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Analysis of related factors and disease costs of respiratory infection and environmental pollution in children

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Abstract.
BACKGROUND: In recent years, air pollution and the number of children with respiratory tract infections increased. This also increased the burden related to the treatment of disease, so the government and relevant departments need to strengthen their management.
OBJECTIVE: The aim of the present study was to quantitatively analyze the relationship between respiratory infection and air quality in children and gain insight into the burden of related diseases.
METHODS: Data regarding outpatient and emergency department visits in children of 14 years or younger in 16 public and private medical institutions were collected for four months. Routine air quality monitoring data in Shanghai from the same period were correlated with these medical data by descriptive statistics, Pearson's correlation analysis and multivariate linear regression analysis.
RESULTS: There was a positive correlation between respiratory tract infections in 73376 children and Air Quality Index (AQI), PM2.5, SO_2 and NO_2 levels. The total medical expense per patient was 80.22 yuan, and the average compensation ratio of medical insurance per patient was 18.95%. The increase in AQI and the concentration of major air pollutants will lead to increased medical treatment for children with respiratory diseases.
CONCLUSION: It is suggested that the intensity of air pollution control should be increased, so that the special period of childhood respiratory protection is strengthened. Moreover, child medical insurance coverage should also be moderately increased to safeguard the rights and interests of children's health.

Keywords: Air Quality Index, pollutant concentration, children, respiratory tract infection, outpatient emergency treatment visits, medical expenses, medical insurance

1. Introduction

Due to the development of the national economy and acceleration of the industrialization process, the problem of environmental pollution is becoming increasingly serious. Environmental pollution not only greatly reduces the quality of the living environment, but also poses a growing threat to human health, especially of children. According to the WHO Environment Air Quality Guidelines (10 μg/m^3) [1], 92% of the population lives in areas with air quality levels that exceed the annual average value of particulate matter smaller than 2.5 μm (PM2.5). There are approximately three million deaths annually due to air pollution, 3% of which occur in children [2]. Studies have shown that every 10 μg/m^3 increase in PM2.5

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will lead to a 1.78% increase in respiratory-related mortality [3]. In recent years, relevant research on the causes of respiratory diseases in children has evolved, and air pollution is now recognized as the main pathogenesis of respiratory diseases in children [4]. However, there exist a plethora of research on respiratory infections and air pollution in children, but research related to disease treatment costs is limited. The present paper is based on an empirical analysis of real data from the Shanghai Pudong New District with respect to air quality, air pollutant indexes, factors closely related to respiratory infections in children, and the status of medical expenses related to the disease. We took the Pudong New District of Shanghai as a typical case to analyze the correlation between the treatment of respiratory tract infection in children, the Air Quality Index and the concentration of air pollutants in view of identifying the burden of related medical expenses. This will help to focus on the treatment of air pollutants that affect children's respiratory tract infections and probe reasonable improvements in children's medical security [5].

2. Information source and methods

2.1. Source of information

Data on disease diagnosis was derived from 13 public and private medical institutions in Pudong New District, including seven general hospitals, one traditional Chinese medicine hospital, three specialized hospitals, two maternal and child health hospitals, six community health service centers and three private hospitals. All emergency data was collected from each medical institution for the four months of January, April, July and October 2018, and children under 14 years old were selected as the research subjects. Disease was diagnosed according to the International Classification of Diseases, Tenth Edition (ICD-10). The ICD-10 code screened out case data encoded as J98.802 (with respiratory infection), yielding a final sample size of 73376. Data included general sociodemographic characteristics, medical dates, medical department, visit-related expenses and type of health insurance.

Air quality monitoring data from the network database of the Shanghai Environmental Monitoring Center published by the Shanghai Environmental Protection Bureau in January, April, July and October 2018 were analyzed to give the daily average Air Quality Index (AQI) and concentration of atmospheric pollutants.

2.2. Statistical analysis

SPSS 19.0 was used for all statistical analyses. Descriptive statistics were calculated for the quantity of children with respiratory infection, real-time Air Quality Index (AQI), air pollutant concentration, and the level of disease cost and reimbursement. Pearson's correlation [6] and multivariate linear regression were used to analyze the relationship between the quantity of emergency hospital visits, air pollutant concentration and AQI [7]. $P < 0.05$ was considered statistically significant.

