnaire," developed by the Chinese Center for Disease Control and Prevention, collected basic information, occupational history, and reproductive and mental health data. The modified KMI was used to assess PMS. Participants were categorized into four groups: asymptomatic (0–5), mild (6–15), moderate (16–30), and severe (>30) (*1*).

Normally distributed continuous variables were described as $\bar{x}\pm s$, and non-normally distributed data as M (P25, P75). The rank-sum test was used for analysis. Categorical data were presented as *n* (%) and analyzed using the rank-sum test. Correlation analysis was performed using Spearman's correlation coefficient. A KMI score ≥6 was defined as having PMS and was coded as 1 in the binary logistic regression analysis; a KMI score <6 was defined as the absence of PMS and coded as 0. Binary logistic regression was used to examine the association between PMS scores and noise exposure. Restricted cubic splines (RCS) were used to explore the dose–response relationship. Exploratory subgroup analyses of CEN and KMI were performed by industry sector, hearing protection device (HPD) use, and work shift (Supplementary Table S1, available at https://weekly.chinacdc.cn).

A standardized operations manual was developed, and all investigators attended a two-day centralized training program. A pilot survey was conducted to test the feasibility of the entire survey process. A formal survey was administered using an on-site, centralized, self-administered questionnaire. All valid questionnaires were entered independently by two data entry personnel in parallel, followed by cross-checking; any discrepancies were resolved by referring to the original paper questionnaires.

The average age of the female workers was 44.3±3.3 years (Table 1). The average $L_{Aeq,8h}$ was 82.1±6.9 dB(A); 61.63% of participants had exposure levels exceeding 80 dB(A) and 37.14% exceeded 85 dB(A), which is the occupational exposure limit. The average CNE was 90.6±8.1 dB(A)·year. The industry, ranked

TABLE 1. Distributions of noise exposure and KMI score across different basic characteristics among participants.

