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Long-Term Exposure to Dust and Noise Can Increase the Risk of Hypertension—A Population Based, Cross-sectional Study

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Objective: The aim of the study is to assess whether occupational groups exposed to dust and noise increase their risk of developing hypertension and to identify associated risk factors. **Methods:** Logistic regression analysis was used to analyze the influence of exposure factors on the occurrence of hypertension, and confounding factors were adjusted to identify independent effects. Stratified analysis and smoothed curve fitting were used to explore the effects in different populations. **Results:** Combined dust + noise exposure significantly increased the risk of hypertension in workers (model 1: odds ratio [OR], 2.75; model 2: OR, 2.66; model 3: OR, 2.85). Further analysis showed that when exposed to dust and noise for more than 17 years, the risk of hypertension increased by 15%. **Conclusions:** The combined exposure of dust and noise significantly increases the risk of hypertension among occupational groups, especially among workers who have worked for more than 17 years.

Keywords: dust, noise, career building, hypertension, hazard factors

Hypertension is one of the common chronic diseases and is a major preventable risk factor for increased prevalence of cardiovascular disease and all-cause mortality worldwide.[1] Its diagnostic criteria are systolic blood pressure ≥140 mm Hg and/or diastolic blood pressure ≥90 mm Hg, and hypertension is statistically ranked first among the 30 risk factors leading to the highest disability-adjusted life year levels and is globally recognized as a major public health problem.[2] In addition, persistently high blood pressure can significantly increase the risk of coronary heart disease, stroke, chronic renal insufficiency, and other target organ damage, seriously affecting human health and even endangering life.

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Ethics Review Form 2021032 (Biomedical Research Ethics Committee of Anhui University of Technology).

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LEARNING OUTCOMES

- Exposure to dust and noise at the same time is more likely to cause hypertension than single exposure.
- There was a significant threshold effect in the exposure years, and the probability of hypertension increased significantly when the exposure was more than 17 years.

Adverse work environment is one of the main influencing factors of hypertension and can increase the risk of developing hypertension.[3]

Dust and noise are common occupational disease exposure factors in modern industrial enterprises, and the health of workers exposed to this risk factor for a long time is at risk. It is well known that occupational noise can cause damage to the human auditory system, but the damage caused by its long-term exposure to the human cardiovascular system is also gaining attention.[4] There is no shortage of reports on the relationship between noise and blood pressure, but the results are inconsistent, with most studies showing that occupational noise exposure is positively associated with blood pressure.[5] Dust is a major pollutant in industrial ambient air, and long-term exposure can seriously damage the respiratory system of the body. Ultrafine particles of dust can collect in the lungs via the respiratory tract and can also cross the air-blood barrier and enter the blood circulation causing a series of diseases, such as pneumoconiosis, atherosclerosis, ischemic heart disease, and cardiac arrhythmia.[6,7]

Combined exposure to dust and noise often accounts for a large proportion of occupational exposure hazards, and previous studies have shown[8] that dust and noise can reduce systolic blood pressure ($P < 0.001$). However, the effect of confounding factors was not considered, and the relationship between the two in different populations was not further explored. In this study, we analyzed the occupational health examination data of 826 workers to investigate the relationship between dust and noise exposure and whether they would develop hypertension and to provide a theoretical basis for assessing the health damage caused by occupational hazard exposure to occupational populations.

METHODS

Study Population

Employees who received occupational health checkups at Huainan Xinkang Hospital from December 2020 to November 2021 were selected, and their exposure to occupational hazards was divided into the following 3 categories: unexposed (n = 266), single exposure to dust (n = 228), single exposure to noise (n = 91), and exposure to dust + noise (n = 507). Inclusion criteria are as follows: (1) Those who did not experience major diseases 6 months before the survey; (2) exposure to hazards (dust, noise) for more than 1 year; and (3) age ≥18 years. Exclusion criteria are as follows: (1) patients who have been diagnosed with hypertension or are taking antihypertensive drugs before starting work and (2) incomplete medical examination data. This study was approved by the biomedical ethics committee of Anhui University of Science and Technology (no. 2021032).