3. Results

3.1. Number of outpatient and emergency department cases in children with respiratory infections

During the four months of the survey, 13 medical institutions received a total of 73,376 outpatient and emergency department cases of respiratory infections in children, accounting for 1.06% of the

Table 1
Daily average concentration of atmospheric pollutants

Index	Jan	Apr	Jul	Oct	P
AQI	108.67 ± 59.49	78.3 ± 25.93	72.67 ± 31.16	77.19 ± 21.29	
PM2.5 (μg/m^3)	75.58 ± 51.88	53.03 ± 22.92	44.74 ± 27.33	39.03 ± 21.38	
PM10 (μg/m^3)	94.64 ± 57.6	66.23 ± 26.65	55.38 ± 25.98	66.7 ± 25.59	
O_3 (μg/m^3)	68.25 ± 15.52	107.8 ± 26.54	109.16 ± 36.05	114.96 ± 30.69	
SO_2 (μg/m^3)	29.8 ± 14.51	14.83 ± 6.73	11 ± 3.43	14.61 ± 7.26	
NO_2 (μg/m^3)	60.58 ± 23.74	47.3 ± 15.08	31.7 ± 12.77	41.87 ± 18.6	
CO (μg/m^3)	0.91 ± 0.38	0.67 ± 0.22	0.69 ± 0.22	0.73 ± 0.2	0.004

total number of emergency visits (6896707) in the same period. On average, 46 (45.89) children with respiratory infections were submitted per institution per day; 369,480 (50.35%) were males and 36,428 (49.65%) were females, and the average age of the children was 5.28 years old (SD = 3.39). The number of emergency visits in January, April, July and October 2018 was 42,364, 16,372, 6,988 and 7,730, respectively.

3.2. Atmospheric pollutant concentration and AQI

The AQI is a dimensionless index that quantitatively describes the air quality and is divided into six levels corresponding to six categories of air quality. The larger the index, the higher the level, and the more serious the pollution and health hazard. The main pollutants involved in air quality assessment are six indicators: particulates with a particle size $\leqslant$ 2.5 μm (PM2.5), particulates with a particle size $\leqslant$ 10 μm (PM10), ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO).

In 2018, Shanghai's ambient air quality was generally good, with an excellent number of days (281) with a ratio of 77.0%. According to an AQI over 101 for light pollution and above, the difference in air pollution level during the four months (January, April, July, and October 2018) was statistically significant ($P = 0.004$). The number of days with mild air pollution was the highest in January, at 13 days, and the lowest in April, at two days. The daily average concentration of atmospheric pollutants and AQI data for these four months are shown in Table 1.

According to the GB3095-2012 Ambient Air Quality Standard, the average concentration of NO_2 in January, April and October exceeded the annual average secondary concentration limit (40 μg/m^3), with over-standard rates of 51.45%, 18.25% and 4.68%, respectively. PM2.5 was higher than the annual average secondary concentration limit (35 μg/m^3) in all 4 months, with over-standard rates of 115.94%, 51.52%, 27.83% and 11.52%, respectively. PM10 in January (70 μg/m^3) was higher than the annual average secondary concentration limit, with an over-standard rate of 35.21%. The O_3 concentration in April, July and October was higher than the first-level concentration limit (100 μg/m^3). The average concentration of CO was below the average primary concentration limit (below 4 μg/m^3), and the concentration values did not fluctuate significantly. The concentrations of various air pollutants were statistically significant among the different months.

3.3. Univariate analysis of the relationship between outpatient and emergency department visits, AQI and atmospheric pollutant concentrations

Pearson's correlation analysis was used to study the relationship between outpatient and emergency department visits in children with respiratory infections, AQI and air pollutant concentration indicators. There was a correlation between the number of emergency department visits and AQI, PM2.5, PM10, O_3

Table 2
Correlation analysis between air pollutant concentration, AQI and admission of children with respiratory infection to the emergency department

	AQI	PM2.5	PM10	O_3	SO_2	NO_2	CO	P
Emergency department	0.983*	0.983*	0.961*	−0.978*	0.977*	0.928	0.899	< 0.05

Table 3
Respiratory infections in children in different age groups

Index	N	Total medical expenses			Drug costs			Self-pay		
		X ± S	F	P	X ± S	F	P	X ± S	F	P
< 1 y (age)	3021	96.1 ± 86.57			83.28 ± 75.37			59.18 ± 67.5		
1–4	32417	88.11 ± 108.04			69.61 ± 84.32			58.33 ± 87.61		
5–9	28520	72.68 ± 87.82			59.69 ± 72.13			51.2 ± 78.36		
10–14	9382	71.79 ± 80.65			61.09 ± 68.31			52.33 ± 78.87		
Total	93376	80.22 ± 96.58	175.958	0.000	54.77 ± 82.22	42.138	0.000	65.19 ± 77.65	144.360	0.000

and SO_2 concentrations ($P < 0.05$). The concentrations of AQI, PM2.5, PM10 and SO_2 were positively correlated with the number of outpatient and emergency department visits, and the concentration of O_3 was negatively correlated with the number of these visits. Detailed data are shown in Table 2.