Characteristic	*N* (%)	$L_{Aeq,8h}$	CNE [dB(A)·year]	KMI score		Perimenopausal syndrome (%)					
				M (P25, P75)	*P*	I (None)	II (Mild)	III (Moderate)	IV (Severe)	*P*	Detected, *n* (%)
Age (years)											
<45	1,301 (57.5)	81.7±6.9	89.9±8.1	6 (2,10)		613 (47.1)	553 (42.5)	127 (9.8)	8 (0.6)		688 (52.9)
45–49	801 (35.4)	82.6±6.9	91.5±8.0	6 (1,12)	0.086	363 (45.3)	329 (41.1)	94 (11.7)	15 (1.9)	0.285	438 (54.7)
≥50	160 (7.1)	82.6±7.3	92.2±8.2	5 (0,10)		81 (50.6)	57 (35.6)	22 (13.8)	0 (0)		79 (49.4)
Educational level											
Junior high school and below	1,229 (54.4)	81.9±6.5	89.5±7.8	4 (0,9)		695 (56.6)	441 (35.9)	86 (7.0)	7 (0.6)		534 (43.5)
High school or vocational school	580 (25.6)	82.2±7.3	91.5±8.4	7 (2,12)	<0.001	237 (40.9)	259 (44.7)	76 (13.1)	8 (1.4)	<0.001	343 (59.2)
Junior college	355 (15.7)	82.3±7.6	92.2±8.3	9 (5,14)		100 (28.2)	185 (52.1)	64 (18.0)	6 (1.7)		255 (71.8)
Bachelor's degree and above	98 (4.3)	83.4±7.1	93.8±7.6	9 (5,14)		25 (25.5)	54 (55.1)	17 (17.4)	2 (2.0)		73 (74.5)
Marital status											
Single	153 (6.8)	82.2±5.9	89.6±7.7	7 (1,12)	0.217	60 (39.2)	71 (46.4)	19 (12.4)	3 (2.0)	0.187	93 (60.8)
Married	2,109 (93.2)	82.1±7.0	90.7±8.1	6 (1,11)		997 (47.3)	868 (41.2)	224 (10.6)	20 (1.0)		1,112 (52.8)
Smoking											
Smoking or exposure to secondhand smoking	75 (3.3)	83.3±7.1	91.3±7.3	10 (4,17)	<0.001	21 (28.0)	34 (45.3)	18 (24.0)	2 (2.7)	<0.001	54 (72.0)
No	2,187 (96.7)	82.1±6.9	90.6±8.1	6 (1,11)		1,036 (47.4)	905 (41.4)	225 (10.3)	21 (1.0)		1,151 (52.7)
Drinking											
Yes	50 (2.2)	83.0±6.9	91.7±8.3	7 (2,12)	0.392	22 (44.0)	19 (38.0)	9 (11.0)	0 (0)	0.353	28 (49.0)
No	2,212 (97.8)	82.1±6.9	90.6±8.1	6 (1,11)		1,035 (46.8)	920 (41.6)	234 (10.6)	23 (1.0)		1,177 (53.2)
Work shift											
Regular shift	1,160 (51.3)	82.1±7.2	90.9±8.3	6 (1,11)	0.437	555 (47.8)	483 (41.6)	110 (9.5)	12 (1.0)	<0.001	605 (52.1)
Rotating shift	1,102 (48.7)	82.2±6.6	90.4±7.9	6 (1,11)		502 (45.6)	456 (41.4)	133 (12.1)	11 (1.0)		600 (54.5)
HPD use											
Wearing as required	1,856 (82.1)	83.0±6.5	91.8±7.5	6 (1,11)		888 (41.0)	760 (41.0)	188 (10.1)	20 (1.1)		968 (52.2)
Not wearing as required	189 (8.4)	81.4±6.0	89.3±7.8	9 (5,17)	<0.001	51 (27.0)	83 (43.9)	52 (27.5)	3 (1.6)	<0.001	138 (73.0)
Not required to wear	217 (9.5)	75.1±6.8	82.1±8.5	4 (0,8)		118 (54.4)	96 (44.2)	3 (1.4)	0 (0)		99 (45.6)
Industry											
Textiles	708 (31.3)	81.5±7.2	91.8±8.1	6 (2,11)		319 (45.1)	325 (45.9)	60 (8.47)	4 (0.6)		389 (54.9)
Food	650 (28.7)	80.5±6.8	87.4±8.4	4 (0,8)		373 (57.4)	234 (36.0)	43 (6.6)	0 (0)		277 (42.6)
Coal	491 (21.7)	84.3±7.3	93.6±8.0	11 (6,16)	<0.001	105 (21.4)	259 (52.8)	113 (23.0)	14 (2.9)	<0.001	386 (78.7)
Electronics	280 (12.4)	82.6±4.8	88.8±5.9	2 (0,7)		187 (66.8)	85 (30.4)	6 (2.1)	2 (0.7)		93 (33.2)
Automotive	133 (5.9)	84.6±4.7	93.1±4.7	5 (0,12)		73 (54.9)	36 (27.1)	21 (15.7)	3 (2.3)		60 (45.1)
Total	2,262	82.1±6.9	90.6±8.1	6 (1,11)		1,057 (46.7)	939 (41.5)	243 (10.7)	23 (1.0)		1,205 (53.3)

Note: Regular occupational health monitoring results indicated that noise was the primary occupational hazard for the female workers surveyed. Significant between-industry moderate heterogeneity was observed in occupational noise exposure, $L_{Aeq,8h}$, dB(A) ε^2=0.060, CNE, dB(A)·year ε^2=0.092.

Abbreviation: $L_{Aeq,8h}$=8-h equivalent sound level; CNE=cumulative noise exposure; HPD=hearing protection device.

from highest to lowest CNE, were coal, automotive, textiles, electronics, and food. The average $L_{Aeq,8h}$ and CNE for the coal mining industry were 84.3±7.3 dB(A) and 93.6±8.0 dB(A)·year, respectively. The KMI score was highest in the coal and textile industries and lowest in the food and electronics industries. Nearly half (46.7%, 1,057/2,262) of female workers had no PMS, whereas 53.3% (1,205/2,262) had mild-to- severe PMS. Among all participants, 41.5% (939/2,262), 10.7% (243/2,262), and 1.0% (23/2,262) were categorized as mild, moderate, and severe, respectively. Among the core symptoms of PMS, the prevalence of fatigue was the highest (59.6%, 1,349/2,262), followed by insomnia (56.3%, 1,273/2,262) and irritability (52.3%, 1,183/2,262) (Supplementary Figure S2, available athttps://weekly.chinacdc.cn).