Occupational Health Screening

According to GBZ188-2014 (Technical Specification for Occupational Health Surveillance), the study subjects were subjected to occupational health examination, filling out the (Occupational Health Examination Form), asking detailed questions about occupational history, history, complaints, etc, and performing blood pressure measurement, electrocardiogram examination, and other testing items.

Blood Pressure Measurement

The subjects rested quietly for at least 5 minutes, refrained from smoking and drinking coffee for 30 minutes before the measurement, and emptied their bladders. The subject is seated, preferably in a reclining chair; the right upper arm is exposed and the elbow is placed at the same level as the heart. The physician uses a mercury column sphygmomanometer that meets the measurement standards to measure the person being measured. The measurements were repeated 2 minutes apart, and the average of the 2 readings was recorded. If the difference between the systolic or diastolic readings of the 2 measurements was greater than 5 mm Hg, the measurements were taken again 2 minutes apart and then the average of the 3 readings was taken. Hypertension: refers to systolic blood pressure ≥140 mm Hg (1 mm Hg = 0.133 kPa) or and diastolic blood pressure ≥90 mm Hg.

Diagnostic Criteria

Body mass index diagnostic criteria are as follows: 18.5 to 23.9 kg/m^2 is normal, and less than 18.5 kg/m^2 or greater than 23.9 kg/m^2 is abnormal; smoking history: the smoking situation is measured by asking the physical examiners whether they smoke and how often they smoke. The categories are "smoking, I smoke every day," "smoking, I smoke occasionally," "I do not smoke now, but I used to smoke every day," "I do not smoke now, but I used to smoke occasionally," and "I never smoke." Those who choose the option of "I never smoke" are considered as having no smoking history, and all other people are classified as having smoking. Drinking situation: drinking history: so far, I have drunk more than 25 mL of high liquor (≥42 degrees, generally 55 degrees), or more than 35 mL of low liquor (<42 degrees, generally 28 degrees), or more than 100 mL of wine, or more than 100 mL of rice wine (about 13 degrees), or more than 400 mL of beer (generally 3.3 degrees). Current drinking: refers to drinking more than 25 mL of high liquor (≥42 degrees, generally 55 degrees), or more than 35 mL of low liquor (<42 degrees, generally 28 degrees), or more than 100 mL of wine, or more than 100 mL of rice wine (about 13 degrees), or more than 400 mL of beer (generally 3.3 degrees) in the past 12 months. The rest are considered as no drinking. Enterprise scale: large (≥1000 employees, operating income ≥400 million yuan), medium-sized (300–1000 employees, operating income 20–40 million yuan), small (20–300 employees, operating income 3–20 million yuan), and micro (<20 employees, operating income <3 million yuan).

TABLE 1. Description of the Study Population

Exposure	Hypertension	
	No	Yes
	n = 881	n = 211
Age	38.55 ± 9.60	41.72 ± 9.51
Work years	6.22 ± 7.62	6.61 ± 7.00
BMI	23.83 ± 3.25	25.83 ± 3.71
Exposure factors		
Unexposed	235 (26.67%)	31 (14.69%)
Dust	197 (22.36%)	31 (14.69%)
Noise	77 (8.74%)	14 (6.64%)
Dust + noise	372 (42.22%)	135 (63.98%)
Enterprise scale		
Miniature	12 (1.36%)	3 (1.42%)
Small scale	333 (37.80%)	51 (24.17%)
Medium	288 (32.69%)	116 (54.98%)
Large	248 (28.15%)	41 (19.43%)
Sex		
Male	687 (77.98%)	186 (88.15%)
female	194 (22.02%)	25 (11.85%)
Smoke history		
No	510 (57.89%)	66 (31.28%)
Yes	371 (42.11%)	145 (68.72%)
Drink history		
No	452 (51.31%)	99 (46.92%)
Yes	429 (48.69%)	112 (53.08%)

