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Asian dust effect on cause-specific mortality in five cities across South Korea and Japan

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HIGHLIGHTS

- Potential toxicity of desert dust can change during long-range transportation.
- Adverse effects of Asian dust which measured by lidar were observed.
- Asian dust was positively associated with all-cause and cerebrovascular disease.
- This association was observed especially in Seoul and in the western part of Japan.

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ABSTRACT

Desert dust is considered to be potentially toxic and its toxicity may change during long-range transportation. In Asian countries, the health effects of desert dust in different locations are not well understood. We therefore evaluated the city-combined and city-specific effects of Asian dust events on all-cause and cause-specific mortality in five populous cities in South Korea (Seoul) and Japan (Nagasaki, Matsue, Osaka and Tokyo). We obtained daily mean concentrations of Asian dust using light detection and ranging (lidar) between 2005 and 2011. We then evaluated city-specific and pooled associations of Asian dust with daily mortality for elderly residents (≥65 years old) using time-series analyses. Each 10 μg/m^3 increase in the concentration of same-day (lag 0) or previous-day (lag 1) Asian dust was significantly associated with an elevated pooled risk of all-cause mortality (relative risk (RR): 1.003 [95% CI: 1.001–1.005] at lag 0 and 1.001 [95% CI: 1.000–1.003] at lag 1) and cerebrovascular disease (RR: 1.006 [95% CI: 1.000–1.011] at lag 1). This association was especially apparent in Seoul and western Japan (Nagasaki and Matsue). Conversely, no significant associations were observed in Tokyo, which is situated further from the origin of Asian dust and experiences low mean concentrations of Asian dust. Adverse health effects on all-cause and cerebrovascular disease mortality were observed in South Korea and Japan. However, the effects of Asian dust differed across the cities and adverse effects were more apparent in cities closer to Asian dust sources.

1. Introduction

Asian dust is a seasonal and frequent phenomenon, being a primary source of aerosols during spring in eastern Asian countries. Asian dust originates in the deserts of Mongolia or China and

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spreads across eastern Asia, travelling thousands of kilometres through transportation by mid-latitude westerlies. The dust absorbs air pollutants from anthropogenic sources throughout its long journey across many industrial cities, which are characterised by dramatic increases in the number of motor vehicles and manufacturing facilities. Desert dust is therefore considered to be potentially toxic. The concentrations of toxic components change during long-range transportation and vary depending on the atmospheric transport route (Mori et al., 2003; Nishikawa et al., 2011; Onishi et al., 2012; Wang et al., 2011). A previous study reported that concentrations of nitrate ions (NO_3^-), one of the components of local pollution sources such as a motor vehicles or power plants, differed between China and Japan (Mori et al., 2003). As such, different adverse health effects of Asian dust could be expected across countries.

Previous epidemiological studies have reported the impact of Asian dust on natural deaths in Taiwan, South Korea and Japan (Chan and Ng, 2011; Hwang et al., 2005; Kashima et al., 2012; Kwon et al., 2002; Lee et al., 2014). Among them, a recent study revealed the diverse effects of Asian dust storms between South Korea, Taiwan and Japan (Lee et al., 2014). Although the definition of 'Asian dust days' in the study was not identical across the countries, the study reported significant excess mortality in South Korea and Japan, but not in Taiwan. Furthermore, another study in Japan observed that the effects of Asian dust were stronger in northern areas close to the Eurasian continent (source of Asian dust) than in western areas (Kashima et al., 2012). The effects of Asian dust on health are different across cities and countries, although the number of studies comparing the effects of Asian dust across different areas is limited. Therefore, we set out to evaluate the city-combined and city-specific effects of Asian dust on mortality in five selected cities in South Korea and Japan using multi-city time-series analyses (Daniels et al., 2000; Zanobetti and Schwartz, 2009). In this work we monitored Asian dust concentrations using light detection and ranging (lidar) to ensure standardisation of methods applied across the study region.