In the fully adjusted model (Model 3), compared with the lowest quartile (Q_1) of $L_{Aeq,8h}$, participants in the third [Q_3, odds ratio (*OR*)=1.715, 95% confidence interval (*CI*): 1.319–2.232, *P*<0.01)] and fourth (Q_4, *OR*=1.631, 95% *CI*: 1.260–2.116, *P*<0.01) quartiles had significantly higher risks of PMS, with a significant dose–response trend (*P* for trend <0.001) (Table 2). For CNE, compared with Q_1, the highest quartile (Q_4) was associated with the greatest risk elevation (*OR*=1.726, 95% *CI*: 1.298–2.298, *P*<0.001), and a similar positive dose–response relationship was observed (*P* for trend <0.001).

The RCS model revealed that the overall association between KMI scores and $L_{Aeq,8h}$ or CNE was statistically significant (*P*-overall<0.01), suggesting a linear dose–response relationship (Figure 1). $L_{Aeq,8h}$ exceeding 83 dB(A) and CNE exceeding 91 dB(A)·year were the action thresholds for increased PMS risk. Above these thresholds, the ORs exceeded 1, and the health risk increased significantly.

DISCUSSION

This study revealed an overall PMS prevalence of 53.3% (1,205/2,262) in female workers, which was higher than the 49.2% reported among petrochemical workers exposed to multiple occupational hazards (*6*). A nationwide meta-analysis encompassing 82,340 women reported an overall PMS prevalence of 61.0% (50,227/82,340) among Chinese women, with age-specific rates of 42.6% (2,979/6,993) (40–45 years), 53.8% (4,127/7,671) (45–50 years), and 64.6% (4751/7,355) (50–55 years), placing our prevalence

TABLE 2. *OR*s of $L_{Aeq,8h}$ and CNE for KMI scores using quartile-based logistic regression analysis.

Noise exposure	IQR, M (Q_1, Q_3)	Model 1		Model 2		Model 3	
		OR (95% *CI*)	*P*	*OR* (95% *CI*)	*P*	*OR* (95% *CI*)	*P*
$L_{Aeq,8h}$ [dB(A)]	Q_1 (50, 76)	Ref		Ref		Ref	
	Q_2 (76, 83)	0.916 (0.725–1.156)	0.459	1.040 (0.817–1.325)	0.751	1.121 (0.873–1.441)	0.370
	Q_3 (83, 86)	1.317 (1.045–1.662)	0.020	1.467 (1.153–1.870)	0.002	1.715 (1.319–2.232)	<0.010
	Q_4 (86, 100)	1.425 (1.130–1.800)	0.003	1.411 (1.108–1.799)	0.005	1.631 (1.260–2.116)	<0.010
	P for trend	<0.001		<0.001		<0.001	
AIC		3,114.86		2,992.41		2,851.50	
BIC		3,137.75		3,061.10		2,960.25	
CNE [dB(A)·year)	Q_1 (55, 86)	Ref		Ref		Ref	
	Q_2 (86, 91)	1.165 (0.922–1.472)	0.201	1.093 (0.858–1.391)	0.472	0.998 (0.768–1.296)	0.988
	Q_3 (91, 95)	1.569 (1.241–1.984)	<0.001	1.481 (1.163–1.888)	0.001	1.334 (1.027–1.734)	<0.050
	Q_4 (96, 114)	2.268 (1.787–2.884)	<0.001	1.976 (1.538–2.544)	<0.001	1.726 (1.298–2.298)	<0.001
	P for trend	<0.001		<0.001		<0.001	
AIC		3,080.34		2,976.92		2,865.08	
BIC		3,103.23		3,045.60		2,973.83	

Note: $L_{Aeq,8h}$ and CNE are divided into four quartiles: Q_1, Q_2, Q_3, and Q_4. Model 1: univariate analysis without adjusting for covariates; Model 2: adjusted for age, body mass index, marital status, education, smoking, and drinking; Model 3: further adjusted for work shift, industry sector, and HPD (hearing protection device) use based on Model 2. There was no multicollinearity among the independent variables in the logistic regression analysis, satisfying the prerequisites for regression analysis. Model fit was compared using the Akaike information criterion (AIC) and Bayesian information criterion (BIC), with lower values indicating a better relative fit. Model 1 yielded the largest AIC and BIC values, followed by Model 2, while Model 3 had the lowest AIC and BIC values.

