Original Article

Prevalence of hypertension and noise-induced hearing loss in Chinese coal miners

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Background: Owing to inconsistent epidemiologic evidence and the presence of confounding factors, the relation between occupational noise exposure and hypertension still remained unclear. We aimed to assess whether Chinese coal miners were at risk of developing hypertension and noise induced hearing loss (NIHL), and whether occupational noise exposure was a risk factor of hypertension.

Methods: A questionnaire was designed to collect information from 738 study participants, all of whom were employees from the Datun Xuzhou Coal Company. The participants were divided into a noise-exposed group and a control group based on the noise level to which they were exposed in the workplace. The differences in the mean of systolic blood pressure (SBP) and diastolic blood pressure (DBP) were compared between the noise-exposed and control groups. Also the prevalence and age-adjusted odds ratio (OR) [95% confidence intervals (CIs)] of audiometric deficit and hypertension was compared in the study. Binary logistic regression was used to assess the relation between occupational noise level and hypertension while controlling for potential confounding factors.

Results: Hypertension was more prevalent in noise-exposed group than the control group, 29.2% *vs.* 21.2% (P=0.012). The noise-exposed group faced an increased risk of hypertension (age-adjusted OR =1.52, 95% CI =1.07–2.15) when the control group was used as reference. The mean values of SBP and DBP of the noise-exposed groups were significantly higher than the control group (P=0.006 and P=0.002 respectively). Hearing loss at low frequencies was significantly more prevalent in the noise-exposed group than the control group, 12.8% *vs.* 7.4% (P=0.015), while the noise-exposed group faced the increased risk of hearing loss at low frequencies (age-adjusted OR =1.81, 95% CI =1.10–2.96). $L_{EX,\,8h}$ (OR =1.036, 95% CI =1.012–1.060) was an independent risk of hypertension when controlling for potential confounding factors.

Conclusions: We found that the occupational noise had an effect on the hypertension and hearing loss of Chinese coal miners. And the occupational noise was an independent risk factor for hypertension and could increase the values of SBP and DBP.

Keywords: Hypertension; occupational noise and hearing loss

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Introduction

Environmental noise endangers human health by damaging the extra-auditory system as well as the auditory system (1). Observational and experimental studies suggested that noise can increase annoyance levels (2,3), undermine sleep quality and cause daytime drowsiness (4), worsen patient outcomes and staff performance in hospitals (5), and impair cognitive performance in school children (6,7). It may induce these physiological and psychosocial responses, and ultimately extra-auditory system disorders, by stimulating the hypothalamus-pituitary-endocrine system and by altering blood dynamics and hormone levels (8).

Although some studies linked occupational noise exposure to hypertension (9-12), the epidemiologic evidence was not consistent (13,14). Owing to dominant confounding factors such as lifestyle and genetic predisposition, it is difficult to accurately assess the contribution of occupational noise to hypertension.

Long-term and high-intensity noise directly impacted hearing and caused noise induced hearing loss (NIHL) (15). NIHL was characterized by high-frequency hearing loss followed by gradual loss of low-frequency (16). NIHL is permanent irreversible damage and there are no effective treatments currently.

The present study was aimed to assess whether Chinese coal miners are at risk of developing hypertension and NIHL, and whether occupational noise exposure was a risk factor for hypertension.

Materials and methods

Participants

Datun Coal Power Company in China has four coal preparation plants, a coal-fired power plant, a coal thermal power plant, an electrolytic aluminium plant, and also has a mechanical repair, construction and installation, motor transport and logistics service units.

In order to establish whether Chinese coal miners were at risk of developing hypertension and NIHL, and whether occupational noise exposure was a risk factor of hypertension, we recruited 738 volunteers from the company for this study, according to the inclusion criteria that one should be a Han Chinese with over 10-year career, and be free from the medication history of anti-hypertensive or ototoxic drugs (e.g., aminoglycosides, macrolide antibiotics), previous ear infections, severe head trauma, electrocardiogram abnormalities, having been worked in shifts or at night, exposure to explosive noise and use of PPE. This cross-sectional study was designed and approved by the Institute of Occupational Disease Prevention, Jiangsu Provincial Center for Disease Prevention and Control. The 738 volunteers were divided into two groups according to the levels of occupational noise. Volunteers who experienced occupational noise ≥5 dB (A) were included into the noise-exposed group, while those who experienced occupational noise <85 dB (A) were included into the control group. The noise-exposed group was composed of 360 volunteers who engaged in the noise-generating activities such as wood sawing, forging, and casting. The control group was composed of 378 volunteers including managers, transport drivers, and maintenance workers. The study was conducted in accordance with the Helsinki Declaration and approved by the local ethics committees.

