Acute effects of air pollutants on pulmonary function among students: a panel study in an isolated island

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Abstract

Background: Many epidemiological studies on the health effects of air pollutants have been carried out in regions with major sources such as factories and automobiles. However, the health effects of air pollutants in regions without major sources remain unclear. This study investigated the acute effects of ambient air pollution on pulmonary function among healthy students in an isolated island without major artificial sources of air pollutants.

Methods: A panel study was conducted of 43 healthy subjects who attended a school in an isolated island in the Seto Inland Sea, Japan. We measured the forced expiratory volume in 1 s (FEV 1) and peak expiratory flow (PEF) every morning for about 1 month in May 2014. Ambient concentrations of particulate matter ≤ 2.5 μm in diameter (PM 2.5), particulate matter between 2.5 and 10 μm in diameter (PM 10-2.5), black carbon (BC), ozone (O 3), and nitrogen dioxide (NO 2) were measured. The associations between the concentrations of air pollutants and pulmonary function were analyzed using mixed-effects models.

Results: A decrease in FEV 1 was significantly associated with BC concentrations (−27.28 mL [95% confidence interval (CI): −54.10, −0.46] for an interquartile range (IQR) increase of 0.23 μg/m 3). The decrease in PEF was significantly associated with indoor O 3 concentrations (−8.03 L/min [95% CI: −13.02, −3.03] for an IQR increase of 11 ppb). Among subjects with a history of allergy, an increase in PM 2.5 concentrations was significantly associated with low FEV 1. In subjects with a history of asthma, an inverse association between the indoor O 3 concentration and pulmonary function was observed.

Conclusions: Our results demonstrate that increases in BC and O 3 concentrations have acute effects on the pulmonary function among students in an isolated island without major artificial sources of air pollutants.

Keywords: Allergy, Asthma, Air pollution, Isolated island, Pulmonary function, Panel study

Background

Many studies have reported the influence of air pollutants on the respiratory system [1–7]. Among air pollutants, particulate matter ≤ 2.5 μm in diameter (PM 2.5) induces an inflammatory response of the airway when inhaled, reducing the pulmonary function [8–11]. In addition, it is known that exposure to black carbon (BC), a component of PM 2.5, impairs the lung function in children [12]. Many studies involving patients with respiratory diseases, such as asthma [13–15] and chronic obstructive pulmonary disease (COPD) [16, 17], have been carried out to evaluate the acute effects of air pollution. In addition, these studies have been primarily conducted in urban areas with a high concentration of air pollutants, involving factories and automobiles [18, 19]. Furthermore, most studies adopted concentrations at monitoring stations in the neighborhood to evaluate the influence of air pollutants on the respiratory system.

However, the results of studies among patients with specific diseases or epidemiological studies in areas with a high concentration of air pollutants are not always adaptable for a general population. Few epidemiological studies have evaluated the health effects of changes in the concentration of air pollutants in an environment...
where healthy persons live. Furthermore, the duration of indoor daily activities is longer than that of outdoor activities; therefore, when concentrations at monitoring stations in the neighborhood were used, exposure assessment may not have been accurately performed.

In this study, we repeatedly performed pulmonary function tests of healthy subjects in an isolated island without major artificial sources of air pollutants, and evaluated the acute effects of changes in the concentrations of air pollutants measured in indoor and outdoor spaces on the respiratory system among the subjects.

**Methods**

**Study design and subjects**

Yuge Island is an isolated island in the Seto Inland Sea, Japan (Fig. 1). Pulmonary function tests among students were conducted every day between May 12 and June 9, 2014. In addition, the atmospheric environment was measured during the same period. On this island, road traffic is light, but there may be little influence of automobile exhausts. Furthermore, there is no large factory, and there are no artificial sources of air pollutants other than ships; the island may be a clean-air area. However, recently, the influence of transported air pollutants derived from the Asian Continent has been indicated [20]. To investigate the relationship between the atmospheric environment and pulmonary function, we conducted pulmonary function tests among subjects who had stayed in Yuge Island over a long period of time; students attending a school on this island were requested to participate in this study. The subjects were 43 students from whom written informed consent was obtained (aged 15–16 years, mean: 15.1 years, 29 males and 14 females). Prior to this study, its protocol was approved by the Ethics Review Board of Hyogo College of Medicine.