Abbreviation: $L_{Aeq,8h}$=8-h equivalent sound level; CNE=cumulative noise exposure; *ORs*=odds ratio; IQR=interquartile range; KMI=Kupperman Menopause Index; *CI*=confidence interval.

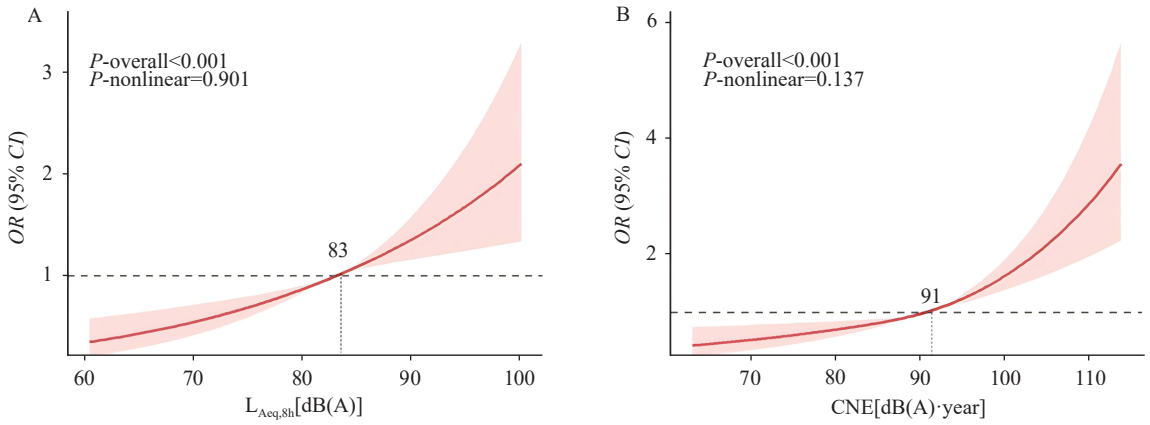


FIGURE 1. The linear relationship between noise exposure and KMI score using restricted cubic spline analysis. (A) The linear relationship between $L_{Aeq,8h}$ and KMI score. (B) The linear relationship between CNE and KMI score.
Note: Covariates adjusted for this model included age, body mass index, education, marital status, smoking, drinking, work shift, and HPD (hearing protection device) use. In panel A, an 83-dB(A) noise level was the action threshold for the KMI score. In panel B, a CNE of 91 dB(A)·year was the action threshold for the KMI score.
Abbreviation: $L_{Aeq,8h}$=8-h equivalent sound level; CNE=cumulative noise exposure; *ORs*=odds ratio; KMI=Kupperman Menopause Index; *CI*=confidence interval.

(53.3%, 1,205/2,262) within the expected range for the general population of similar age (*5*). However, marked industry-specific variation emerged: coal miners in this study had a prevalence of 78.6% (386/491), substantially higher than the general population rates for the 45–50 (53.8%) and 50–55 (64.6%) age groups, whereas textile workers (54.9%) (389/708) had a prevalence comparable to that of the general population. The prevalence of perimenopausal syndrome (PMS) in the present study and relevant literature is shown in Supplementary Table S2. These comparisons suggest that noise exposure may significantly increase PMS risk in specific high-noise industries such as coal mining, yet the magnitude of this effect is likely modulated by factors including industry-specific characteristics, noise intensity, cumulative exposure duration, and co-exposure to other occupational hazards, underscoring the need for industry-tailored occupational health strategies for perimenopausal female workers.

KMI scores were positively correlated with both the $L_{Aeq,8h}$ and CNE. Furthermore, RCS analysis confirmed a linear dose–response relationship between $L_{Aeq,8h}$ (or CNE) and KMI scores. These findings indicate that PMS severity is closely related to the cumulative effects of noise exposure. One study indicated that 86% of female students were exposed to disruptive campus noise, a factor that, when compounded by academic and economic stressors, amplifies psychological strain and threatens menstrual regularity (*7*). Previous studies have confirmed that psychological stress is a key cause of ovarian dysfunction, acting on the hypothalamus–pituitary–adrenal, sympathetic–adrenal–medullary, and hypothalamus–pituitary–ovarian axes (*8*). Metabolic disorders such as obesity and abnormal glucose metabolism induced by psychological stress can also damage ovarian function (*9*). As a physical and psychological stressor, noise can aggravate the fluctuating ovarian function of perimenopausal women or amplify inherent metabolic disorders by activating the same neuroendocrine and metabolic pathways (*3*). While reproductive and gynecological histories may influence PMS presentation, the biological pathways linking noise exposure to ovarian and endocrine disruption are largely independent of these factors.

