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Associations between mortality and prolonged exposure to elevated particulate matter concentrations in East Asia

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ABSTRACT

Previous epidemiological studies regarding mortality and particulate matter with an aerodynamic diameter of < 10 μm (PM_{10}) have considered only absolute concentrations of PM_{10} as a risk factor. However, none have evaluated the durational effect of multi-day periods with high PM_{10} concentrations. To evaluate the durational effect (i.e., number of days) of high PM_{10} concentrations on mortality, we collected data regarding 3,662,749 deaths from 28 cities in Japan, South Korea, and China (1993–2009). Exposure was defined as consecutive days with daily PM_{10} concentrations ≥ 75 μg/m^3. A Poisson model was used with duration as the variable of interest, while controlling for daily PM_{10} concentrations, meteorological variables, seasonal trends, and day of the week. The increase in mortality risk for each additional consecutive day with PM_{10} concentrations ≥ 75 μg/m^3 was 0.68% in Japan (95% confidence interval [CI]: 0.35–1.01%), 0.48% in South Korea (95% CI: 0.30–0.66%), and 0.24% in China (95% CI: 0.14–0.33%). The annual average maximum number of consecutive days with high PM_{10} in Japan (2.40 days), South Korea (6.96 days), and China (42.26 days) was associated with non-accidental death increases of 1.64% (95% CI: 1.31–1.98%), 3.37% (95% CI: 3.19–3.56%), and 10.43% (95% CI: 10.33–10.54%), respectively. These findings may facilitate the planning of public health interventions to minimize the health burden of air pollution.

1. Introduction

Ambient particulate matter (PM) exposure was listed among the top ten health risk factors, based on the Global Burden of Disease study conducted in 2010 (Lim et al., 2013). In addition, many time series studies have provided evidence of associations between daily mortality and changes in air pollution level (Katsouyanni et al., 1997; Kim et al., 2017; Samet et al., 2000; Schwartz and Dockery, 1992; Ware et al., 1981; Wong et al., 2008). However, previous time series data regarding particulate air pollution and mortality were generally analyzed using log-linear Poisson regression models for over-dispersed counts, with the daily number of deaths as the outcome, the absolute (possibly lagged) daily concentrations of pollution as the main risk factor, and smoothing of weather variables and calendar time to adjust for time-varying confounders (Daniels et al., 2000; Schwartz and Dockery, 1992; Ware et al., 1981; Wong et al., 2008). While some studies did examine the effects of cumulative days of exposure, to the best of our knowledge, no study has investigated whether health risks are associated with the number of consecutive days of exposure to elevated particulate air pollution levels. In this context, it is important to consider both absolute daily air pollution levels and multi-day periods with high air pollution levels, as there is growing concern regarding the health effects of high air pollution levels in several megacities of developing countries (Romieu and Hermandez-Avila, 2003). Thus, information regarding the effects of prolonged exposure to high air pollution levels (rather than the effects of single-day air pollution levels) might allow policy makers to address a spectrum of related public health problems, especially in the highly polluted regions of the world.

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In the present study, we evaluated 28 cities in East Asia (Japan, South Korea, and China) that are relatively similar in their geography and culture, but are exposed to different air pollution conditions (Fang et al., 2009; Jeong and Park, 2013; Kim et al., 2017; Lee et al., 2013; Wang and Mauzerall, 2004). This approach was selected because studies with multiple locations can compare geographical areas and provide a more accurate estimation of inter-location variations using a unified analytical framework. Thus, we were able to observe the associations between mortality and the number of consecutive days of elevated air pollution levels, and to quantify the durational effect estimates while also considering the mortality effects of the air pollution level.

2. Methods

2.1. Study design

The present study evaluated data from 6 Japanese cities (Sapporo, Sendai, Tokyo, Nagoya, Osaka, and Kitakyushu), 7 South Korean cities (Seoul, Incheon, Daejeon, Daegu, Gwangju, Ulsan, and Busan), and 15 Chinese cities (Shenyang, Anshan, Beijing, Tangshan, Tianjin, Taiyuan, Lanzhou, Xian, Suzhou, Shanghai, Wuhan, Hangzhou, Fuzhou, Guangzhou, and Hong Kong) (Fig. 1). The data collection periods varied according to location, with the earliest year being 1993 and the latest year being 2009.

2.2. Mortality data

Daily mortality counts were obtained from the Japanese Ministry of Health and Welfare, the Korean National Statistics Office, and the Chinese Centre for Disease Prevention and Control. All causes were classified according to the 10th edition of the International Classification of Diseases (ICD-10) (World Health Organization, 2004). We excluded cases of accidental mortality and suicide, and included only non-accidental mortality cases in the analyses (codes A00–R99 for total non-accidental mortality, J00–J99 for respiratory diseases, and I00–I99 for cardiovascular diseases). Non-accidental mortality data was stratified by age group (< 65 and ≥ 65 years) for Korean and Japanese individuals only, due to the unavailability of Chinese data.

2.3. Environmental data

Data regarding weather variables were supplied by the Japanese Meteorological Agency, the Korean Meteorological Office, and the Chinese Meteorological Data Sharing Service System. The data included daily mean temperature (°C), daily mean relative humidity (%), and daily mean pressure (hPa; Japan and South Korea only). For air pollution, we collected data regarding PM_{10} (PM with an aerodynamic diameter of < 10 μm), and calculated the daily representative concentrations of PM_{10} for each city by averaging the 24-h values from all monitoring stations in that city. Data regarding PM_{10} concentrations were provided by the Japanese National Institute for Environmental Studies, the Korean Research Institute of Public Health, and the Environmental Monitoring Centre of China.

2.4. Statistical analysis

We calculated the independent effects of consecutive days of exposure to PM_{10} concentrations that exceeded the threshold value after adjusting for absolute PM_{10} concentrations. The threshold value was based on the World Health Organization's Air Quality Guidelines, which recommend a 24-h average concentration of 50 μg/m^3, with interim targets of 150 μg/m^3 (IT-1), 100 μg/m^3 (IT-2), and 75 μg/m^3 (IT-3) (World Health Organization, 2006). Because Japan, South Korea, and China have different ranges for PM concentrations, we defined days with elevated PM_{10} concentrations as days with concentrations of

Fig. 1. The locations of 28 cities in Japan (6 cities), South Korea (7 cities), and China (15 cities).