Questionnaires

A questionnaire was used to obtain personal information such as age, sex, length of service, lifestyle (smoking and drinking), exposure to explosive noise, use of personal protective equipment (PPE), past and previous health status, family history of cardiovascular diseases (CVD), and use of ototoxic drugs. Smoking was defined as more than one cigarette per day for the last six months; drinking was defined as more than one alcoholic beverage per week for the last six months. Use of PPE was based on the percentage of time that the subjects wore PPE and the type of PPE (e.g., earplugs and earmuffs). All the subjects filled out the questionnaire after giving informed consent and before a physical examination.

Clinical measurements

All the subjects were required to fast for 10 h before the medical examination to ensure the accuracy of blood glucose and lipid indicators. And the subjects should were required to rest for at least 15 min and refrained from smoking for at least 15 min before blood pressure measurement. Blood pressure was measured by a trained nurse using a mercury sphygmomanometer on the left arm of a patient seated. The cuff-size is 12–14 cm. Three measurements were made and the mean value was used. Each measurement had an interval of 5 min, and all measurements were taken between 8 and 10 AM. Subjects were classified as hypertensive if the systolic blood pressure (SBP) was ≥140 mm Hg or the diastolic blood pressure (DBP) was ≥90 mm Hg according to the World

Health Organization (WHO) 2007 classification. Systolic hypertension is defined as SBP ≥140 mm Hg, and diastolic hypertension is defined as DBP ≥90 mm Hg. Height (m) and weight (kg) were measured by using an automatic measuring instrument, and body mass index (BMI) was calculated as weight (kg)/height^2 (m^2). Total cholesterol (TC), triglyceride (TG), high-density lipoprotein (HDL), low-density lipoprotein (LDL) levels were measured biochemically in blood samples.

Pure tone audiometry and environmental noise evaluation

An otolaryngologist inspected the ears of all the subjects. All the subjects had undergone pure tone audiometry tests in a sound-attenuating chamber with a background noise level <25 dB (A). Both ears were tested by using ascending pure tones at frequencies of 0.5, 1, 2, 3, 4, and 6 kHz. The subjects were required to avoid a noisy environment over 12 h before test. Trials were repeated at least 3 times to determine the lowest signal intensity, which served as the final threshold value for each ear. The mean threshold values at 0.5, 1, and 2 kHz were used to determine low-frequency hearing status, while the mean threshold values at 3, 4, and 6 kHz were used to determine high-frequency hearing status. A notch of NIHL was showed around 3 to 6 kHz, and threshold values at high-frequency were substantially worse than threshold values at low-frequency. Audiometric deficit or hearing loss was defined as a hearing threshold >25 dB at high frequency or at both high and low frequencies. The diagnostic criteria of occupational NIHL were based on the Chinese occupational health standard (GBZ49-2002, http://www.zybw.net). On a certain test frequency, normal hearing was defined as binaural hearing level ≤25 dB, unilateral hearing loss was defined as monaural hearing is >25 dB, and bilateral hearing loss was defined as binaural hearing level >25 dB.

Workplace noise was measured by using a sound pressure noise meter (Noise-Pro, Quest, Oconomowoc, WI) at 10 am, 3 pm, and 5 pm for three consecutive days, twice per year and evaluated, according to China national criteria for noise in the workplace (GBZ43-2002, http://www.zybw.net). To determine the actual noise levels, the equivalent continuous a-weighted sound pressure was normalized to a nominal eight-hour per day ($L_{EX,\,8h}$). A sound pressure noise meter was chosen to measure the occupational noise levels of fixed position. An individual noise dosimeter was used for the levels of flow positions measurement. The eight-hour continuous equivalent sound levels ($L_{EX,\,8h}$) of each jobs was calculated by the following formula.

$$L_{EX,8h} = L_{Aeq,Te} + 10\lg \frac{T_e}{T_0}\ \mathrm{dB(A)}$$

here *Te* represents the actual working time of one working day, $L_{Aeq,\,Te}$ represents the equivalent sound level of the actual working day, and T_0 represents the eight-hour standard working time.