Variations in the onset timing and symptomatology of the menopausal transition across racial and ethnic groups are well established, which may alter the susceptibility threshold of perimenopausal women to environmental stressors, including occupational noise (*10*). Heterogeneity in regulatory frameworks for noise control across countries complicates direct cross-study comparisons and may underlie inconsistent findings in prior research on the exposure threshold at which noise adversely affects perimenopausal health (*11*). Noise severely impairs auditory signal discrimination, and auditory scene analysis is a core physiological mechanism for extracting target acoustic signals from complex noisy backgrounds (*12*).

Noise exposure levels were generally high ($L_{Aeq,8h}$ = 82.1±6.9 dB(A)), especially in the coal industry. The highest KMI scores were found in the coal industry (11 [6, 16]), followed by the textile industry (6 [2, 11]).

These findings indicate that female workers in the coal industry face high-noise exposure and considerable PMS burden. Given the large workforce and widespread noise exposure in the coal industry, noise control and reproductive health interventions are needed for female workers in this sector (*13*).

The findings in this report are subject to at least three limitations. First, as this was a cross-sectional study, a causal relationship could not be inferred. Selection bias may arise if healthier workers are more likely to remain in high-noise environments. Second, CNE was calculated based solely on $L_{Aeq,8h}$ and actual years of exposure, without accounting for historical changes in workplace noise levels, job transfers, or the healthy worker effect. Finally, the study lacked objective data such as blood biochemical indicators, and the effects of combined exposure to noise and other occupational hazards were not evaluated.

Occupational noise exposure significantly increases the risk of PMS among female workers. Effective interventions should be implemented, including engineering noise control to prioritize source reduction in high-noise processes, personal protective equipment matching exposure patterns, stratified health education to address the interaction between occupational stressors and menopausal symptoms for perimenopausal workers, and institutionalized periodic health screening for noise-exposed women aged 40–55 years. Future research should focus on prospective cohort studies and investigate the molecular mechanisms underlying the effects of noise exposure on the reproductive health of female workers.

Conflicts of interest: No conflicts of interest.

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Ethical statement: The study protocol was approved by the Ethics Committee of the National Institute of Occupational Health and Poison Control, Chinese Center for Disease Control and Prevention (NIOHP202324).