**Assessment of the effects on health**

Using a standard questionnaire [21], respiratory symptoms and the presence or absence of a history of asthma or allergy were evaluated. Subjects who selected “Yes” to the question “Have you ever been diagnosed with asthma?” were regarded as having a history of asthma. Those who selected “Yes” to the question “Have you ever been diagnosed with allergic rhinitis?” or “Have you ever been diagnosed with pollinosis?” were regarded as having a history of allergy.

For pulmonary function testing, an electronic peak flow meter (Vitalograph 2110, Vitalograph Ltd., Buckingham, U.K.) was delivered to each subject, and self-measurement of the peak expiratory flow (PEF) and forced expiratory volume in 1 s (FEV\(_1\)) was conducted before the start of the first lesson every morning from Monday until Friday.

**Measurement of the atmospheric environment**

To measure the atmospheric environment, an automatic particulate matter-measuring device (SPM-613D, Kimoto Electric Co., Ltd., Osaka, Japan) was installed on the roof of the school, and PM\(_{2.5}\), particulate matter between 2.5 and 10\(\mu\)m in diameter (PM\(_{10-2.5}\)), and BC were measured continuously. In addition, the outdoor concentrations of ozone (O\(_3\)) and nitric oxide (NO\(_2\)) were measured using a passive sampler (Ogawa & Co., Ltd., Kobe, Japan) and a filter badge NO\(_2\) (Advantec Co. Ltd., Tokyo, Japan), respectively. The sampler and badge were exchanged every 24 h on Monday to Friday for measurement, and 72-h measurement was conducted on weekends. Furthermore, the indoor concentrations of O\(_3\) and NO\(_2\) were measured in school classrooms, where the students had stayed for most of each school day, as described for outdoor measurement. The indoor concentration of PM\(_{2.5}\) was measured serially using a digital dust indicators (Model LD-5, Sibata Scientific Technology Ltd., Tokyo, Japan) in the classroom.

**Statistical analysis**

The relationships between the indoor and outdoor concentrations of PM\(_{2.5}\), O\(_3\), and NO\(_2\) were expressed as correlation coefficients. Those between the results of a pulmonary function test and the concentrations of air pollutants were evaluated using a mixed effect model with the rate of change per interquartile range (IQR) increase of each pollutant for 24 h before a pulmonary function test after adjusting for the atmospheric temperature, humidity, and subject’s height. Furthermore, the analyses were performed using two-pollutant models to adjust for potential confounding effects of co-pollutants, for outdoor conditions.
and indoor air pollutants, respectively. A p-value of 0.05 was regarded as significant. For analysis, we used SPSS 22 software (IBM Co., Armonk, NY, U.S.A.).

**Results**

The background characteristics of the subjects are shown in Table 1. A total of 868 pulmonary function tests were conducted. The means ± standard deviations of PEF and FEV₁ were 390.1 ± 110.2 L/min and 2.48 ± 0.74 L, respectively. Of the subjects, 7 (16.3%) had a history of asthma, and 19 (44.2%) had a history of allergy without asthma. Seventeen subjects (39.5%) did not have either history. During the study period, no subject developed respiratory symptoms, such as cough, sputum, or wheezing.

The mean indoor/outdoor concentrations of air pollutants during the study period are shown in Table 2. The mean outdoor concentration of PM₂.₅ was 30.9 ± 12.5 μg/m³. Those of PM₁₀₂.₅ and BC were 22.7 ± 15.4 and 0.55 ± 0.22 μg/m³, respectively. The maximum outdoor concentration of PM₂.₅ was 61.6 μg/m³, which was measured on the day with yellow sand carried from China to Japan. On the same day, the concentration of PM₁₀₂.₅ was also high (53.8 μg/m³). The mean indoor concentration of PM₂.₅ was 17.0 ± 9.6 μg/m³.

There were strong positive correlations between the outdoor and indoor concentrations of PM₂.₅ and NO₂ (r = 0.82 and 0.92, respectively). However, the correlation between those of O₃ was weak (r = 0.42) (Fig. 2). The mean indoor concentrations of PM₂.₅, O₃, and NO₂ were lower than the outdoor values.

