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Original article

Effect of Asian dust on pulmonary function in adult asthma patients in western Japan: A panel study

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Abbreviations:
AD, Asian dust; CI, confidence interval; GINA, Global Initiative for Asthma; IQR, interquartile range; LIDAR, Light Detection and Ranging; NO_2, nitrogen dioxide; O_x, photochemical oxidants; PEF, peak expiratory flow; PM_{10}, particulate matter smaller than 10 μm; $PM_{2.5}$, particulate matter smaller than 2.5 μm; SD, standard deviation; SO_2, sulfur dioxide; SPM, suspended particle matter

A B S T R A C T

Background: Asian dust (AD) has become a major health concern. The concentration of AD is typically expressed in particulate matter less than 10 μm (PM_{10}) and 2.5 μm ($PM_{2.5}$). However, PM_{10} and $PM_{2.5}$ consist of various substances besides AD. Light detection and ranging (LIDAR) systems can selectively measure the quantity of AD particles to distinguish non-spherical airborne particles from spherical airborne particles. The objective of this study was to investigate the relationship between pulmonary function in adult asthma patients and AD using LIDAR data.

Methods: Subjects were 231 adult asthma patients who had their morning peak expiratory flow (PEF) measured from March to May 2012. A linear mixed model was used to estimate the association of PEF with sand dust particles detected by LIDAR.

Results: Increases in the interquartile range of AD particles (0.018 km^{-1}) led to changes in PEF of −0.42 L/min (95% confidence interval [CI], −0.85 to 0.01). An increase of 11.8 μg/m^3 in suspended particulate matter and 6.9 μg/m^3 in $PM_{2.5}$ led to decreases of −0.17 L/min (−0.53 to 0.21) and 0.03 L/min (−0.35 to 0.42), respectively. A heavy AD day was defined as a day with a level of AD particles >0.032 km^{-1}, which was the average plus one standard deviation during the study period, and six heavy AD days were identified. Change in PEF after a heavy AD day was −0.97 L/min (−1.90 to −0.04).

Conclusions: Heavy exposure to AD particles was significantly associated with decreased pulmonary function in adult asthma patients.

Introduction

The large-scale and long-range transport of sand dust from East Asia deserts (so-called Asian dust [AD], yellow sand, or kosa in Japanese) is an important source of particulate matter in East Asia. Recently, AD started containing considerable amounts of pollutants such as anthropogenic metal components, chemicals, and

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microorganisms due to rapid industrial expansion and an increased number of cars on the road in East Asia.[1–6] Therefore, AD has become a serious health concern. Studies have shown that heavy exposure to AD increases mortality rates, emergency treatment, and hospitalization for cardiovascular and pulmonary diseases.[7–10] In addition, other studies have shown that heavy exposure to AD increases the risk of hospitalization, and exacerbates pulmonary function and respiratory symptoms in patients with asthma in Japan and South Korea.[11,12]

The majority of studies have investigated the effects of AD on health based on the levels of particulate matter <10 μm in diameter (PM_{10}) and $PM_{2.5}$. However, PM_{10} and $PM_{2.5}$ are a complex mixture of various solid and liquid particles. Therefore, PM_{10} and $PM_{2.5}$ are unable to clearly distinguish AD particles from other particulate matter. To overcome this problem, Japanese studies started using Light Detection and Ranging (LIDAR) data.[12–15] LIDAR systems can measure particulate matter by illuminating a target with two length laser beams and analyzing the reflected light.[16,17] They can also distinguish non-spherical airborne particles, which are sand dust particles, from spherical airborne particles, which consist of air pollution aerosols including organic aerosols, inorganic sulfates and nitrates.[16,17] LIDAR systems are simultaneously applied within <1 km above ground, and measurements have been made continuously in various locations in Japan, South Korea, China, Mongolia, and Thailand.[16,17] LIDAR systems are able to measure the amount of long-range transported AD particles from East Asia to Japan. Therefore, the levels of non-spherical particles based on LIDAR measurements are equivalent to the concentration of AD particles. LIDAR systems calculate the levels of spherical and non-spherical particles using the extinction coefficient, which is a measure of how strongly a substance absorbs light. The extinction coefficient is proportional to the reciprocal of visibility (e.g., a non-spherical particles level of 0.1 km^{-1} equals a visibility range of 10 km).[18] On the other hand, LIDAR measurements do not distinguish particles by size and lack defined criteria for heavy AD.