TABLE 2. Univariate Analysis of the Risk of Hypertension

Exposure	OR	95% CI	*P*
Exposure factors			
Unexposed	Ref		
Dust	1.19	0.70–2.03	0.516
Noise	1.38	0.70–2.72	0.356
Dust + noise	2.75	1.80–4.20	<0.001
Enterprise scale			
Miniature	Ref		
Small scale	0.61	0.17–2.25	0.460
Medium	1.61	0.45–5.81	0.466
Large	0.66	0.18–2.45	0.535
Sex			
Male	Ref		
Female	0.48	0.30–0.74	0.001
Age	1.03	1.02–1.05	<0.001
Smoke history			
No	Ref		
Yes	3.02	2.19–4.16	<0.001
Drink history			
No	Ref		
Yes	1.19	0.88–1.61	0.253
Work years	1.01	0.99–1.03	0.499
BMI	1.18	1.13–1.24	<0.001

CI, confidence interval; OR, odds ratio.

Statistical Analysis

All analyses were performed using Empower Stats software (http://www. empowerstats.com). Continuous and categorical variables are expressed as mean ± standard deviation and percentage, respectively. Multivariate logistic regression was used to develop a model to detect the association between combined dust + noise exposure and the development of hypertension in workers, model 1, no covariate adjustment; model 2, adjustment for age and sex; model 3: adjustment for all potential confounders, including age, sex, and BMI. Further subgroup analysis was performed to investigate the relationship between the two in different populations. A weighted generalized summation model and a smoothed curve fitting method were used to explore the nonlinear relationships. Threshold effect analysis was performed

TABLE 3. Probability of Hypertension under Different Exposure Factors

Group	Total	Hypertension		χ^2	*P*
		Yes, n (%)	No, n (%)		
Unexposed	266	31 (11.7%)	235 (88.3%)	156.45	<0.01
Dust	228	31 (13.6%)	197 (86.4%)	120.86	<0.01
Noise	91	14 (15.4%)	77 (84.6%)	43.615	<0.01
Dust + noise	507	135 (26.6%)	372 (73.4%)	110.787	<0.01
P		<0.05	<0.05		

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TABLE 4. Multiple Regression Analysis of Different Models

Exposure	Model 1			Model 2			Model 3		
Exposure Factors	**OR**	**95% CI**	***P***	**OR**	**95% CI**	***P***	**OR**	**95% CI**	***P***
Unexposed		Ref			Ref			Ref	
Dust	1.19	0.70–2.03	0.516	0.99	0.57–1.71	0.972	1.04	0.60–1.83	0.878
Noise	1.38	0.70–2.72	0.356	1.53	0.76–3.06	0.230	1.79	0.88–3.65	0.109
Dust + noise	2.75	1.80–4.20	<0.001	2.66	1.73–4.09	<0.001	2.85	1.83–4.43	<0.001

CI, confidence interval; OR, odds ratio.

to find the optimal inflection point. $P < 0.05$ considered the difference to be statistically significant.

RESULTS

Baseline Characteristics of the Study Population

A total of 1092 workers were included according to the nadir criteria and were divided into 2 groups that developed hypertension (n = 211) and did not develop hypertension (n = 881). Among workers who developed hypertension, a greater proportion of workers were exposed to combined dust + noise exposure (63.98%) compared with unexposed (14.69%), dust alone (14.69%), and noise alone (6.64%). The baseline characteristics of the included workers are described in Table 1.

Risk Factors for the Development of Hypertension in Employees

The baseline characteristics of the workers in Table 1 were included in the univariate analysis (Table 2), and the results showed that exposure factors, sex, age, smoke history, and BMI were risk factors for the development of hypertension in the workers ($P < 0.05$). The results of the analysis of the incidence of hypertension under different exposure factors (Table 3) showed that the incidence of hypertension was significantly higher ($P < 0.05$) in workers under combined exposure of dust + noise (26.6%) compared with the unexposed (11.7%), dust group (13.6%), and noise group (15.4%).

