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Effect of Asian dust storms on mortality in three Asian cities

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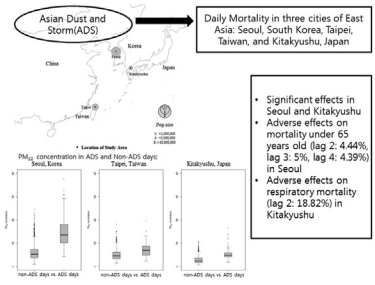
HIGHLIGHTS

- We examine ADS effect on mortality in three Asian cities (Seoul, Taipei, Kitakyushu).
- We explore the differences in the extent of ADS effects in each city.
- Time-series analyses using a generalized additive model are conducted.
- We found significant adverse effects of ADS in Seoul and Kitakyushu.
- Negative association between ADS and mortality was found in Taipei.

GRAPHICAL ABSTRACT



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ABSTRACT

Asian dust storms (ADS) have affected several Asian countries and have been a major concern due to adverse effects on public health. The occurrence of ADS differs in each country based on geographical features and distance from the storms' origin. Many studies have reported significant associations between ADS and morbidity. However, regarding the association between ADS and mortality, only a few studies have found statistically significant ADS effects in Korea, Taiwan and Japan. Accordingly, this study aimed to examine the effects of ADS on daily mortality in three Asian cities (Seoul, South Korea; Taipei, Taiwan; and Kitakyushu, Japan) and to explore the differences in the extent of effects in each city. We performed time-series analyses using a generalized additive model (GAM) with Quasi-Poisson regressions. Deaths due to accidents or external causes were excluded. We used a dummy variable as an indicator of ADS and considered lag effects of ADS. Stratified analyses by disease and age and sensitivity analyses controlling for NO_2, SO_2, and PM_{10} were also conducted respectively. Additionally, influenza epidemics were adjusted for considering seasonal patterns, and a meta-analysis was performed. We reported results as excess mortality by percentage due to Asian dust storms. We found significant excess mortality in Seoul and Kitakyushu as follows. In Seoul, ADS showed adverse effects on mortality under 65 years old (lag 2: 4.44%, lag 3: 5%, lag 4: 4.39%). In Kitakyushu, ADS had adverse effects on respiratory mortality (lag 2: 18.82%). Contradictory to results in Seoul and Kitakyushu, ADS seemed to have a protective effect in Taipei: total non-accidental mortality (lag 0: −2.77%, lag 1: −3.24%), mortality over 65 years old (lag 0: −3.35%, lag

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1: −3.29%) and respiratory mortality (lag 0: −10.62%, lag 1: −9.67%). Sensitivity analyses showed similar findings as the main results. Our findings suggest that ADS may affect mortality in several Asian cities, and that a dust storm warning system could help protect people from dust storms.

1. Introduction

Dust storms are a natural phenomenon attributed to deserts and the turbulent flow of winds (Westphal et al., 1988). It has been reported that dust storms from desert regions in several countries have been transported to and have adversely affected other countries, in addition to the inner cities in the countries of origin (Chen et al., 2003; Kloor, 2008). Currently, the problem is that dust storms and current climate change characterized by global warming are interconnected, and have accelerated the desertification of arid and semi-arid lands (Lavee et al., 1998; Goudie, 2009). This, in turn, would cause more frequent dust storms (Han et al., 2008).

Recently, the effects of natural sources of dust, such as from deserts or volcanoes, on human health have become a major concern (Derbyshire, 2013). The adverse health effects of artificial particles have already been demonstrated in many previous studies (Harrison and Yin, 2000; Laden et al., 2000). Recent studies have reported adverse effects of dust storms on human health. Some studies applied animal models, and found negative effects of dust storm particles (Lei et al., 2004; Meng and Zhang, 2006, 2007). Epidemiological studies using different populations and statistical methods also reported adverse dust storm effects on human health (Gyan et al., 2005; Johnston et al., 2011). Specifically, a considerable number of studies have consistently shown adverse effects of dust storms on hospitalization and emergency visits for cardiovascular or respiratory diseases (Middleton et al., 2008; Kang et al., 2012). However, findings regarding the association between dust storms and mortality have been inconsistent, and the research is still in progress (Schwartz et al., 1999; Mage, 2000; Perez et al., 2008; Chan and Ng, 2011; Lee et al., 2013).