LIDAR permits investigation of possible differences in the effects of AD particles (non-spherical particles) and particulate matter on pulmonary function. In this study, we investigated the effects of exposure to AD on pulmonary function in adult patients with asthma using LIDAR data.

Methods

Study design

A panel study was conducted using monitoring of daily morning PEF in adult patients with asthma from March to May 2012. A total of 231 outpatients aged >18 years old with asthma were recruited into the study from December 2011 to January 2012. The patients were residents who lived within 25 km of Tottori University Hospital in Yonago City, which is located in western Japan. The patients lived in five different locations: Yonago City, Matsue City, Sakaiminato City, Yasugi City, and Saihaku Town. On the basis of Global Initiative for Asthma (GINA) criteria, asthma was defined as positive if a case met (1) and (2) or (3) of the following criteria: (1) a history of intermittent wheezing; (2) airway hyperresponsiveness to methacholine; and (3) reversible airflow limitation (12% and 200 mL variability in FEV_1).[19] Allergic rhinitis and/or chronic sinusitis were defined based on diagnosis by an otolaryngologist. Treatment for each patient was determined using GINA criteria.[19] The study was approved by the institutional ethics committee (Ethics Committee of Tottori University, Approval Number 1656) and all patients gave written informed consent.

Definition of the period of heavy exposure to AD and monitoring of air pollutants

Particulate matter is classified into several categories according to its size. PM_{10} is defined as any particle measuring less than l0 μm in diameter with a 50% cut-off and $PM_{2.5}$ as any particle measuring less than 2.5 μm diameter with the same cut-off as PM_{10}.[20] In Japan, suspended particulate matter (SPM) is defined under the National Air Quality Standard as any particle with a diameter of less than 10 μm with a 100% cut-off.[21] The theoretical 50% cut-off diameter for SPM is assumed to be approximately 7 μm.[21] The particle diameter of SPM measured in Japan is intermediate to those classified under $PM_{2.5}$ and PM_{10} parameters. Although the daily fluctuations of SPM are similar to those of $PM_{2.5}$,[22] the constituents of particulate matter could differ among countries. The Japanese Ministry of the Environment monitors the levels of SPM instead of PM_{10}. Concentrations of SPM, sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and photochemical oxidants (O_x) are monitored at many locations in Japan by the Japanese Ministry of the Environment. Data for SPM, SO_2, NO_2, and O_x were taken from those collected in Yonago City. Data for $PM_{2.5}$, and data for non-spherical and spherical particles from LIDAR were obtained from the Matsue observatory. LIDAR systems measure aerosol levels at 15-min intervals by distinguishing between non-spherical particles and spherical particles.[16,17] Daily particle levels are determined based on the median value of 96 measurements collected over a 24-h period from midnight of one day to midnight of the next day. The daily levels were only calculated when the number of available measurements exceeded 50% of the total number of measurements. This study used values measured from 120 m to 150 m above ground, which is the minimum altitude required by LIDAR systems to measure non-spherical and spherical particles. A heavy AD day was defined as a level of non-spherical particles higher than 0.032 km^{-1}, which corresponded to the average value plus one standard deviation from March 1 to May 31.

Recording of daily morning PEF and ACT scores

From February to May 2012, all patients recorded their daily morning PEF using a peak flow meter (Mini-Wright, Harlow, England, American Thoracic Society scale). February was used as the practice period. PEF was measured three times in the morning and before the patients inhaled corticosteroids or β_2-agonists or took oral drugs. Each patient recorded the best value from three attempts. At the end of each month, the Japanese version of the Asthma Control Test (ACT-J) scores were recorded.[23]

Statistical analysis

Linear mixed models that accounted for correlations among repeated measurements within a subject were used to estimate the effect of heavy exposure to AD, AD and spherical particles detected by LIDAR, and other air pollutants (SPM, $PM_{2.5}$, SO_2, NO_2, and O_x) on daily PEF.[24,25] The daily (24-h) averages of air pollutants and meteorological variables such as daily temperature, humidity, and atmospheric pressure were used. The linear mixed models include a random intercept for subjects in the analysis, individual characteristics (age, gender, smoking, presence of allergic rhinitis, treatment step and pulmonary function), and meteorological variables such as daily temperature, humidity, and atmospheric pressure, gaseous air pollutions (SO_2, NO_2, and O_3), and other parameters of AD particles, spherical particles, SPM, and $PM_{2.5}$ deviated from the evaluation. Estimates are given as the absolute difference in PEF per interquartile range (IQR) change in exposure, with 95% confidence intervals (CIs). The effect of heavy exposure to AD and the post-