The associations between the concentrations of air pollutants and changes in parameters of pulmonary function during the study period are shown in Table 3. FEV₁ decreased significantly in relation to an increase in the BC concentration (−27.28 mL [95% confidence interval (CI): −54.10, −0.46] per IQR increase of 0.23 μg/m³). The PEF reduced significantly in relation to an increase in the indoor O₃ concentration (−8.03 L/min [95% CI: −13.02, −3.03] per IQR increase of 11.0 ppb). There was no significant correlation between the concentrations of the other pollutants and changes in pulmonary function.

**Table 1** Characteristics of study subjects

|               | Male (n = 29) | Female (n = 14) | Total (n = 43) |
|---------------|--------------|----------------|---------------|
| Height, mean (SD) (cm) | 166.4 ± 6.8 | 156.9 ± 5.1 | 163.3 ± 7.7 |
| PEF (L/min)   | 420.8 ± 110.2 | 320.7 ± 73.7 | 390.1 ± 110.2 |
| FEV₁ (L)      | 2.66 ± 0.75  | 2.10 ± 0.55  | 2.48 ± 0.74  |
| Measurements of pulmonary function (n) | (594) | (274) | (868) |

SD standard deviation; PEF peak expiratory flow; FEV₁ forced expiratory volume in 1 s

We performed analyses using two-pollutant models to adjust for confounding effects of co-pollutants. Additional file 1: Table S1 shows the estimated changes in PEF and FEV₁ associated with an IQR increase of each pollutant [see Additional file 1]. The FEV₁ showed a significant decrease in relation to an increase in O₃ after adjustment for outdoor PM₂.₅ or NO₂. Furthermore, PEF reduced significantly in relation to an increase in outdoor PM₂.₅ or BC, after adjustment for outdoor NO₂.

The associations between the concentrations of air pollutants and PEF with respect to the presence or absence of a history of asthma or allergy are shown in Fig. 3(a). In subjects with a history of allergy, PEF reduced significantly with an increase in the indoor concentration of PM₂.₅ (−6.71 L/min [95% CI: −13.36, −0.06] per IQR increase). In those with a history of asthma, PEF reduced significantly with an increase in the indoor concentration of O₃ (−22.6 L/min [95% CI: −41.08, −4.13] per IQR increase). On the other hand, the PEF reduced significantly with an increase in the indoor concentration of O₃ in those without either history (−8.84 L/min [95% CI: −16.28, −1.40] per IQR increase). In those with a history of allergy, FEV₁ reduced significantly with an increase in the outdoor concentration of PM₂.₅ (−7.0 mL [95% CI: −130.1, −9.94] per IQR increase) (Fig. 3(b)). In addition, FEV₁ reduced significantly with an increase in the indoor concentration of O₃ in subjects with a history of asthma (−130.3 mL [95% CI: −243.5, −17.2] per IQR increase).

**Discussion**

Even in an isolated island without artificial sources of air pollutants, there were changes in the atmospheric concentrations of air pollutants, indicating that changes in the concentration of BC have an acute influence on the pulmonary function in healthy students. The indoor concentration of O₃ more markedly influenced pulmonary function compared with its outdoor concentration. In subjects with a history of asthma, pulmonary function reduced significantly with an increase in O₃ concentration. In those with a history of allergy, it reduced significantly with an increase in PM₂.₅ concentration. These results suggested that subjects with these histories were more susceptible to changes in the concentrations of air pollutants.

Although we thought that this island in the Seto Inland Sea should be a clean-air area, the concentration of PM₂.₅ was considerably high in the island. It was thought that the high concentrations recorded were largely due to transported air pollutants including yellow sand and the emissions from marine ships. Allen et al. showed that...
PM$_{2.5}$ are transported over long distances and affects distant clean-air areas [22]. It was also reported that transported air pollutants and emissions from marine ships affect the levels of air pollution in Kyushu, Japan [23, 24]. If the emission from marine ships contribute to air quality in the island, the concentration of sulfur dioxide may be also high. However, the concentrations have not been measured around the island.