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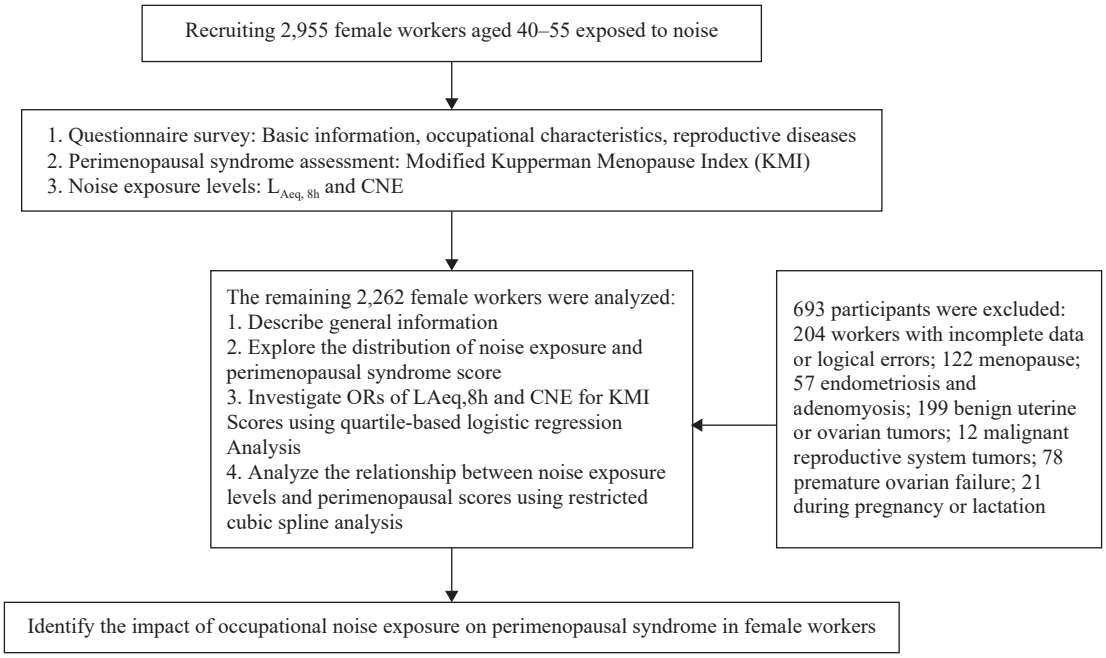
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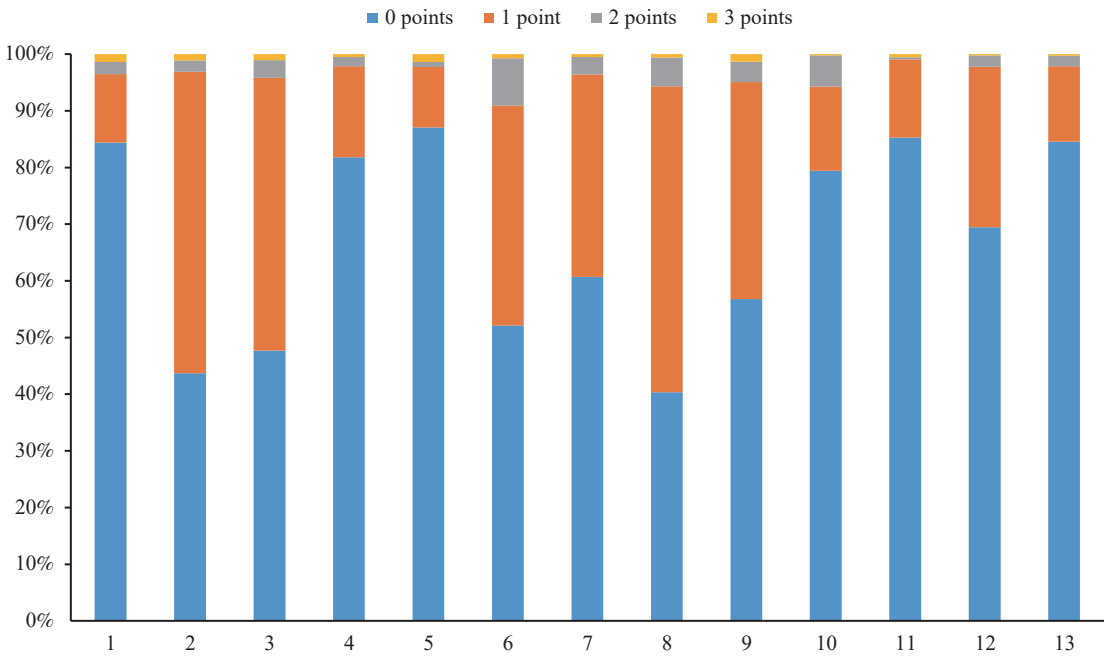
REFERENCES

