Letter to the Editor

The Weather Temperature and Air Pollution Interaction and Its Effect on Hospital Admissions due to Respiratory System Diseases in Western China*

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Air pollution has ever become a global major public health problem. Previous studies showed that air pollution is associated with excessive mortality and morbidity of respiratory disease[1-2]. The extreme weather temperature can impact human health and the thermal stresses can lead not only to direct deaths and illnesses, but also to aggravation of respiratory disease[3-4]. Though the independent impacts of extreme weather temperature and air pollution on human health have been widely explored, the interactive effect of weather temperature and air pollution on human health has been scarcely reported in the recent years. In China, the largest developing country in the world, although the interactive effect of weather temperature and air pollution on daily mortality has been examined in several economically developed large cities, such as Tianjin[5], Shanghai[6], and Wuhan[7], no data available from within the country so far on the association between exposure to air pollution and increased hospital admissions.

Though there are previous studies showing the significant association between weather temperature and health impacts of air pollution, the results from all these studies are not consistent. Some studies exhibited more adverse health effects in warm days than in cold days[7-8], while a few other studies showed a contrary effect[6,9]. Therefore, the interaction between the weather temperature and air pollution impacts remains unclear and, a variety of studies with replicated findings are needed to throw light on different characteristics of outdoor air pollution, weather patterns, geographic information, and socio-demographic status.

In Lanzhou of western China, air pollution has long been a well-known problem and the concentrations of gaseous and particulate pollutants measured here in the city have been documented as the highest among urban cities in China. In the present study, the relationship between hospital admissions of respiratory system diseases and air pollutants, including particulate matter less than 10 μm in diameter (PM_{10}), sulfur dioxide (SO_2), and nitrogen dioxides (NO_2) was investigated and analyzed. Time series analysis was used in the study in order to evaluate the potential weather temperature factor related to the impacts of air pollution on human health.

The data on daily hospital admissions for respiratory system diseases were collected between January 1, 2001 and December 31, 2005 from four largest general hospitals in Lanzhou City. Data of patients on age, gender, occupation, home address, diagnosis, and the date of hospital admission and discharge was collected The cases were coded according to the tenth revision (ICD-10) for diseases of the respiratory system (ICD10：J00~J99) of International Classification of Disease, And the diseases caused by unintentional injuries and anthropic factors were excluded.

The air pollution data for the study period were obtained from the Lanzhou Environmental Monitoring Center. The Center, as part of a nationwide network of monitoring stations, reports daily to the China Environmental Monitoring Chief Station. The meteorological data, including daily mean temperature and relative humidity were collected from the Gansu Meteorological Bureau.

Poisson generalized additive model (GAM) approach was used to model the natural logarithm of the expected daily respiratory disease hospital admissions as a function of the predictor variables. We examined in the present study the effect of air pollutants with different lag structures including both single-day lag (from lag 0 to lag 6) and multiday lag (lag 01 and lag 06). In general, the largest pollutant effects were observed at the lag 06, where pollution concentrations were evaluated at 7-day moving average of pollutant concentration in the current day and in previous 6 days. Therefore, for

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achieving the target of this study we focused on the results of the lag 06 model.

Firstly, we generated core models limited to variables representing time trends and day of the week (DOW). The partial autocorrelation function (PACF) was used to select the degree of freedom of time trends until the absolute values of the sum of PACF for lags up to 30 reached a minimum. The day of the week (DOW) was included as a dummy variable also in the basic models. After the basic regression model of hospital admissions was built, we introduced the pollutants and weather variables and analyzed their effects on hospital admissions for respiratory system diseases. For weather condition, the selection of degree of freedom was based on minimizing Akaike's Information Criterion (AIC)[10].

In order to examine the interaction of weather temperature with the effects of air pollutants, the adverse health effects of each air pollutant were tested separately for different temperature levels. The high temperature days and low temperature days were defined as those days on which the highest or lowest daily average temperatures were >85th percentile or <15th percentile of the 5 year data, respectively[6]. And those within these ranges were defined as the normal temperature days.