After further multiple regression analysis (Table 4), in model 1 (unadjusted for confounders), combined exposure to dust and noise increased the risk of hypertension among workers by 1.75 fold (odds ratio [OR], 2.75; 95% confidence interval [CI], 1.80–4.20; $P < 0.001$); in model 2 (adjusted for age and sex), combined dust and noise exposure increased the risk of hypertension by 1.66 fold (OR, 2.66; 95% CI, 1.73–4.09; $P < 0.001$); in model 3 (adjusted for age, sex, and BMI), combined dust and noise exposure increased the risk of hypertension by 1.85 fold (OR, 2.85; 95% CI, 1.83–4.43; $P < 0.001$).

Stratification Analysis

A stratified analysis of demographic factors revealed that combined dust + noise exposure increased the risk of hypertension in workers whether they were male or female (Fig. 1A), younger than 45 years or 45 years or older (Fig. 1B), and had a normal BMI (BMI = 18.5–23.9 or BMI <18.5 or >23.9; Fig. 1C). Further analysis of the effect of workers' lifestyle habits showed the same positive trend regardless of whether they smoked (Fig. 2A) and whether they drank alcohol (Fig. 2B).

Effect of Working Years on the Development of Hypertension in Workers Exposed to Dust + Noise

Based on the previous findings, we explored the effect of working years on the development of hypertension using smoothed curve fitting for workers exposed to dust + noise. The results showed that the risk of hypertension among workers with combined dust + noise exposure gradually increased with increasing years of work (Fig. 3A). When the threshold effect was analyzed for years of work, it was found that their risk of developing hypertension increased by 15% (OR, 1.15; 95% CI, 1.04–1.27; $P = 0.006$) when their years of work exceeded 17 years (Fig. 3B, Table 5). After stratification analysis using age and sex and found that the risk of hypertension in men and workers 45 years or older increased gradually with increasing working age (Figs. 4A, B), while a positive trend was observed after stratification with BMI, smoke history, and drink history (Figs. 4C, 5A, B).

DISCUSSION

The main objective of this study was to investigate the relationship between workers' exposure to dust and noise hazards and their risk of developing hypertension. The results of the study showed that combined dust + noise exposure significantly increased the risk of hypertension in workers compared with single exposure to dust and single exposure to noise (OR, 2.85; 95% CI, 1.83–4.43; $P < 0.001$), and further stratified analysis showed that this risk was present in different populations. For workers exposed to dust + noise, their risk of developing hypertension increased by 15% (OR, 1.15; 95% CI, 1.04–1.27; $P = 0.006$) when their working years exceeded 17 years.

In previous studies on the relationship between sex and hypertension,[9] men were more associated with the risk of developing hypertension. Similarly, both age and BMI have the potential to influence

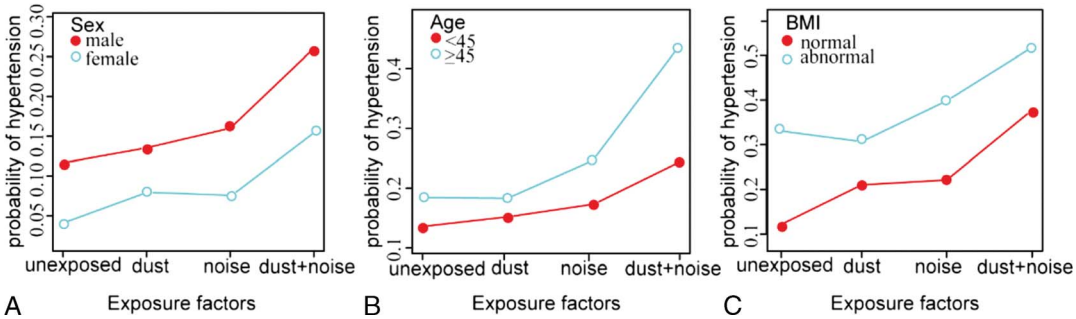

FIGURE 1. The risk of hypertension among workers exposed to risk factors stratified by demographic factors. A, Stratified by sex (male or female). B, Stratified by age (<45 or ≥45 years). C, Stratified by BMI (normal or abnormal).