2. Materials and methods

2.1. Study area and subjects

We selected five cities (Seoul, South Korea and Nagasaki, Matsue, Osaka and Tokyo, Japan) where Asian dust concentrations were measured using lidar. There were three monitoring sites in South Korea and 13 in Japan. In South Korea, only the monitoring site in Seoul could be used because this was the only site for which complete data was available for analysis. In Japan, out of 13 sites, five had monitoring data that extended to 2011. Of the five sites, we excluded one site that was located in the smallest city (Goto; population in 2008: 44,167) to ensure sufficient statistical power. Overall, we selected four sites in Japan: two average-sized cities (Nagasaki and Matsue) in western Japan and two metropolitan areas (Osaka and Tokyo) in the central part of the country. We focused on elderly residents $\geq$65 years old at their death because they are at the greatest risk of developing adverse health effects from exposure to dust events (Chan and Ng, 2011; Kashima et al., 2012; Lipsett et al., 2006; Yorifuji and Kashima, 2013; Yorifuji et al., 2014a,b; Zauli Sajani et al., 2011).

2.2. Study period

We obtained Asian dust concentrations, mortality data and other covariate data, including particulate matter (PM) with aerodynamic diameters < 10 μm (PM_{10}) concentrations, between 2005 and 2011. Because the periods for which we could obtain data differed between the cities, we included different study periods for each city (Table 1).

2.3. Asian dust data

We obtained daily atmospheric Asian dust concentrations (averaged from heights between 120 and 1000 m) at the selected cities using the Asian Dust and Aerosol Lidar Observation Network (AD-Net) lidar system operated by the National Institute for Environmental Studies of Japan (http://www-lidar.nies.go.jp/AD-Net/). Lidar is a ground-based optical remote sensing technology that measures aerosols profiles. By measuring the backscattering and depolarization (the change of polarization by scattering) of the transmitted laser, lidar can distinguish between non-spherical mineral dust particles and spherical non-mineral dust particles emitted from anthropogenic sources, such as traffic-generated air pollutants (Shimizu et al., 2004; Sugimoto et al., 2003; Uno et al., 2009). For reference, an Asian dust event is reported when the average dust extinction coefficient measured by lidar reaches or exceeds 0.1 km^{-1} according to the Dust and Sandstorm Information website of the Japanese Ministry of the Environment (Environmental Management Bureau, 2015). The extinction coefficient 0.1 km^{-1} approximately corresponds to 100 μg/m^3 of dust particles in South Korea and Japan.

For days with missing lidar data, we assigned the average of the concentrations recorded on the days immediately before and after the day(s) to the missing data, given that these sporadically occurred. The numbers of days with missing lidar data over the study period were 78 days (5.6% of eligible days) in Seoul, 7 days (0.3%) in Nagasaki, 93 days (3.7%) in Matsue, 9 days (0.6%) in Osaka and 7 days (0.5%) in Tokyo. The longest period of consecutive missing data was 41 days, which occurred in Seoul (24 August–3 October 2007) and Matsue (13 November–23 December 2008). Three consecutive days were missed in Nagasaki, two consecutive in Osaka and no consecutive days were missed in Tokyo. To evaluate the validity of our imputation method, we attempted to verify whether Asian dust days had occurred in Seoul and Matsue, where we had longer periods of missing lidar data. The Korea Meteorological Administration and Japanese Meteorological Agency provided data on Asian dust from visual assessments. According to visual assessments, no events occurred during any of these missing periods in Seoul and Matsue. We did not assess this in other cities because the missing days occurred only sporadically.

2.4. Climate factors

Daily temperature and relative humidity data were obtained from the Korea Meteorological Administration and the Japanese Meteorological Agency. We calculated the daily means for each target city. There were no missing data related to meteorological conditions for any of the target cities.

2.5. Particulate matter (PM)

As an additional potentially confounding variable, we obtained daily mean PM_{10} concentrations during the study period for each city from environmental databases managed by the Ministry of Environment of Korea, the National Institute for Environmental Studies in Japan and each local government office in Japan. When more than one PM_{10} monitoring site existed in a given city, we averaged the concentration data to create representative values for the respective cities. Because PM is measured as suspended PM (SPM) in Japan, which is approximately equivalent to PM with aerodynamic diameters of <7 μm (PM_7) (Working group on health effects assessment for fine particulate matter, 2008), we converted