Statistical analyses

Continuous data were shown as mean ± standard deviation and were analyzed by using independent-sample, two-sided *t*-tests. Categorical data were analyzed by using two-sided chi-square tests. Binary logistic regression was used to assess the association between occupational noise level and hypertension by computing odds ratios (ORs) and 95% confidence intervals (CIs) while controlling for potential confounding factors. Multivariate logistic regression was used to assess the association between occupational noise level and hearing loss by computing age-adjusted OR and 95% CIs. Differences would be considered significant if the P value was <0.05. All the analyses were carried out by using SPSS 13.0 software.

Results

According to the different departments, all the subjects in this study were exposed to noise levels from 60 to 110 dB of eight-hour continuous equivalent sound ($L_{EX,\,8h}$). *Table 1* indicated the measurements of the $L_{EX,\,8h}$ in 14 different locations.

The demographic characteristics and potential risk factors associated with high blood pressure in noise-exposed and control groups are shown in *Table 2*. There were no significant differences in age, sex, body mass index, length of service, total cholesterol level (TC), triglyceride level (TG), high-density lipoprotein (HDL), low-density lipoprotein (LDL), smoking, alcohol consumption, or family history of CVD between the groups (P>0.050).

Table 3 shows the percentages of subjects with hypertension, systolic hypertension and diastolic hypertension were significantly higher in noise-exposed group than control group: hypertension, 29.2% *vs.* 21.2% (P=0.012); systolic hypertension, 16.1% *vs.* 9.0% (P=0.003); and systolic hypertension, 23.3% *vs.* 17.2% (P=0.038). Taking the control group as reference, we found that the noise-exposed group had the increased risk of hypertension (age-adjusted OR =1.52, 95% CI =1.07–2.15) and systolic hypertension (age-adjusted OR =1.96, 95% CI =1.23–3.13). The mean values of SBP and DBP of the noise-exposed groups were significantly higher than the control group (P=0.006 and P=0.002 respectively).

Hearing loss at low frequencies was significantly more prevalent in noise-exposed group than control group: 12.8% *vs*. 7.4% (P=0.015); bilateral hearing loss at 500 Hz: 8.6% *vs*. 3.4% (P=0.005); bilateral hearing loss at 1,000 Hz: 6.7% *vs*. 3.2% (P=0.033), bilateral hearing loss at 4,000 Hz: 21.1% *vs*. 13.2% (P=0.006). We found that the noise-exposed group had the increased risk of hearing loss at low frequencies (age-adjusted OR =1.81, 95% CI =1.10–2.96), bilateral hearing loss at 500 Hz (age-adjusted OR =2.63, 95% CI =1.35–5.13), bilateral hearing loss at 1,000 Hz (age-adjusted OR =2.17, 95% CI =1.06–4.41), and bilateral hearing loss at 4,000 Hz (age-adjusted OR =1.75, 95% CI =1.18–2.61) when we took the control group as reference.

Table 4 shows a binary regression model was established for a more accurate assessment for the relation between noise-exposed intensity and hypertension. This model included several potential risk factors for hypertension: age, $L_{EX, 8h}$, NIHL, sex, BMI, length of service, TC, TG, HDL, LDL, education level, smoking, alcohol consumption, and family history of CVD. Applying the backward method and removing variables according to the condition of the likelihood ratio test result, six factors entered into the regression model. We found that such factors were significantly correlated with high blood pressure as following: age (OR =1.112, 95% CI =1.055–1.171), sex (OR =0.367, 95% CI =0.228–0.591), $L_{EX, 8h}$ (OR =1.036, 95% CI =1.012–1.060), TC (OR =3.817, 95% CI =2.020–7.013), HDL (OR =0.155,

Table 1 Eight-hour continuous equivalent sound levels ($L_{EX, 8h}$) of each job location.

