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Effects of particulate matter on respiratory disease and the impact of meteorological factors in Busan, Korea

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ABSTRACT

Background: Both air pollution and weather impact hospitalization for respiratory diseases. However, few studies have investigated the contribution of weather to hospitalization related to the adverse effects of air pollution. This study analyzed the effects of particulate matter (PM) on daily respiratory-related hospital admissions, taking into account meteorological factors.

Methods: Daily hospital admissions for respiratory diseases (acute bronchitis, allergic rhinitis, and asthma) between 2007 and 2010 were extracted from the National Health Insurance Corporation, Korea. Patients were divided into three age-based groups (0–15, 16–64, and ≥65 years). PM levels were obtained from 19 monitoring stations in Busan.

Results: The mean number of patients admitted for acute bronchitis, allergic rhinitis, and asthma was 5.8 ± 11.9, 4.4 ± 6.1, and 3.3 ± 3.3, respectively. During that time, the daily mean PM_{10} and $PM_{2.5}$ concentrations were 49.6 ± 20.5 and 24.2 ± 10.9 μg/m^3, respectively. The mean temperature anomaly was 7.0 ± 2.3 °C; the relative humidity was 62.0 ± 18.0%. Hospital admission rates for respiratory diseases increased with increasing PM and temperature, and with decreasing relative humidity. A multivariate analysis including PM, temperature anomaly, relative humidity, and age showed a significant increase in respiratory-related admissions with increasing PM levels and a decreasing relative humidity. Higher $PM_{2.5}$ levels had a greater effect on respiratory-related hospital admission than did PM_{10} levels. Children and the elderly were the most susceptible to hospital admission for respiratory disease.

Conclusions: PM levels and meteorological factors impacted hospitalization for respiratory diseases, especially in children and the elderly. The effect of PM on respiratory diseases increased as the relative humidity decreased.

1. Introduction

Air pollution is increasing as urbanization and industrialization processes expand worldwide. The adverse effects of air pollution on health, especially that of the cardiovascular and respiratory systems, have been confirmed in several studies [1–3]. In children, air pollution increases the prevalence and incidence of asthma [4–6]; in all age groups, it is associated with acute exacerbations of asthma, bronchitis, chronic obstructive pulmonary disease (COPD), and hospital admissions for respiratory diseases [7–10].

Abbreviations: PM, particulate matter; COPD, chronic obstructive pulmonary disease; PM_{10}, particulate matter with aerodynamic diameters <10 μm; $PM_{2.5}$, particulate matter with aerodynamic diameters <2.5 μm; SD, standard deviation; IRR, incidence rate ratio.

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Climate factors can also affect the development and severity of respiratory diseases. Both hyperthermia and hypothermia have been linked to respiratory morbidity and mortality, and relative humidity have been related to aggravation of respiratory diseases [11–14]. Relative humidity is thought to reduce the number of total suspended particulates contained in air [15]. Particulate matter (PM), a major component of air pollution, consists of a mixture of solid and liquid particles suspended in air [16,17]. Among the major sources of PM release are traffic, industry, biomass burning, and long-range transport. However, whether the effects of PM on health vary in response to climate has not been investigated, except in a few recent studies [13,18,19].

Busan is the second largest city in the Republic of Korea. Its high concentration of PM is due to automobile exhaust and the presence of mid-to small-level industries, such as chemical and shipbuilding industries, and to its active ports [20]. Because the southern end of Busan meets the sea and the northern end is surrounded by mountains, the city's weather is relatively warm and humid. In this Busan-based study we investigated the effect of PM on hospital admission rates for respiratory diseases and asked whether they varied depending on meteorological factors.

2. Materials and methods

2.1. Hospital admissions for respiratory disease

Data on daily hospital admissions for respiratory diseases in Busan were extracted from the National Health Insurance Corporation, Republic of Korea, for the period 2007–2010. The data included the admission date, diagnostic code (International Classification of Diseases, ICD-10) of each admission, and the age and sex of the patient. Respiratory diseases analyzed in this study were acute laryngotracheobronchitis (J05), influenza (J10-11), pneumonia (J18), acute bronchitis (J20-21), allergic rhinitis (J30), chronic bronchitis (J40-42), chronic obstructive pulmonary disease (COPD, J44), asthma (J45-46), and hypersensitivity pneumonitis (J67). Patients were categorized in three age-based groups, I (0–15 years), II (16–64 years), and III (≥65 years), to assess the relative frequency of respiratory diseases with respect to age. Hospital admission rates were calculated as:

$$\mathrm{Rate}_{(c,d)} = \frac{\mathrm{Hospitalization}_{(c,d)} \times 1,000,000}{\mathrm{Freq}_{(c,d)} \times \mathrm{POP}_d}$$

where $\mathrm{hospitalization}_{(c,d)}$ is the number of patients with respiratory disease by age group, $\mathrm{Freq}_{(c,d)}$ is the frequency of hospital admission by age group, and POP_d is the size of the population in Busan.