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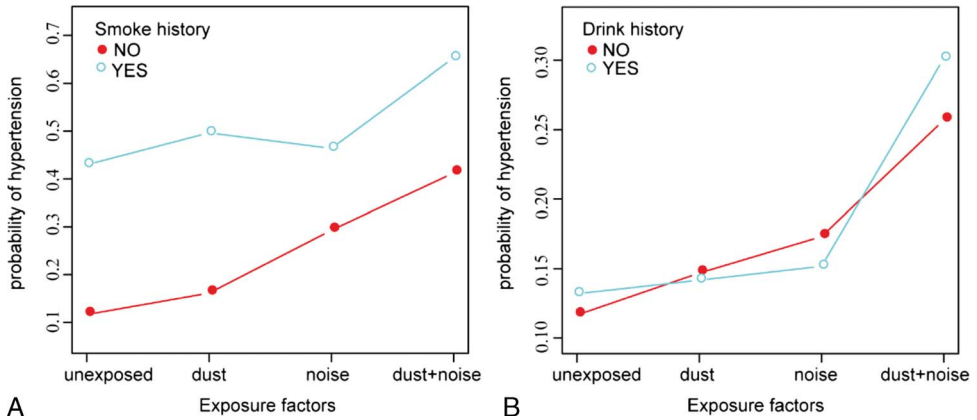

FIGURE 2. Risk of hypertension among employees exposed to risk factors after stratified according to living habits. A, Stratified by smoke history (no or yes). B, Stratified by drink history (no or yes).

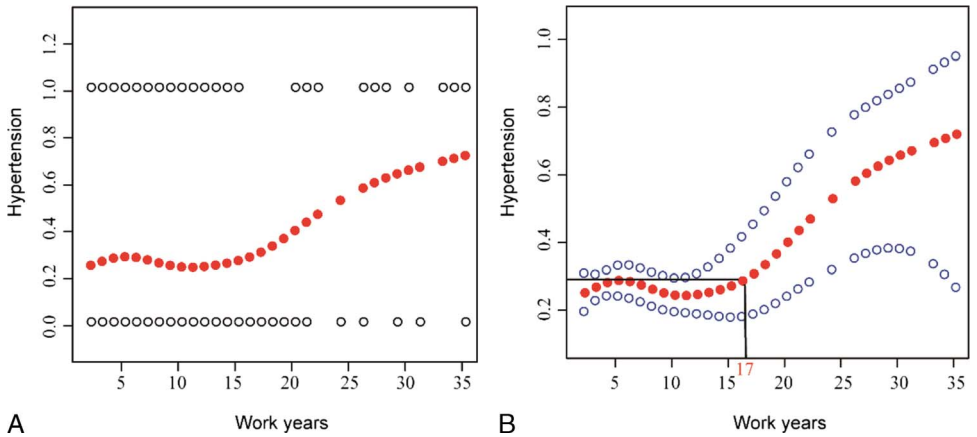

FIGURE 3. Effect of work years on the development of hypertension in workers with combined exposure to dust + noise. A, Each black dot represents a sample. The vertical coordinate 0.0 represents the absence of hypertension, 1.0 represents the occurrence of hypertension, and the red dot represents the number of years of work corresponding to each sample. B, The red bar represents the smoothed curve fit between the variables, and the blue bar represents the fitted 95% confidence interval.

human blood pressure profiles,[10,11] and considering their possible influence on the results of the analysis, and to try to avoid bias in the results caused by confounding factors, we constructed 3 models (model 1: unadjusted variables, model 2: adjusted for age and sex, and model 3: adjusted for age, sex, and BMI) in a multiple regression equation for the analysis. All results showed that combined dust + noise exposure significantly increased the risk of hypertension in workers.