Location	Department	$L_{EX, 8h}$ (dB(A))
1	Gangue choosing	108.8
2	Wood sawing	100.2
3	Casting	86.7
4	Hot rolling	88.5
5	Cold rolling	91.2
6	Rivet welding	86.8
7	Winch station	85.8
8	Compressor station	87.4
9	Exhauster station	92.6
10	Water supplying	82.1
11	Water purifying	76.8
12	Transporting	72.4
13	Electrification	70.5
14	Managerial position	62.5

Table 2 Demographic characteristics and risk factors for hypertension in the noise-exposed and control groups

Characteristic	Control (N=378)			Noise-exposed (N=360)			P Value
	Mean (SD)	No.	%	Mean (SD)	No.	%	
Age (years)	42.83 (6.91)			43.45 (6.38)			0.209[a]
Male		249	65.9		245	68.1	0.529[b]
Female		129	34.1		115	31.9	
Body mass index (kg/m^2)	23.57 (3.00)			23.78 (2.84)			0.222[a]
Length of service (years)	21.96 (7.16)			22.95 (6.65)			0.052[a]
TC (mg/dL)	5.01 (0.96)			4.98 (0.93)			0.640[a]
TG (mg/dL)	1.57 (1.61)			1.53 (1.15)			0.700[a]
HDL (mg/dL)	1.32 (0.38)			1.30 (0.30)			0.244[a]
LDL (mg/dL)	3.23 (0.77)			3.17 (0.81)			0.317[a]
Smoking		138	36.5		117	32.5	0.252[b]
Alcohol consumption		88	23.3		71	19.7	0.240[b]
Family history of CVD		137	36.2		126	35.0	0.724[b]

SD, standard deviation; CVD, cardiovascular disease; TC, total cholesterol; TG, triglyceride; HDL, high-density lipoprotein; LDL, low-density lipoprotein. [a], two-sided *t*-test of the continuous variable difference between the noise-exposed group and the control group; [b], two-sided χ^2 test for the frequency difference between the two groups.

Table 3 Prevalence and age-adjusted OR (95% CIs) of hypertension and audiometric deficit in the study groups

Variablew	Control (N=378)			Noise-exposed (N=360)			OR (95% CIs)	P value
	Mean (SD)	No.	%	Mean (SD)	No.	%		
Hypertension		80	21.20		105	29.20	1.52 (1.07–2.15)	0.012[b]
Systolic hypertension		34	9.0		58	16.1	1.96 (1.23–3.13)	0.003[b]
Diastolic hypertension		65	17.2		84	23.3	1.44 (0.99–2.08)	0.038[b]
SBP (mm Hg)	121.00 (15.47)			124.16 (15.71)				0.006[a]
DBP (mm Hg)	78.62 (12.27)			81.52 (13.10)				0.002[a]
NIHL		103	27.2		115	31.9	1.24 (0.90–1.70)	0.162[b]
Hearing loss at high frequencies		102	27.0		111	30.8	1.19 (0.86–1.64)	0.249[b]
Hearing loss at low frequencies		28	7.40		46	12.8	1.81 (1.10–2.96)	0.015[b]
Hearing loss at 500 HZ								0.011[b]
Normal hearing		340	89.9		303	84.2	1.00	
Unilateral hearing loss		25	6.6		26	7.2	1.16(0.66–2.06)	0.607[b]
Bilateral hearing loss		13	3.4		31	8.6	2.63 (1.35–5.13)	0.005[b]
Hearing loss at 1,000 HZ								0.074[b]
Normal hearing		341	90.2		309	85.8	1	
Unilateral hearing loss		25	6.6		27	7.5	1.17 (0.67–2.07)	0.579[b]
Bilateral hearing loss		12	3.2		24	6.7	2.17 (1.06–4.41)	0.033[b]
Hearing loss at 2,000 HZ								0.163[b]
Normal hearing		334	88.4		302	83.9	1	
Unilateral hearing loss		26	6.9		30	8.3	1.26 (0.73–2.18)	0.411[b]
Bilateral hearing loss		18	4.8		28	7.8	1.69 (0.92–3.12)	0.094[b]
Hearing loss at 3,000 HZ								0.172[b]
Normal hearing		287	75.9		260	72.2	1	
Unilateral hearing loss		57	15.1		52	14.4	0.99 (0.66–1.50)	0.971[b]
Bilateral hearing loss		34	9.0		48	13.3	1.53 (0.95–2.45)	0.080[b]
Hearing loss at 4,000 HZ								0.016[b]
Normal hearing		273	72.2		233	64.7	1	
Unilateral hearing loss		55	14.6		51	14.2	1.08 (0.71–1.64)	0.721[b]
Bilateral hearing loss		50	13.2		76	21.1	1.75 (1.18–2.61)	0.006[b]
Hearing loss at 6,000 HZ								0.260[b]
Normal hearing		234	61.9		207	57.5	1	
Unilateral hearing loss		76	20.1		71	19.7	1.05 (0.72–1.52)	0.813[b]
Bilateral hearing loss		68	18.0		82	22.8	1.35 (0.93–1.96)	0.116[b]