1. Du J, Tong ZL, Wang L, Xue XW, Liu JS, Yan X, et al. Analysis of perimenopausal syndrome and its related factors among female staffs in municipal hospitals in Anhui Province. Anhui J Prev Med 2020;26(4):258-61,266. http://dx.doi.org/10.19837/j.cnki.ahyf.2020.04.004. (In Chinese).
2. Basu S, Aggarwal A, Dushyant K, Garg S. Occupational noise induced hearing loss in India: a systematic review and meta-analysis. Indian J Community Med 2022;47(2):166 – 71. https://doi.org/10.4103/ijcm.ijcm_1267_21.
3. Bala R, Singh V, Rajender S, Singh K. Environment, lifestyle, and female infertility. Reprod Sci 2021;28(3):617 – 38. https://doi.org/10.1007/s43032-020-00279-3.
4. Ding L, Xie LL, Zhang HX, Ding JH, Li J, Wang SJ, et al. Present situation and analysis of factors affecting perimenopausal syndrome among clinical nurses-a cross-sectional survey. Ann Palliat Med 2022;11(7):2432 – 42. https://doi.org/10.21037/apm-22-563.
5. Jia Y, Zhou ZT, Cao XH, Hu WQ, Xiang F, Xiong LY, et al. Incidence of perimenopausal syndrome in Chinese women aged 40 to 65 years: a meta-analysis. Chin Gen Pract 2023;26(32):4080 – 8. https://doi.org/10.12114/j.issn.1007-9572.2023.0303.
6. Zhao L, Yu WL, Li H, Wang SL, Kou ZX. Kupperman index-based analysis of factors influencing perimenopausal symptoms and establishment of risk nomogram in female petrochemical workers. J Environ Occup Med 2022;39(4):404 – 9. https://doi.org/10.11836/JEOM21380.
7. Gbaranor KB, Ekeng OB, Oreh Adaeze C, John EE, Barinua-Gbaranor NP, Mube AW, et al. Stress as a predictor of menstrual delay among students in tertiary institutions in south-south Nigeria. SAR J Med 2025;6(5):80 – 4. https://doi.org/10.36346/sarjm.2025.v06i05.004.
8. Hu Y, Wang WY, Ma WQ, Wang WW, Ren W, Wang SX, et al. Impact of psychological stress on ovarian function: insights, mechanisms and intervention strategies (Review). Int J Mol Med 2025;55(2):34. https://doi.org/10.3892/ijmm.2024.5475.
9. Zhang J, Zhang WZ. Stress-induced metabolic disorders: mechanisms, pathologies, and prospects. Am J Biomed Sci Res 2025;26(6):834 – 42. https://doi.org/10.34297/AJBSR.2025.26.003506.
10. Gold EB, Colvin A, Avis N, Bromberger J, Greendale GA, Powell L, et al. Longitudinal analysis of the association between vasomotor symptoms and race/ethnicity across the menopausal transition: study of women's health across the nation. Am J Public Health 2006;96(7):1226 – 35. https://doi.org/10.2105/AJPH.2005.066936.
11. Zeng AK, Huang YW, Xin JR, Li JZ, Qiu W, Zhang MB. Progress and recommendations of developing occupational exposure limits for noise-a systematic review. Heliyon 2024;10(18):e37878. https://doi.org/10.1016/j.heliyon.2024.e37878.
12. Gómez-Roig MD, Pascal R, Cahuana MJ, García-Algar O, Sebastiani G, Andreu-Fernández V, et al. Environmental exposure during pregnancy: influence on prenatal development and early life: a comprehensive review. Fetal Diagn Ther 2021;48(4):245 – 57. https://doi.org/10.1159/000514884.
13. Patil SM, Aithala M, Ganganahalli P. An observational study of lung function alterations in stone quarry workers of North Karnataka. Cureus 2025;17(3):e80838. https://doi.org/10.7759/cureus.80838.

SUPPLEMENTARY MATERIAL



SUPPLEMENTARY FIGURE S1. The flowchart of participant selection and analysis.
Abbreviation: $L_{Aeq,8h}$=8-h equivalent sound level; CNE=cumulative noise exposure; *ORs*=odds ratio; KMI=Kupperman Menopause Index.



SUPPLEMENTARY FIGURE S2. Distribution of Scores for Perimenopausal Indicators.
Note: Bars are categorized as follows: 1, hot flashes and sweating; 2, insomnia; 3, irritability; 4, depression and suspicion; 5, sexual dysfunction; 6, bone and joint pain; 7, dizziness; 8, fatigue; 9, headaches; 10, sensory abnormalities; 11, urinary tract infections; 12, palpitations; 13, crawling skin sensations.

SUPPLEMENTARY TABLE S1. Exploratory subgroup analyses of occupational noise exposure and perimenopausal syndrome.

