Association between dust weather and number of admissions for patients with respiratory diseases in spring in Lanzhou

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ABSTRACT

Controlling the confounding factors on respiratory hospitalizations such as long-term trend, meteorological factor, atmospheric pollution, and calendar effect, the research is designed to study the effect of sand-dust weather on respiratory diseases from 2001 to 2005 in Lanzhou City on the basis of the semi-parametric generalized additive model (GAM). The results indicate that there is an association between sand-dust weather and the increase in respiratory hospitalizations, and with lagging effect. There are gender and age differences in the effect of sand-dust weather on health, on male severer than on female (RR value being 1.148 for male, while 1.144 for female without statistical significance), and much greater on the aged ≥65 years than on <65 years (RR value being 1.266 for ≥65 yr, and 1.119 for <65 yr).

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1. Introduction

Sand storm is a commonly seen severe weather in Northern China. During a sand-dust storm period, the strong wind raises rough sand and fine particles, which turn into a sand storm or a floating dust storm after long-distance transfer. Among them, particles with a diameter smaller than 10 μm (PM₁₀) account for over 55% of the whole (Zhang et al., 1997). During long-distance transfer, the dust possibly carrying heavy metal, bacteria, virus, and poisonous minerals may be inhaled by people into their respiratory tracts and lungs, resulting in great impact on human health within the reach or influence of sand-dust storm (Huang and Wang, 2001; Li et al., 2002; Meng et al., 2003).

There are few researches in the world on association between sand-dust storms and human health. The epidemiologic studies on the sand-dust fine particles causing respiratory diseases are preliminary ones. In recent years, many researches indicate that there is association between sand-dust storms and rheumatism, Assam fever, and especially pneumonia (Nouh, 1989; West, 1993; Killick-Kendrick and Peters, 1992), and that sand-dust storms may cause desert storm pneumonitis (Korényi-Both et al., 1992, 1997), acute bacterial pneumonia and atypical pneumonia (Kurashi et al., 1992). Kwaasi indicates that sand-dust storms are the trigger for anaphylactic and non-anaphylactic respiratory diseases (Kwaasi et al., 1998).

Within decades, the intensity and frequency of sand-dust storms in China have increased (Wang et al., 2000; Zhou, 2001). Lanzhou (102°35′–104°34′29″E, 35°34′20″–37°07′N), which is located in northwest inland area of China (Fig. 1), at the lower stream of sand-dust source area in Southern Xinjiang Basin and Gansu Corridor, is frequently swept through by sand-dust storm in springs. Large quantity of incoming particles, sand and dust greatly deteriorate air quality and influence people’s health. The study investigates the impact of sand-dust weather on local people’s respiratory system in Lanzhou City during the spring sand-dust storm periods from 2001 to 2005 on the basis of the GAM and the sand-dust model, so as to provide evidences for the evaluation of calamity from the perspective of people’s health.

2. Materials and methodologies

2.1. Material sources

2.1.1. Disease materials

The authors collected the clinical data of hospitalized patients with primary diagnoses of respiratory disease from four large-scale comprehensive hospitals in Lanzhou (International Classification of Diseases Tenth Revision (ICD-10)) (Health Statistical Information Center, Ministry of Health, Peking Union Medical College WHO Disease Classification Cooperation Center, 2001) in springs (from March to May) from 2001 to 2005. These cases included total respiratory disease (ICD-10:J00-99), excluding cases of patients suffering from respiratory diseases due to accidents or surgeries.

2.1.2. Sand-dust weather materials

The authors collected sand-dust weather materials in Lanzhou City in springs (from March to May) in 2001 through 2005 from Meteorological Bureau of Gansu Province.
2.1.3. Atmospheric pollution materials
The authors collected daily average concentration data of three major pollutants (PM₁₀, SO₂, NO₂) in Lanzhou City from January 1, 2001 to December 31, 2005 from Environmental Monitoring Station of Lanzhou City. The complete daily average value alignment was obtained through fillings of data vacancies on the basis of linear interpolation.

2.1.4. Meteorological materials
The authors collected from Meteorological Bureau of Gansu Province daily surface meteorological materials in Lanzhou City in spring (from March to May) from 2001 to 2005, including meteorological factors such as average temperature, maximum temperature, minimum temperature, and relative humidity.