The results of the analysis were expressed in relative risk (RR) and their 95% confidence interval (CI) which was produced using regression coefficient for air pollutants in the above log-linear model. RR was calculated for the interquartile range (75th percentile to 25th percentile) of the air pollution concentration for each pollutant, as observed during the study period. In addition, we also estimated the effects by gender and age (less than 65 years and more than 65 years) separately. All analyses were conducted in R 2.13.0 statistical software by using "mgcv" package.

There were a total of 28 065 hospital admissions for respiratory system diseases during this period. Table 1 showed that there were approximately 15.4

Table 1. Statistics of Weather Conditions, Air Pollution Concentrations and Daily Hospital Admissions of Respiratory System Diseases in Lanzhou (2001-2005)

	Mean±SD	Min	P_{25}	Median	P_{75}	Max	IQR
Daily Hospital Admissions							
Total	15.4±8.5	1	9	14	20	51	11
Gender							
Male	10.2±5.9	0	6	9	14	41	8
Female	5.2±3.4	0	3	5	7	19	4
Age							
<65	10±5.6	0	6	9	13	32	7
≥65	5.3±3.8	0	2	5	8	27	6
Meteorological Measures							
Temperature (°C)	11.1±9.9	-12.2	2.1	11.9	20	30.1	17.9
Relative humidity (%)	50.5±14.0	15.9	40.2	50.7	60.3	89.8	20.1
Air Pollutant Concentrations							
PM_{10} (μg/m^3)	200.3±175.0	16	102	149	241	2561	139
Low	268.2±179.6	21	139.5	238	347.5	1766	208
Normal	201.4±184.3	16	99	153	237	256.1	138
High	124.0±53.0	32	91.3	115	141.8	551	50.5
NO_2 (μg/m^3)	45.8±29.3	4	25	37.5	56	260	31
Low	68.4±36.2	12	40	63	90.5	195	50.5
Normal	44.0±27.1	4	25	37	54	260	29
High	30.7±13.3	6	21	27	39.8	87	18.8
SO_2 (μg/m^3)	79.1±61.4	2	37	58	106	371	69
Low	132.3±72.8	11	79	117	172.5	350	93.5
Normal	74.8±57.0	2	35.5	58	98.5	371	63
High	43.6±17.8	7	31	41	52	129	21

Abbreviates: SD: Standard Deviation; Min: Minimum; P_{25}: 25th Percentile; P_{75}: 75th Percentile; Max: Maximum; IQR, Interquartile Range.

hospital admissions for respiratory system diseases per day in the study area. Also, during the study period, the mean daily average temperature and relative humidity were 11.1 °C and 50.5%, reflecting the temperate continental climate in Lanzhou. Meanwhile, the average concentrations of PM_{10}, SO_2, and NO_2 were 200.3 μg/m^3, 79.1 μg/m^3, and 45.8 μg/m^3, respectively. In addition, the daily mean concentrations of PM_{10}, SO_2, and NO_2 were much lower in high temperature days than in low-temperature and normal-temperature days.

As Table 2 shown, the effects of these air pollutants were strongest in low-temperature days, less strong in normal-temperature days, and not significant association in high-temperature days. In low-temperature days, RR of hospital admissions due to respiratory system disease for one IQR increase in PM_{10}, NO_2, and SO_2 were 1.303 (95% CI: 1.226-1.384), 1.383 (95% CI: 1.280-1.494), and 1.141 (95% CI: 1.077-1.208), respectively. In general, the effects of air pollution were more obvious in the younger age group than in the elderly group and different temperature levels represented different effects by gender. In low temperature days, men had higher RRs than women except for SO_2. However, in normal temperature days, the effects were significant in women for PM_{10}, NO_2, and SO_2.

Figure 1 shows the exposure-response association of PM_{10}, SO_2, and NO_2 with hospital admissions for respiratory system disease at different weather temperature levels. In low temperature days, for SO_2 and NO_2, the curves tended to be a linear. For PM_{10}, they tended to be slightly flat at higher concentrations. In normal temperature days, exposure-response curves were similar with that in low temperature days. For high temperature days, data was not presented here due to no significant association (Table 2).