Exposure	Subgroup	Level	*N*	Cases, *n* (%)	Adjusted *OR* per 1-SD increase (95% *CI*)	*P*	*P* interaction
$L_{Aeq,8h}$	Industry	Textiles	708	389 (54.9)	0.96 (0.82–1.11)	0.566	<0.001
	Industry	Food processing	650	277 (42.6)	1.54 (1.27–1.88)	<0.001	
	Industry	Coal mining	491	386 (78.6)	1.46 (1.18–1.81)	0.001	
	Industry	Automotive	133	60 (45.1)	NE	NE	
	Industry	Electronics	280	93 (33.2)	0.83 (0.55–1.25)	0.372	
	HPD use	Wearing as required	1,856	968 (52.2)	1.16 (1.04–1.29)	0.008	0.001
	HPD use	Not wearing as required	189	138 (73.0)	NE	NE	
	HPD use	Not required to wear	217	99 (45.6)	1.94 (1.34–2.82)	<0.001	
	Work shift	Regular shift	1,160	605 (52.2)	1.22 (1.07–1.39)	0.003	>0.050
	Work shift	Rotating shift	1,102	600 (54.4)	1.22 (1.06–1.42)	0.007	
CNE	Industry	Textiles	708	389 (54.9)	1.04 (0.89–1.22)	0.620	0.004
	Industry	Food processing	650	277 (42.6)	1.50 (1.24–1.81)	<0.001	
	Industry	Coal mining	491	386 (78.6)	1.50 (1.19–1.90)	0.001	
	Industry	Automotive	133	60 (45.1)	NE	NE	
	Industry	Electronics	280	93 (33.2)	1.08 (0.73–1.60)	0.693	
	HPD use	Wearing as required	1,856	968 (52.2)	1.26 (1.12–1.41)	<0.001	0.051
	HPD use	Not wearing as required	189	138 (73.0)	1.32 (0.88–1.97)	0.175	
	HPD use	Not required to wear	217	99 (45.6)	1.87 (1.31–2.67)	0.001	
	Work shift	Regular shift	1,160	605 (52.2)	1.34 (1.16–1.53)	<0.001	>0.050
	Work shift	Rotating shift	1,102	600 (54.4)	1.32 (1.14–1.54)	<0.001	

Note: *OR*s are expressed as standard deviation increases in the corresponding continuous exposure metric. The models were adjusted for age, body mass index, education, marital status, smoking, alcohol consumption, work shift, HPD use, and industry sector; however, the stratification variable was omitted from the corresponding subgroup models. NE indicates that the estimate was not reported because the maximum likelihood model did not converge reliably in the small subgroup. Subgroup-specific statistical significance should not be interpreted as evidence of effect modification without a significant interaction test. Significant interactions were observed between the industry sector and both noise exposure metrics, and between HPD use and $L_{Aeq,8h}$. The CNE-by-HPD interaction was borderline, whereas the interaction with work shift was not statistically significant. As several strata had limited sample sizes and exposure overlaps, all subgroup findings were considered exploratory.

Abbreviation: *ORs*=odds ratio; $L_{Aeq,8n=}$8-h equivalent sound level; CNE=cumulative noise exposure; HPD=hearing protection device.

SUPPLEMENTARY TABLE S2. Comparison of the prevalence of perimenopausal syndrome between this study and previous studies.

Population category	Sample size (*n*)	Age range (years)	Assessment tool	PMS prevalence (%)	Mild/moderate/severe distribution (%)	Source
I. General female group						
Nationwide meta-analysis	82,340	40–65	KMI	61.0	–	Reference 5
II. Occupational female group						
Our study	2,262	40–55	Modified KMI	53.3	41.5 / 10.7 / 1.1	This study
Textile industry	708	40–55	Modified KMI	54.9	45.9 / 8.5 / 0.6	This study
Food processing	650	40–55	Modified KMI	42.6	36.0 / 6.6 / 0.0	This study
Coal mining	491	40–55	Modified KMI	78.6	52.8 / 23.0 / 2.9	This study
Electronics manufacturing	280	40–55	Modified KMI	33.2	30.4 / 2.1 / 0.7	This study
Automotive manufacturing	133	40–55	Modified KMI	45.1	27.1 / 15.7 / 2.3	This study
Petrochemical workers	2,653	40–55	KMI	49.2	–	Reference 6
Textile enterprise	369	>40	KMI	82.4	–	Reference 14
Various occupations	3,606	40–60	KMI	32.1	–	Reference 15
Municipal hospital staff	895	40–60	Modified KMI	49.2	–	Reference 1

"–" means this reference does not report this data.
Abbreviation: PMS=perimenopausal syndrome; KMI=kupperman menopause index.