[a], two-sided *t*-test of the continuous variable difference between the noise-exposed group and the control group; [b], two-sided χ^2 test for the frequency difference between the two groups. OR, odds ratio; CI, confidence interval; SBP, systolic blood pressure; DBP, diastolic blood pressure; NIHL, noise induced hearing loss.

Table 4 Binary logistic regression model assessing the relationship between occupational noise and hypertension

Variable	B	SE	EXP(B)	95% CI for EXP(B)		P value
				Lower	Upper	
Constant	−10.688	2.397				
Age	0.106	0.027	1.112	1.055	1.171	<0.001
Sex	−0.967	0.280	0.367	0.228	0.591	<0.001
$L_{EX, 8h}$	0.035	0.012	1.036	1.012	1.060	0.003
TC	1.339	0.325	3.817	2.020	7.013	<0.001
HDL	−1.865	0.434	0.155	0.066	0.363	<0.001
LDL	−1.181	0.332	1.396	1.132	1.722	0.002

CI, confidence interval; TC, total cholesterol; HDL, high-density lipoprotein; LDL, low-density lipoprotein. B, partial regression coefficient; SE, standard error.

95% CI =0.066–0.363), LDL (OR =1.396, 95% CI = 1.132–1.722).

Discussion

In this cross-sectional study, we found the relationship between occupational noise exposure and high blood pressure as well as hearing loss, despite the similarity of confounding factors.

Overall, hypertension, systolic hypertension and diastolic hypertension were more prevalent in noise-exposed group than control group. SBP and DBP levels could increase in response to the exposure to high noise levels. These findings implied that occupational noise increased the prevalence blood pressure owing to its influence on both the SBP and the DBP. This result was consistent to the previous studies (10,17,18). In our study, occupational noise exposed group had the higher risk of hypertension compare to the control group (age-adjusted OR =1.52, 95% CI =1.07–2.15).

The mechanism of noise-induced hypertension was not yet clear. However, it can be assumed that noise, as an environmental stressor, signals the activation of the automatic nervous and endocrine systems and the consequent release of stress hormones such as catecholamines (19). When released, catecholamines enhance myocardial contractility and increase blood pressure, and cardiac output via modulation of β-1 receptors (20).

In order to exclude the influence of the confounding factors on the relation of noise levels and hypertension, we also established a regression model to adjust the confounding risk factors for further test. The model included six variables: age, sex, TC, HDL, LDL and $L_{EX, 8h}$. The results showed that the older and male were more likely to develop high blood pressure than younger and female. The higher levels of TC, LDL and the lower level of HDL were also the risk factors for hypertension. Noise-exposed level was still an independent risk factor for hypertension after controlling the potential confounding factors, which was consistent with the report by Tomei *et al.* (21).

Long-term, high-intensity noise exposure negatively impacted hearing, and caused both high and low frequency hearing loss (22,23). The noise deteriorated hearing in high tones primarily. Of the systems in the body, the auditory system was the most sensitive part to external noise (24). And we found that the exposure to occupational noise could increase the risk of hearing loss, this is indicated that subjects who had long occupational noise exposure were more likely to suffer from hearing loss.

Our study showed that confounding factors had relations to hypertension and established a tentative connection between occupational noise and hypertension. However, as it was cross-sectional, it could not explain this effect. Based on the results of the present study, we would perform a prospective cohort study in the future to determine how the occupational noise to promote hypertension. Other factors will also be considered in future study, such as environment noise, noise annoyance, the salt intake in diet factors and the exercise frequency in lifestyle risk factors. Finally, selection bias may exist in this survey as a result of the healthy worker effect. The average length of service was up to about 20 years in both groups. The exposed workers had habituated to the environment with high occupational noise intensity, while the workers who were sensitive to noise had been away from their noisy posts.

In conclusion, we found that the occupational noise had an effect on the hypertension and hearing loss of Chinese coal miners. And the occupational noise was an independent risk factor for hypertension and could increase the values of SBP and DBP.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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