The results of this study showed that pulmonary function reduced significantly with an increase in the atmospheric concentration of BC, and the association was still significant after adjustment for O$_3$. Huang et al. reported that a pulmonary function test in healthy adults after they stayed in a transport hub of a big city for 2 h showed a significant decrease in FEV$_1$ related to an increase in BC concentration [25]. Patel et al. conducted a study among school children in New York, and indicated that symptoms, such as wheezing and shortness of breath, deteriorated with an increase in BC concentration [26]. The results of these studies were consistent with those of our study. Diesel emission gas contains a large volume of BC [27]. A study reported that when persons were exposed to diesel emission gas, the bronchial mucosal neutrophil and mast cell counts increased, inducing transient increases in the number of inflammatory cells in the airway and cytokine levels [28]. With an increase in BC concentration, an inflammatory response in the airway may have occurred, thereby reducing pulmonary function. The area investigated in this study was an isolated island with light traffic, which unlike urban areas, and had relatively low concentration of BC. Our results suggested that an increase in BC concentration influences pulmonary function even in such an area with a low air pollutant concentrations. Huang et al. evaluated adults

**Table 2** The 24-h mean concentrations of outdoor and indoor air pollutants and meteorological parameters during the study period

|                          | n  | Mean | SD  | Minimum | Median | Maximum | IQR  |
|--------------------------|----|------|-----|---------|--------|---------|------|
| **Outdoor air pollutants** |    |      |     |         |        |         |      |
| PM$_{2.5}$ ($\mu$g/m$^3$) | 29 | 30.9 | 12.5| 13.7    | 30.6   | 61.6    | 18.4 |
| PM$_{10-2.5}$ ($\mu$g/m$^3$) | 29 | 22.7 | 15.4| 6.0     | 16.2   | 54.2    | 24.2 |
| BC ($\mu$g/m$^3$)          | 29 | 0.55 | 0.22| 0.26    | 0.49   | 1.25    | 0.23 |
| O$_3$ (ppb)               | 21 | 44.6 | 10.3| 25.7    | 46.1   | 58.5    | 20.8 |
| NO$_2$ (ppb)              | 21 | 9.2  | 3.8 | 4.2     | 8.6    | 16.7    | 6.3  |
| **Indoor air pollutants**  |    |      |     |         |        |         |      |
| PM$_{2.5}$ ($\mu$g/m$^3$) | 29 | 17.0 | 9.6 | 3.7     | 16.5   | 39.3    | 12.6 |
| O$_3$ (ppb)               | 21 | 15.9 | 7.5 | 1.9     | 16.2   | 30.0    | 11.0 |
| NO$_2$ (ppb)              | 21 | 6.3  | 3.0 | 2.2     | 5.8    | 15.3    | 4.2  |
| **Meteorological parameters** |    |      |     |         |        |         |      |
| Temperature (°C)          | 29 | 20.2 | 2.1 | 15.8    | 19.8   | 23.9    | 3.6  |
| Relative humidity (%)     | 29 | 71.5 | 11.1| 52.0    | 69.0   | 92.0    | 15.5 |

SD standard deviation; IQR interquartile range; PM$_{2.5}$ particulate matter ≤ 2.5 μm in diameter; PM$_{10-2.5}$ particulate matter between 2.5 and 10 μm in diameter; BC black carbon; O$_3$ ozone; NO$_2$ nitrogen dioxide

![Fig. 2](image-url)
Table 3  Associations between air pollutants and pulmonary function during the study period

|                  | PEF (L/min) | FEV1 (mL) |
|------------------|-------------|------------|
|                  | Changea | 95% CI     | P-Value | Changea | 95% CI     | P-Value |
| Outdoor air pollutants |          |            |         |          |            |         |
| PM2.5            | −4.57    | (−10.67, 1.52) | 0.141   | −41.19   | (−84.38, 1.99) | 0.062   |
| PM10-2.5         | −2.71    | (−9.04, 3.62) | 0.401   | −37.50   | (−81.80, 6.79) | 0.097   |
| BC               | −3.53    | (−7.31, 0.25) | 0.067   | −27.28   | (−54.10, 0.46) | 0.046   |
| O3               | −3.84    | (−15.42, 7.74) | 0.515   | −30.93   | (−112.84, 50.99) | 0.459   |
| NO2              | 2.18     | (−3.67, 8.02) | 0.466   | −28.23   | (−69.40, 12.95) | 0.179   |
| Indoor air pollutants |        |             |         |          |            |         |
| PM2.5            | −3.21    | (−8.63, 2.20) | 0.245   | −9.58    | (−48.50, 29.34) | 0.629   |
| O3               | −8.03    | (−13.02, −3.03) | 0.002   | −20.14   | (−55.36, 15.09) | 0.262   |
| NO2              | 0.81     | (−3.96, 5.59) | 0.738   | −9.88    | (−43.22, 23.46) | 0.561   |