Especially, Asian Dust Storms (ADS) originate from the Taklamakan and the Gobi deserts of western China and Mongolia, and these deserts constitute major global dust source regions (Tanaka and Chiba, 2006). ADS affect several Asian countries (China, Taiwan, Korea, and Japan) and are a matter of public health concern (Guo et al., 2004; Chen and Yang, 2005; Kwon, 2012). Previous studies performed in each of these Asian countries have reported the long-range transport of ADS from their origins (Kwon et al., 2002; Chan et al., 2008; Kanatani et al., 2010), and it is noticed that the transport of ADS to countries depends on geographical features and distance from the origin. Thus, the effects of the same ADS would differ by country. Many studies have shown a significant association between ADS and morbidity in Taiwan (Yang et al., 2005; Yang, 2006). Some studies in Korea and Japan have also reported associations between ADS and adverse health outcomes. However, only a few studies have found a significant effect of ADS on mortality in Taiwan, Korea, and Japan (Chan and Ng, 2011; Kashima et al., 2012; Lee et al., 2013).

This study aimed to examine the effect of ADS on daily mortality in three Asian cities (Seoul, South Korea; Taipei, Taiwan; and Kitakyushu, Japan) and explore differences in the extent of ADS effects in each city. The ultimate objective was to provide evidence of ADS effects on mortality through a multi-Asian city study.

2. Materials and methods

2.1. Data

2.1.1. Study area

Three Asian cities (Seoul, Korea; Taipei, Taiwan; and Kitakyushu, Japan) were selected to explore the effect of ADS on daily mortality. This study originally intended to examine ADS effects in the capitals of three Asian countries, but ultimately selected Kitakyushu as the study area for Japan. Tokyo, the capital of Japan, is far from the storms' origin, and so dust storms hardly occur, which limited our ability to find statistically significant results. We selected Kitakyushu considering dust storm frequencies as well as data availability. As Fig. 1 shows, Kitakyushu is close to the storms' origin within Japanese cities.

Fig. 1 shows the location and the population size (census 2005) of the three cities; Seoul in Korea, Taipei in Taiwan and Kitakyushu in Japan. These countries can be categorized as part of Northeast Asia, but Taiwan is also considered a subtropical area. Seoul has an area of 605.3 square km, with a population of approximately 10 million people and population density of 16,000 people per square km. Taipei has an area of 271.8 square km and approximately 3.7 million residents, with a population density of 9600 per square km. Finally, Kitakyushu has an area of 486.8 square km, a population of 990,000, and population density of 2000 per square km.

2.1.2. Mortality data

Data were collected from each city for different time periods according to data availability. We collected mortality data for Seoul from the Korean National Statistical Office for the period of January 2001–December 2009, data for Taipei were collected from the National Death Registry of Taiwan from January 2002 to December 2006, and data for Kitakyushu were obtained from the Ministry of Health and Welfare of Japan from December 2004 to March 2009. Deaths due to external causes or accidents (codes S00–Y99 of ICD-10 [International Classification of Diseases 10th Revision]) were excluded from this study. We stratified deaths by disease (cardiovascular [codes I00–I99] and respiratory disease [codes J00–J99]) and age (<65 years old and ≥65 years old) for subgroup analyses.

2.1.3. Asian dust storms

Dummy variables were established for Asian dust storms (ADS days and non-ADS days) (Kwon et al., 2002). We collected ADS data from the Korean Meteorological Administration (KMA) for Seoul, from the Taiwan Environmental Protection Administration (TEPA) for Taipei, and from the Japan Meteorological Agency (JMA) for Kitakyushu.

ADS days are defined by the KMA as follows (Lee et al., 2013); first, determine whether an ADS occurred in the deserts of China and Mongolia with daily weather reports of East Asian countries. Next, if an ADS occurred, observe the transport of the ADS to Korea