Table 2. Relative Risk (RR) and 95% Confidence Interval of Daily Hospitalization due to Respiratory System Disease Associated with an IQR Increase of Air Pollutants in Different Weather Temperature Levels in Lanzhou from 2001 to 2005[a]

		Low Temperature	Normal Temperature	High Temperature
PM_{10}	Total	1.303 (1.226~1.384)*	1.077 (1.054~1.101)*	0.996 (0.929~1.069)
	Gender			
	Male	1.300 (1.206~1.401)*	1.074 (1.046~1.103)*	0.999 (0.927~1.078)
	Female	1.288 (1.167~1.421)*	1.084 (1.045~1.125)*	0.909 (0.811~1.018)
	Age			
	<65	1.310 (1.219~1.409)*	1.076 (1.047~1.105)*	0.964 (0.889~1.045)
	≥65	1.280 (1.148~1.427)*	1.078 (1.039~1.117)*	0.966 (0.869~1.074)
NO_2	Total	1.383 (1.280~1.494)*	1.062 (1.037~1.087)*	1.004 (0.904~1.114)
	Gender			
	Male	1.385 (1.258~1.524)*	1.050 (1.020~1.810)*	1.097 (0.986~1.222)
	Female	1.272 (1.155~1.401)*	1.880 (1.044~1.133)*	1.081 (0.945~1.275)
	Age			
	<65	1.420 (1.295~1.557)*	1.063 (1.032~1.095)*	1.051 (0.943~1.171)
	≥65	1.279 (1.114~1.468)*	1.062 (1.022~1.105)*	1.101 (0.980~1.237)
SO_2	Total	1.141 (1.077~1.208)*	1.076 (1.046~1.106)*	0.991 (0.927~1.059)
	Gender			
	Male	1.127 (1.051~1.209)*	1.054 (1.018~1.091)*	1.061 (0.984~1.144)
	Female	1.160 (1.055~1.276)*	1.127 (1.076~1.181)*	1.005 (0.904~1.118)
	Age			
	<65	1.197 (1.118~1.282)*	1.083 (1.046~1.121)*	1.031 (0.986~1.071)
	≥65	1.022 (0.924~1.129)	1.058 (1.012~1.107)*	1.051 (0.955~1.113)

Note. [a]: Multi-day lag 0-6 pollutants concentrations were used; *P<0.05.

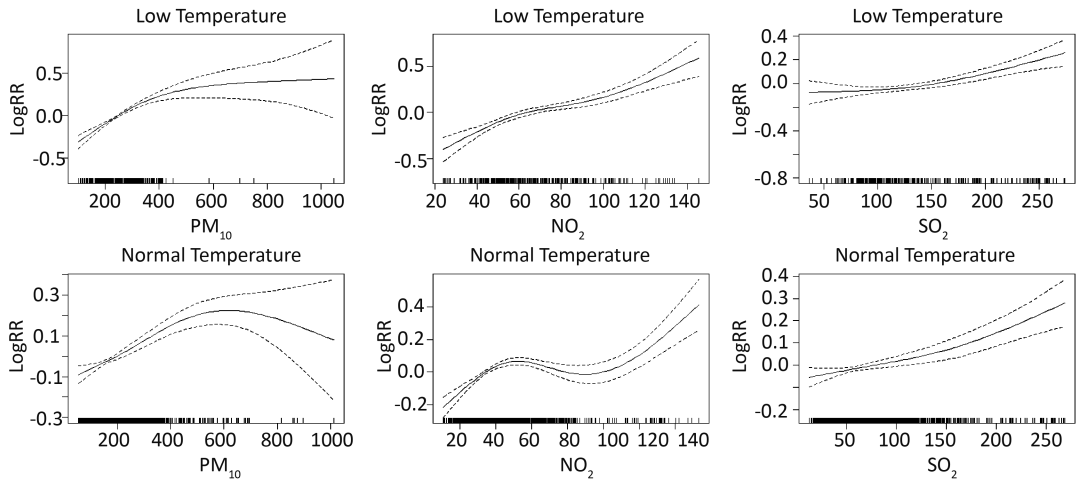

Figure 1. Smoothing plots of PM_{10}, SO_2, and NO_2 against hospital admissions (df=3) in low temperature days and in normal temperature days. X-axis is the pollutant concentrations (μg/m^3). The solid lines indicate the estimated mean percentage of change in daily hospital admissions, and the dotted lines represent twice the standard error.