Noise pollution is a growing problem faced in industrial production, which not only affects the health of the auditory system but also can cause autonomic responses in the body through indirect or direct activation of the sympathetic and endocrine systems, causing derangements in blood pressure, heart rate, and heart rhythm.[12–14] Although a number of studies have reported on the relationship between noise and blood pressure, the results are inconsistent. Some studies claim that chronic noise exposure can increase blood pressure in subjects,[15,16] while others claim that exposure to noise pollution does not affect blood pressure in subjects,[17,18] and there are even studies that report that noise can cause a decrease in blood pressure in subjects.[19,20] The inconsistency between studies may be due to the failure to circumvent the effects of confounding factors. In the results of this study, although no statistical differences were shown, workers with single exposure to noise still showed a trend toward an increased risk of developing hypertension (OR, 1.79; 95% CI, 0.88–3.65; $P = 0.109$) after adjusting for age, sex, and BMI in model 3, which are confounding factors that may affect the results.

Industrial workers are more likely than the general population to be exposed to high concentrations of dust, which can affect human function in the long run. Dust exposure is most likely to impair human lung function, and some studies have reported that long-term dust exposure significantly increases the risk of obstructive lung disease in workers,[21,22] and slowly the effects of dust on hypertension and the cardiovascular system are also starting to cause concern. A population-based cohort study showed that chronic exposure to particulate matter (≤2.5-μm aerodynamic diameter, PM2.5) was associated with the occurrence of hypertension (hazard ratio, 1.13; 95% CI, 1.05–1.22 per 10-μg/m^3 PM2.2 increase) in 35,303 nonhypertensive adults.[23] In addition, some studies have shown that long-term exposure

TABLE 5. Analysis of Threshold Effects

Outcome:	Hypertension
Model 1	
One line effect	1.04 (1.01–1.07) 0.015
Model 2	
Turning point	17 y
≤17-y segment effect	1.00 (0.95–1.05) 0.913
>17-y segment effect	1.15 (1.04–1.27) 0.006
>17- vs <17-y effect difference	1.15 (1.01–1.32) 0.033
Log-likelihood ratio test	0.026

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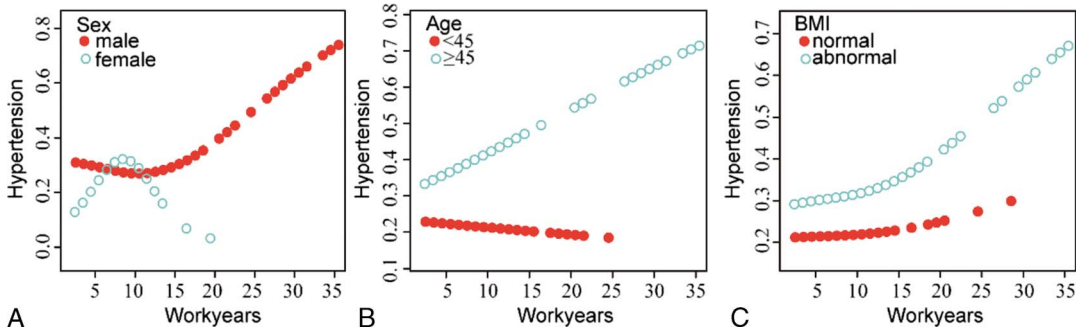

FIGURE 4. The effect of working years on the development of hypertension in workers exposed to dust + noise after stratified by demographic factors. A, Stratified by sex (male or female). B, Stratified by age (<45 or ≥45 years). C, Stratified by BMI (normal or abnormal).