3.4. Multivariate linear regression analysis of the relationship between emergency department visits, AQI and atmospheric pollutant concentrations

The number of emergency department visits related to respiratory infection in children was the dependent variable Y, and PM2.5, PM10, O_3, SO_2, NO_2, CO and AQI were the independent variables X1, X2, X3, X4, X5, X6 and X7, respectively. The results of multivariate linear regression analysis show that $Y = 1127.420 + 8.914\ X1 + 35.873\ X4 + 4.307\ X5 + 5.009\ X7$, $R2 = 0.832$, $F = 36.817$, $P < 0.001$, indicating that respiratory infection in children is positively correlated with AQI, PM2.5, SO_2 and NO_2.

3.5. Analysis of medical expenses related to respiratory infection in children

The total cost of sub-hospital emergency medical treatment for all children was 80.22 yuan. The cost of medicine was 54.77 yuan, which accounted for 68.27%, while the patient's average self-pay was 65.19 yuan, which accounted for 81.26%. The average medical insurance compensation ratio was 18.94%. Specifically, the total cost of sub-hospital emergency medical care in January, April, July and October 2018 was 105.16 yuan (95% CI 102.57–107.74), 70.94 yuan (95% CI 70.14–71.73), 96.76 yuan (95% CI 95.01–98.51) and 69.82 yuan (95% CI 67.26–72.38), respectively. The average self-pay was 73.50 yuan (95% CI 71.56–75.45), 61.52 yuan (95% CI 60.85–62.19), 73.31 yuan (95% CI 71.99–74.64) and 58.80 yuan (95% CI 56.75–60.85), respectively. The children's self-paid medical expenses accounted for 52.20%, 79.12%, 61.36% and 78.54% of the total cost, respectively. The average ratios of compensation for participating medical insurance were 30.77%, 15.98%, 21.73% and 13.96%, respectively.

The analysis results of children grouped by age are shown in Table 3. There were statistical differences in the cost of the outpatient and emergency medical expenses, drug expenses and out-of-pocket expenses among children in different age groups ($P < 0.01$). The average cost of sub-hospital emergency medical care, average drug cost and sub-average out-of-pocket expenses decreased with age. The proportion of out-of-pocket expenses increased with age by 61.58%, 66.20%, 70.45% and 72.89%, respectively, and the medical insurance compensation ratio increased with age by 16.15%, 15.74%, 22.13% and 22.59%, respectively.

4. Discussion and conclusion

4.1. Strengthening the control of air pollution and the protection measures for children's respiratory tract

Respiratory diseases have become a threat to children's health [8]. In recent years, there has been a significant increase in respiratory tract infections in children. Besides certain deficiencies in their own immunity and organ function, which render these children more sensitive to invasion by pathogenic bacteria and other pathogenic factors, respiratory tract infections are also related to population-intensive places, such as schools, and increasingly serious air pollution [9].

Many studies found that there is a positive correlation between the concentrations of AQI and major air pollutants and the number of emergency cases of respiratory diseases in hospitals [10]. However, some scholars believe that the concentrations of air pollutants are not closely related to the amount of emergency cases of respiratory diseases. In the present paper, based on multivariate linear regression analysis of all 73,376 visits to 13 medical institutions in four months, it was found that there was a close relationship between respiratory tract infections in children and AQI, PM2.5, SO_2 and NO_2 [11]. Particularly during low temperature months, the concentrations of air pollutants and AQI are higher, and children are more prone to respiratory diseases. On the one hand, it has been suggested that the control of environmental pollution should be increased, including the regulation and control of illegal industrial emissions, locomotive exhaust emissions, dust raising and building dust, in addition to a reduction in the emission concentrations of PM2.5, SO_2 and NO_2, which are closely related to children's respiratory system to the lowest level. On the other hand, it is necessary to strengthen the protective measures for children's respiratory tracts, especially in winter when the temperature is low and children are more susceptible to diseases.

4.2. Increasing children's medical insurance coverage to ensure their health rights and interests

For the urban and rural residents of Shanghai, the standard deductible for insurance coverage of outpatient and emergency treatment in children and infants is 300 yuan. Since the physique of children is different from that of adults, there are certain limitations in the diagnosis and treatment of childhood diseases and in the use of drugs. The cost of each visit related to respiratory tract infections is not high and fails to meet the deductible. The proportion of out-of-pocket expenses within the total outpatient and emergency medical expenses is higher, especially in infants and very young children. However, recurrent respiratory tract infections often occur, which brings direct and indirect economic burden to children and their families. We suggest that the management and compensation methods of children's medical insurance coverage should be further improved, and the overall reimbursement level moderately raised. On the one hand, the catalogue of drugs and medical devices should be classified according to children's specific medication and medical treatments, expanding and perfecting the scope of child health insurance as distinct from that of adults. On the other hand, using the experiences of certain provinces and cities as a reference, the present paper explores family medical treatment and allows individual accounts of medical insurance to pay for family members, including children's self-paid medical expenses.

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Conflict of interest

None to report.

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