PEF peak expiratory flow; FEV1 forced expiratory volume in 1 s; CI confidence interval; PM2.5 particulate matter ≤ 2.5 μm in diameter; PM10-2.5 particulate matter between 2.5 and 10 μm in diameter; BC black carbon; O3 ozone; NO2 nitrogen dioxide

aMean changes in PEF or FEV1 associated with an increase in the interquartile range of each air pollutant

Fig. 3  Estimated changes in (a) PEF and (b) FEV1 with increases in air pollutants in relation to a history of asthma or allergy. The estimated changes and 95% confidence intervals for (a) PEF and (b) FEV1 are shown per increase in interquartile range (IQR) of the concentration of air pollutants in relation to a history of asthma or allergy. A: Subjects with a history of asthma. B: Subjects with a history of allergy other than asthma. C: Subjects without a history of asthma or allergy.
exposed to air pollutants for 2 h in a previous study [25]. In our study, the subjects were adolescent students who attended school for many hours. Because this survey was conducted in an isolated island, the subjects resided both in the island and along the coast. As the 1-month survey was carried out in such a place, the influence of exposure to air pollutants on daily living could be evaluated accurately. Furthermore, most subjects were healthy, and the results of our study may be representative.

The indoor concentration of O₃ was more markedly associated with pulmonary function compared with its outdoor concentration, and the effect of O₃ was still significant after adjustment for PM₂.₅ or NO₂. O₃ exhibits acute effects on the lungs [29]. When the indoor concentration of O₃ increased, PEF decreased significantly. However, there was no significant relationship with an increase in the outdoor concentration of O₃. Altug et al. reported that the PEF among elementary school children decreased significantly with an increase in the concentration of O₃ [30]. McConnell et al. performed a 5-year follow-up survey of 3535 children without asthma, and indicated that 265 were newly diagnosed with asthma during the follow-up, suggesting that high-intensity exercise in an area with a high concentration of O₃ promotes the onset of childhood asthma [31]. Furthermore, Amadeo et al. reported that, even at an O₃ concentration lower than the reference value presented in the WHO guidelines, PEF decreased with an increase in the concentration of O₃, suggesting the acute effects of O₃ on the pulmonary function of children [32]. Pulmonary function reduces with an increase in O₃ concentration, because O₃ may increase inflammation of the airway as a potent acidic pollutant [10, 33]. Intra-pulmonary O₃ uptake was reported to peak in the terminal bronchioles [34]. In our study, the relationship with the indoor concentration of O₃ and pulmonary function was marked. Gaseous substances, such as O₃, are sometimes generated indoors; therefore, their concentrations in living spaces should be measured and used for exposure assessments.

Neither the indoor nor outdoor concentrations of PM₂.₅ were significantly associated with PEF and FEV₁ among all the subjects in a single-pollutant model. However, after adjustment for outdoor NO₂, PEF significantly decreased with an increase in the outdoor concentration of PM₂.₅. Moreover, PEF decreased significantly with an increase in BC after adjustment for NO₂. These findings may be due to the interactions between NO₂ and other air pollutants. The results suggested acute effects related to changes in the concentrations of O₃ and PM₂.₅ in subjects with a history of asthma or allergy. In those with a history of allergy, the PEF and FEV₁ significantly reduced when the indoor and outdoor concentrations of PM₂.₅ increased, respectively. With respect to the acute effects of PM₂.₅, Huang et al. reported that FEV₁ decreased by −0.15% (95% CI: −0.28, −0.02%) when the exposure concentration for 2 h increased by 10 μg/m³ [25]. Bernals et al. indicated that allergic airway diseases are not merely disorders of the immune system, and that allergic diseases primarily arise from airway epithelium defects resulting from immaturity or caused by environmental insults [35]. In our study, pulmonary function may also have reduced through such a pathophysiological mechanism. Based on the results of this study, there was no relationship between PM₁₀₋₂.₅ and changes in pulmonary function. PM₁₀₋₂.₅ is deposited in the nasal cavity, pharynx, and upper airway when it is inhaled. However, PM₂.₅ reaches the bronchiolar and alveolar levels in the lungs because its particle diameter is small. A previous study reported that the influence of PM₂.₅ on the respiratory system was more marked than that of PM₁₀₋₂.₅ [36]. Based on the results of this study, there was no relationship between the PM₂.₅ concentration and PEF or FEV₁ in subjects with a history of asthma, but this was possibly because the number of subjects was small.