This study was approved by the Institutional Review Board of Pusan National University Hospital (H-1508-007-033).

2.2. Air pollution and meteorological data

Hourly levels of PM with aerodynamic diameters <10 μm (PM_{10}) and <2.5 μm ($PM_{2.5}$) were obtained from 19 monitoring stations in Busan (Fig. 1). The data were collected and made available by the Korean Ministry of Environment. Meteorological observation data were provided by the Korean Meteorological Administration and included temperature and relative humidity.

2.3. Statistical analysis

Descriptive data are presented as the means ± standard deviation (SD), minimum, lower quartile, median, upper quartile, and maximum. The relative risk of hospitalization was estimated using Poisson regression analysis, which is appropriate for analyzing rare events in subjects followed for variable lengths of time. Hospitalization for respiratory diseases as a function of PM_{10} and $PM_{2.5}$ levels, temperature anomalies, and relative humidity were estimated adjusting for age. PM-specific incidence rates were then adjusted for the covariates temperature anomaly, relative humidity, and age. The regression results are presented as the incidence rate ratio (IRR) and the 95% confidence interval. P values < 0.05 were considered to indicate statistical significance.

3. Results

3.1. Daily hospital admissions for respiratory diseases as a function of air pollution

Daily hospital admissions for respiratory diseases, air pollution levels, and weather variables in Busan for the period 2007–2010 are presented in Table 1. The mean daily admission for respiratory diseases was 58.3 ± 36.2 patients. Because acute bronchitis, allergic rhinitis, and asthma accounted for the majority of the underlying diseases, they were the focus of this study.

The mean daily hospital admission rates for acute bronchitis, allergy rhinitis, and asthma were 5.8 ± 11.9, 4.4 ± 6.1, and 3.3 ± 3.3 patients, respectively. During the study period, air quality, as measured by the mean PM_{10} and $PM_{2.5}$ levels, were normal (as defined by the daily exposure limits set by the World Health Organization: 50 μg/m^3 and 25 μg/m^3 for PM_{10} and $PM_{2.5}$, respectively), with a daily mean of 49.6 ± 20.5 μg/m^3 and 24.2 ± 10.9 μg/m^3, respectively. The mean temperature was 15.1 ± 4.9 °C (range: −4.3–30.1 °C), the mean temperature anomaly was 7.0 ± 2 °C (range: 1.0–13.6 °C), and the mean relative humidity was 62.0 ± 18.0% (range: 16.5–97.3%).

The number of patients admitted with respiratory disease and PM level showed a seasonal variation, with a maximum in spring (Fig. 2). Therefore, we used the temperature anomaly rather than the mean temperature to assess the effects of air pollution, to avoid a potential confounding effect of mean temperature on the effects of air pollution. Respiratory-related admissions showed an increasing trend as the PM_{10}, $PM_{2.5}$, and temperature anomaly increased and the relative humidity decreased (Figs. 3 and 4). Admission rates were higher in groups I and group III than in group II (Fig. 4).

3.2. Age-adjusted daily hospital admission rates for respiratory diseases according to air pollution and weather factors

The age-adjusted IRR for respiratory-related admissions was significantly associated with increases in PM_{10}, $PM_{2.5}$, and temperature anomaly and with a decrease in relative humidity (Table 2). An increase in the PM_{10} or $PM_{2.5}$ of 10 μg/m^3 corresponded to an increase in the total respiratory-related hospital admission rate of 6% and 12%, respectively. A higher temperature anomaly or a lower relative humidity increased hospital admissions for all three respiratory diseases examined in this study (Table 2).

3.3. The effect of air pollution on hospital admission for respiratory diseases with respect to meteorological factors

Weather was previously shown to impact hospital admissions for respiratory diseases [13], and the same was demonstrated in this study. Since weather may alter the impact of air pollution, we analyzed the relationship between these two factors. Table 3 shows the adjusted IRR for PM_{10} and relative humidity. An analysis adjusting for the effects of temperature anomaly, relative humidity, and age group showed that PM_{10} levels greatly affected hospital