2.2. Statistical analysis
With respect to the whole population, patients hospitalized for respiratory diseases only account for a small part, whose distribution is similar to Poisson [Schwartz et al., 1996]. Therefore, the authors incorporate the Poisson Regression Model into GAM Model. The equation is as follows:

$$\log(E[Y_k]) = \alpha + DOW + [X_k + s(time, df)] + s(Z_k, df).$$

In this formula, \(Y_k\) is the number of respiratory hospitalizations; \(E[Y_k]\) is the expected value of counts of daily respiratory hospitalization; \(\alpha\) is the intercept term; \(DOW\) is the indicator variable for the days of the week, as the dummy variable; \(\beta\) is the regression coefficient; \(X_k\) is the concentration of PM₁₀ or whether it is sand-dust weather or not on day \(k\); \(s\) is the smoothing spline function, excluding long-term trend effect, calendar effect, and meteorological factors; \(df\) is the degree of freedom; \(time\) is calendar day; \(Z_k\) is certain meteorological factors or air pollutants on day \(k\).

In PM₁₀ model, a smoothing parameter for time is chosen to remove long-term temporal trends from the data \((df = 3).\) Smoothing parameters are also defined for the average temperature \((df = 3),\) pressure \((df = 3)\) and relative humidity \((df = 3),\) with these chosen to minimize Akaike’s information criteria [Akaike, 1973]. In sand-dust model, smoothing parameters are also defined for daily concentration of PM₁₀ \((df = 5),\) SO₂ \((df = 3)\) and NO₂ \((df = 4)\) except long-term temporal trends \((df = 4),\) average temperature \((df = 3),\) pressure \((df = 3)\) and relative humidity \((df = 3).\)

3. Results
3.1. Analysis of meteorological and atmospheric pollutant materials
According to the frequency distribution of meteorological data and atmospheric pollutant data in Lanzhou City from March 1 to May 31 from 2001 to 2005, only the value of NO₂ is lower than the national secondary ambient air quality standard, while PM₁₀ and SO₂ values are higher than the standard. According to Table 1, as compared to non-sand-dust weather, relative humidity is significantly lower \((P \leq 0.05)\) and PM₁₀ is significantly higher \((P \leq 0.01)\) under sand-dust weather, while other indices are not statistically significant.

3.2. Description of the number of respiratory hospitalizations
There are 7110 respiratory hospitalizations in four large-scale comprehensive hospitals in Lanzhou City from March to May from 2001 to 2005. Among them, 67.2% are male and 32.8% are female. 28.7% are aged ≥65 yr and 71.3% are aged <65 yr. Age<65 yr constitutes the majority, about 11 people/day, and the second is the group of male patients, about 10 people/day. Meanwhile, female and people ≥65 yr are relatively fewer, only about 5 people/day and 4 people/day (Table 2).

3.3. PM₁₀ model
Table 3 illustrates the GAM result of the influence of PM₁₀ on different groups of respiratory hospitalizations from March to May from 2001 to 2005. The table reveals that PM₁₀ has certain effect on different groups of respiratory hospitalizations, with evident lag effect for most people. For the total, male, age ≥65 yr and <65 yr, the effect is the greatest on respiratory hospitalizations after 3–4 days of lag, and the statistics are significant. The RR (95% CI) values per an IQR (161 μg/m³) increase in PM₁₀ of the total, male, ≥65 yr and <65 yr are 1.045 (1.019–1.073), 1.044 (1.016–1.078), 1.064 (1.016–1.112) and 1.073 (1.040–1.108), respectively.

<table>
<thead>
<tr>
<th>Year</th>
<th>PM₁₀ (μg/m³)</th>
<th>SO₂ (μg/m³)</th>
<th>NO₂ (μg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>53.6 ± 42.9*</td>
<td>65.1 ± 34.0</td>
<td>37.4 ± 14.3</td>
</tr>
<tr>
<td>2002</td>
<td>53.6 ± 42.9*</td>
<td>65.1 ± 34.0</td>
<td>37.4 ± 14.3</td>
</tr>
<tr>
<td>2003</td>
<td>53.6 ± 42.9*</td>
<td>65.1 ± 34.0</td>
<td>37.4 ± 14.3</td>
</tr>
<tr>
<td>2004</td>
<td>53.6 ± 42.9*</td>
<td>65.1 ± 34.0</td>
<td>37.4 ± 14.3</td>
</tr>
<tr>
<td>2005</td>
<td>53.6 ± 42.9*</td>
<td>65.1 ± 34.0</td>
<td>37.4 ± 14.3</td>
</tr>
</tbody>
</table>