In subjects with a history of asthma, PEF and FEV₁ decreased significantly with an increase in the indoor concentration of O₃. In these subjects, the two parameters decreased slightly with an increase in the outdoor concentration of O₃. Mortimer et al. reported that PEF in the morning decreased with an increase in O₃ concentration in children with asthma [37]. In our study, when analyzing the results with respect to medical histories, PEF was associated with an increase in O₃ concentration in subjects other than those with a history of allergy. There was no significant difference in those with a history of allergy, but the reason was unclear.

There was no association between an increase in NO₂ concentration and pulmonary function. In power plant workers exposed to NO₂, pulmonary functions were reduced significantly [38]. Gauderman et al. indicated that the odds ratio of asthma was 1.83 (95% CI: 1.04–3.22) when the outdoor concentration of NO₂ increased by 5.7 ppb (IQR) [39]. Furthermore, Liu et al. conducted a study among children with asthma, and reported that an increase in NO₂ concentration significantly reduced pulmonary function [40]. The concentration of NO₂ measured in our study was relatively low; therefore, there may have been no influence on the respiratory system.

We had conducted the survey in the same area in the autumn of 2013, and found negative associations between pulmonary function and the concentrations of PM₂.₅, NO₂, and BC among subjects with a history of asthma [41]. In the present study, to estimate the exposure to air pollutants accurately, we conducted measurements of the indoor concentrations of air pollutants in addition to outdoor concentrations. The subjects in the present study were different from those in the previous
one, and this survey was conducted during spring. In the results of this study, an inverse association between pulmonary function and the concentrations of air pollutants among subjects with a history of asthma or allergy, which was compatible with the previous study. Therefore, subjects with a history of asthma or allergy were considered to be more susceptible to air pollutants. These adverse effects of air pollution may be modified by medication for asthma or allergy. However, in this study, information on the medication taken by the subjects was not obtained. The interaction with medication should be further evaluated.

This study has several limitations. One is that the number of subjects was small, resulting in an insufficient detection power; therefore, the influence of air pollution may have been underestimated. However, pulmonary function tests were conducted every morning, and a significant reduction in pulmonary function related to increases in BC or O₃ concentrations was observed, even though the number of subjects was relatively small. The second limitation is that the study period was short and was limited to one season. It has been reported that the concentrations and sources of air pollutants have seasonal variations. In the future, a large-scale survey involving a larger number of subjects should be conducted for a longer period. The third limitation is that only PEF and FEV₁ were used as pulmonary function parameters. Although inflammation of the airway may be involved in a reduction of pulmonary function, it was not tested in this study. In the future, the inflammatory state of the airway should be evaluated objectively in addition to pulmonary function tests.

Conclusion

In an isolated island without major artificial sources of air pollutants, changes in the concentrations of air pollutants acutely influenced the pulmonary function of healthy subjects. The results suggest that gaseous substances, such as O₃, are sometimes generated indoors, and that the indoor concentration of O₃ more markedly influences pulmonary function compared with its outdoor concentration. In subjects with a history of allergy, pulmonary function reduced with an increase in the concentration of PM₂.₅.

Additional file

Additional file 1: Table S1. Associations between air pollutants and pulmonary function during the study period in each single- and two-pollutant model. (DOCX 23 kb)

Abbreviations

BC: Black carbon; FEV₁: Forced expiratory volume in 1 s; IQR: Interquartile range; NO₂: Nitrogen dioxide; O₃: Ozone; PEF: Peak expiratory flow; PM₁₀: Particulate matter between 2.5 and 10 μm in diameter; PM₂.₅: Particulate matter ≤2.5 μm in diameter

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Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Authors’ contributions

MS was the research leader of this study. YY, HT, JW and MS designed the study. HT, JW and TI performed pulmonary function tests among students. RN, YH and TH conducted measurement of the atmospheric environment. YY performed the statistical analyses and wrote the first draft of this manuscript, and MS revised it to make the final manuscript. All authors have approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable.

Ethics approval and consent to participate

This study was approved by the Ethics Review Board of Hyogo College of Medicine (17-May-2013, approval number 1474). The objectives and methods of this study were fully explained to all participants, and written, informed consent was obtained from each participant before the study.

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