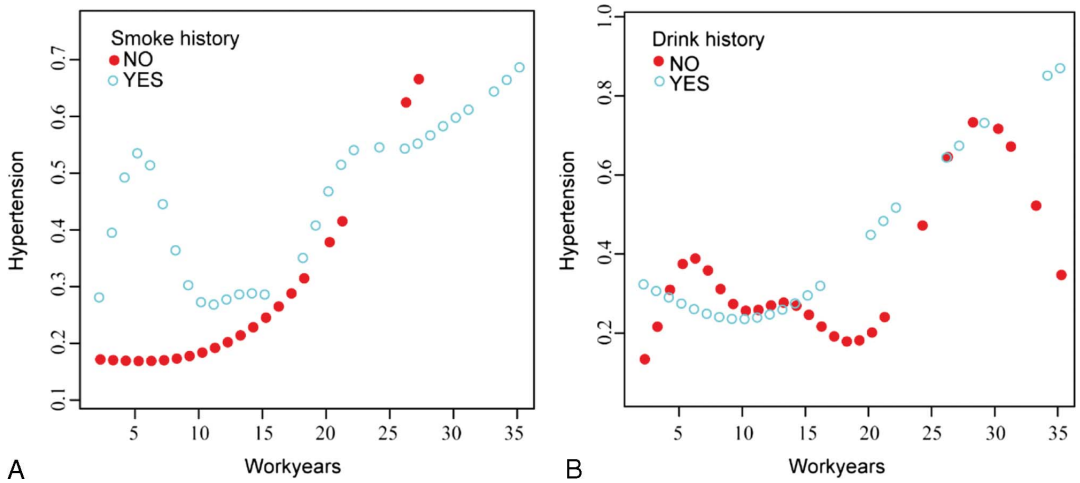

FIGURE 5. The influence of working years on the development of hypertension in workers exposed to dust + noise at the same time after stratification according to living habits. A, Stratified by smoke history (no or yes). B, Stratified by drink history (no or yes).

to dust, deposition of dust in the lungs leads to fibrosis of lung tissue and direct entry into the bloodstream, causing stress reactions in other systems, leading to the formation of pulmonary hypertension, accelerating atherosclerosis, and further affecting the function of cardiovascular and other systems.[24] Therefore, dust exposure is a risk factor for occupational groups that cannot be ignored.

The occurrence of hypertension is not only related to the hazardous factors in the work environment, but also the role of working hours cannot be ignored. In a study analyzing the effect of work hours on the risk ratio for hypertension in adults, there was a U-shaped dose-response relationship between weekly work hours and risk of hypertension. The risk ratio for hypertension first decreases and then gradually increases with longer working hours.[25] Increased risk of hypertension in workers with combined dust + noise exposure with increasing working age, especially after more than 17 years. With the increase of working years, the influence of unhealthy behaviors will be greater, such as sedentary, smoking, drinking, and lack of exercise, which will increase the risk of hypertension. In further stratified analysis, we found that the risk of hypertension was more significant in men and in workers 45 years or older with increasing length of service. Men have more bad habits and are under more social pressure than women. In addition, as men age, the body's functions begin to decline and blood vessels harden, all of which are risk factors that may increase the incidence of hypertension.

However, this study also has some limitations. (1) Many potential factors affecting high blood pressure, such as emotion, diet, and work and rest habits, have not been included in the records and studies, but the effects of these factors should not be ignored. (2) This study was a cross-sectional study and was not followed up. (3) The study population is from the coal mining industry, and dust properties may be different from other industries, which may also lead to the deviation of the results.

CONCLUSIONS

The results of this study suggest that combined dust + noise exposure significantly increases the risk of hypertension in workers compared with unexposed, single exposure to dust and single exposure to noise and that this risk is present in different populations. In addition, workers with more than 17 years of service were at higher risk of developing hypertension. Our findings allow those involved to take appropriate measures to reduce their hazards and have a positive impact on the protection of workers' health.

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