* P ≤ 0.05, ** P ≤ 0.01; data means average ± standard error.
Asian dust events is roughly 3
humidity. Previous studies indicate that the concentration of particles
on respiratory hospitalizations. During the best lag days, RR value of
In this study, it indicates that daily average PM10 may reach
than in non-Asian dust storm days (Ma et al., 2001; Xie et al., 2005).
search time, sand-dust weather in Lanzhou City has signi
1.202(1.087–1.318),
65 yr is relatively small.
over 65 yr and 65 yr. That is to say, the aged and female are more sensitive to PM10.
3.4. Sand-dust weather model
Table 4 illustrates the GAM results of the sand-dust weather. It in-
dicates that sand-dust weather has an effect on all respiratory hospi-
talizations with lag effect. However, the impact differs for different
group people. For the total, male, female, age <65 yr and ≥65 yr, the best lag day is the fourth days (lag4), and the RR (95% CI) are 1.202(1.087–1.318), 1.148(1.025–1.271), 1.144(0.977–1.312), 1.119(1.000–1.238) and 1.266 (1.087–1.444) respectively. Through model fitting, a conclusion can be made that during the selected re-
search time, sand-dust weather in Lanzhou City has significant effect on respiratory hospitalizations. During the best lag days, RR value of <65 yr is relatively small.
4. Discussion
Sand-dust weather is characterized by strong wind, sharp increase in concentration of particles in the atmosphere, and drop of relative humidity. Previous studies indicate that the concentration of particles in Asian dust events is roughly 3–5 times or even 5–10 times higher than in non-Asian dust storm days (Ma et al., 2001; Xie et al., 2005).
In this study, it indicates that daily average PM10 may reach 536.1 μg/m3 under sand-dust weather, 3 times as high as the value under non-sand-dust weather, namely 190.6 μg/m3. That is to say, sand and dust particles contribute a lot to the increase in the concentration of PM10. As the concentration of PM10 increases, the outpatient rate, inpatient rate, and death rate of respiratory diseases increase (Atkinson et al., 2001; Zanobetti et al., 2000; Wong et al., 1999; Samet et al., 2000; Sunyer et al., 2000; Kim et al., 2003).
Numerous studies have found an association between PM10 and respiratory hospitalizations (Atkinson et al., 2001; Zanobetti et al., 2000; Wong et al., 1999; Samet et al., 2000; Sunyer et al., 2000; Kim et al., 2003).

Table 3
RR and 95%CI for per IQR (161 μg/m3) increase in PM10 on different groups of respiratory hospitalizations from March to May from 2001 to 2005.

<table>
<thead>
<tr>
<th>Lag days</th>
<th>Lag0</th>
<th>1.017</th>
<th>0.997</th>
<th>0.968</th>
<th>0.968</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(0.937–1.047)</td>
<td>(0.931–1.000)</td>
<td>(0.939–1.033)</td>
<td>(0.934–1.034)</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td>(0.979)</td>
<td>(0.976)</td>
<td>(0.964–1.036)</td>
<td>(0.969–1.036)</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td>(0.953–1.056)</td>
<td>(0.964–1.036)</td>
<td>(0.964–1.036)</td>
<td>(0.964–1.036)</td>
</tr>
<tr>
<td>≥65 yr</td>
<td></td>
<td>(0.979)</td>
<td>(0.976)</td>
<td>(0.979)</td>
<td>(0.979)</td>
</tr>
<tr>
<td>&lt;65 yr</td>
<td></td>
<td>(0.976–1.046)</td>
<td>(0.965–1.034)</td>
<td>(0.965–1.034)</td>
<td>(0.965–1.034)</td>
</tr>
</tbody>
</table>

Note: *Statistics significance of RR value, P< 0.05.

Table 2
Description of daily respiratory hospitalization in Lanzhou from March 1st to May 31st from 2001 to 2005.

<table>
<thead>
<tr>
<th>Type</th>
<th>Index</th>
<th>Mean</th>
<th>Min</th>
<th>P25</th>
<th>Median</th>
<th>P75</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total admissions for patients (person/day)</td>
<td>15.46</td>
<td>0</td>
<td>9</td>
<td>14</td>
<td>20</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>Diseases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male (person/day)</td>
<td>10.39</td>
<td>1</td>
<td>6</td>
<td>9</td>
<td>14</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Female (person/day)</td>
<td>5.06</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>7</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>(March–May)</td>
<td>&lt;65 (person/day)</td>
<td>11.02</td>
<td>0</td>
<td>7</td>
<td>10</td>
<td>15</td>
<td>34</td>
</tr>
<tr>
<td>≥65 (person/day)</td>
<td>4.43</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