The study showed that the effects of PM_{10}, SO_2, and NO_2 on the daily hospitalization due to respiratory system diseases were more pronounced in low temperature days, while no significant in higher weather temperature. In low-temperature days, relative risks (RRs) of hospital admissions due to respiratory system diseases for one IQR increase in PM_{10}, NO_2, and SO_2 were 1.303 (1.226-1.384), 1.383 (1.280-1.494), and 1.141 (1.077-1.208), respectively. Located inland, Lanzhou has a typical temperate, semi-arid continental monsoon climate. We therefore assume that in the winter in Lanzhou the climate is chilly and dry which may cause human respiratory mucosa to be fragile and susceptible to air pollution.

Generally speaking, the effects of air pollution were more obvious in the younger age group than in the elderly group, which was not consistent with some other similar studies[11-12]. This might be explained by the fact that sample size of the elderly group was smaller than that of the younger group and further studies should therefore, be warranted. Interestingly, the effect of air pollutions by gender was observed and it was showed that in low temperature days, men had higher RRs than women, while such an effect was significant for women in normal temperature days. In winter, women always took face mask to cope with the cold weather, which may also possibly protect them against air pollutions. In general, women are considered a susceptible group.

Some previous studies have been conducted in order to estimate the interactions between temperature and air pollutants[5-7] as well as season-specific effects of air pollution[9,13]. Our findings confirmed the results from earlier seasonal analyses in Hong Kong[9] and Shanghai[13], but are not in consistent with those of several other previous reports that noted greater effects during the warm or hot season[5,7]. For example, Stafoggia et al. identified in Italy, that the increments of 10 μg/m^3 in PM_{10} was significantly associated with 2.54% increase in risk on death in summer compared with 0.20% increase in winter[14]. Similar studies in Tianjin and Wuhan in China on the interactions between weather temperature and PM_{10} revealed that the effect of PM_{10} on mortality due to the respiratory system diseases was all strong in warm days[5,7]. For SO_2 and NO_2, a case-crossover analyses was conducted in Taiwan showing that the effects of these two air pollutants on hospital admissions due to asthma were all obvious in high temperature days[15].

Our findings of stronger effects of air pollution in low temperature days from the present study might be due to the special topographic characteristics and regional meteorology in Lanzhou. Lanzhou is located in a valley basin, along the northeast of the Qinghai-Tibet Plateau. The basin is elliptical and is surrounded by mountains with the Yellow River flowing across the city[16]. In such a basin the weather is generally stable with a weak wind and a strong temperature inversion, which are considered to be the important meteorological factors affecting the diffusion and transport of atmospheric pollutants in the area, particularly in winter[17]. In addition, the energy structure of Lanzhou is mainly formed by coal, providing 71% of the total energy. Coal is widely used as the primary fuel for household heating during several winter months[18]. Meanwhile, a large input of desert dust from the Hexi Corridor in spring is also the important risk of serious air pollution in the cool season of Lanzhou[19]. And during the warm season, the meteorological condition (increased convection and heavy rainfall events) make air pollution easy to disperse and deposit. In addition, with the use of air conditioners gradually in hot summer, the exposure to air pollution is probably reduced[20]. Further studies therefore need to be conducted to reveal the reasons for the effects of air pollution by seasons.

In sum, the findings from our study enriched the scientific evidence of the interactions among air pollution, extreme weather temperature and its health impact on humans, providing reference for health policy analysis regarding air pollution control and prevention in Lanzhou.

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