1.114, and 1.034 (1.002–1.068) respectively. For females, there is no lag effect as to PM10 on respiratory hospitalizations, with the lag 0 day most severe and RR (95% CI) values are 1.051 (95%CI: 1.001–1.104) per an IQR (161 μg/m3), with statistical significance. In conclusion, PM10 has different effect on different people, greater on female than on male, and greater on ≥65 yr than on <65 yr. That is to say, the aged and female are more sensitive to PM10. The RRs of the total, male, female, age ≥65 yr and <65 yr. Similar studies have shown positive as-

The research indicates that there exists lag effect in the in-
fluence on respiratory hospitalizations in Lanzhou. With reference to non-sand-
dust weather, it is found that sand-dust days are positively associated with increases in the daily counts of respiratory hospitalizations, with lag effect. The RRs of the total, male, female, ≥65 yr and <65 yr are re-
spectively 1.202, 1.148, 1.144, 1.226 and 1.119, and RR of the aged ≥65 yr is bigger than <65 yr. Similar studies have shown positive asso-
ciation between dust events and hospitalization or respiratory death in China, Korea, Canada and so on. For example, Meng and Lu. (2007) provided strong evidence that dust events in Minqin are associated with the risk of respiratory hospitalizations, RR of male and female are 1.14 (95%CI: 1.01–1.29) and 1.18 (95%CI: 1.00–1.41). Hwang et al. (2003) reported that dust events in Seoul have little effect on respiratory hospitalizations, and RR (95%CI) is 1.00 (0.96–1.03). Another report also indicates that there is no association between dust events and respiratory hospitalization in Vancouver region (Bennett et al., 2006).

The research indicates that there exists lag effect in the influence of sand-dust weather on the increase in the number of hospitalized patients suffering from respiratory diseases. During a certain period of time after the sand-dust weather, inhalable particles keep staying in the atmosphere and people are exposed to the particles for a longer time (Meng et al., 2007), causing or worsening respiratory diseases. In this case, RR value of daily respiratory hospitalizations increases with statistical significance. It takes some time from sand and dust invasion to biochemical or physiological changes or presence of symptoms, which is known as the lag effect. In addition, sand-dust...
It usually comes up in the afternoon or at nightfall (Wang et al., 2005), and people may delay medical treatment so as not to be struck by sand and dust.

5. Conclusion

There is a certain association between sand-dust weather and respiratory hospitalizations, with evident lag effect. The values for all different groups of people on the lag4 day are statistically significant. In addition, there is not only gender difference but also age difference in the effect of sand-dust weather on the RR value of respiratory diseases. The aged people are less resistant to sand-dust weather.

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References


Table 4

<table>
<thead>
<tr>
<th>Lag days</th>
<th>Lag0</th>
<th>Lag1</th>
<th>Lag2</th>
<th>Lag3</th>
<th>Lag4</th>
<th>Lag5</th>
<th>Lag6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>0.873</td>
<td>1.021</td>
<td>0.913</td>
<td>0.999</td>
<td>1.202*</td>
<td>1.045</td>
<td>0.999</td>
</tr>
<tr>
<td>Male</td>
<td>0.893</td>
<td>1.010</td>
<td>0.941</td>
<td>1.004</td>
<td>1.148*</td>
<td>1.055</td>
<td>0.995</td>
</tr>
<tr>
<td>Female</td>
<td>0.937</td>
<td>1.052</td>
<td>0.849</td>
<td>0.886</td>
<td>1.144</td>
<td>0.995</td>
<td>0.939</td>
</tr>
<tr>
<td>≥65 yr</td>
<td>0.769</td>
<td>0.885</td>
<td>1.066</td>
<td>0.977</td>
<td>1.312</td>
<td>0.819–1.712</td>
<td>0.755–1.122</td>
</tr>
<tr>
<td>&lt;65 yr</td>
<td>0.948</td>
<td>1.031</td>
<td>0.989</td>
<td>0.975</td>
<td>1.076</td>
<td>0.837–1.221</td>
<td>0.812–1.203</td>
</tr>
<tr>
<td></td>
<td>0.658–0.983</td>
<td>0.921–1.198</td>
<td>0.749–1.100</td>
<td>0.897–1.137</td>
<td>1.000–1.238</td>
<td>0.924–1.169</td>
<td>0.883–1.135</td>
</tr>
</tbody>
</table>

Note: *Statistics significance of RR value, P<0.05.


