# The Association Between Particulate Matter Air Pollution and Respiratory Health in Elderly With Type 2 Diabetes Mellitus

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**Objective:** We investigated the association between respiratory health and particulate matter (PM) air pollution in elderly type 2 diabetes mellitus (T2DM) pre-, during, and post-the Chinese Lunar New Year (CLNY) holiday in Shanghai, China. **Methods:** We conducted repeated measurements of lung function and inflammation biomarker in a cohort consisted of 60 participants with T2DM. **Results:** Decreased $PM_{2.5}$ exposure had an effect on respiratory health by increasing in forced expiratory flow in 1 second ($FEV_1$) and forced vital capacity (FVC). Positive associations between PM exposure and exhaled nitric oxide (eNO) were observed. **Conclusions:** Our observations indicated that PM air pollution exposure would exert adverse effect on respiratory health in elderly T2DM population.

As non-invasive parameters of respiratory health, lung function was associated with ambient particulate matter (PM) air pollution in numerous epidemiology studies, however, not all aspect of the association have been consistent.[1–7] One reason for the inconsistence might be the large gap of ambient PM level in these study fields.[8–10] Also, the dynamic exposure–response association may relate to the different PM characteristics and varied subpopulation susceptibilities.[11–13] A large number of animal and cell experiments also suggested that PM exposure may be related to increased neutrophil recruitment into the airways and exert adverse effect on respiratory system.[14–16] One of the key hypothesized mechanism for progression of type 2 diabetes mellitus (T2DM) is systemic inflammation response to environmental factors.[17] However, there are only limited studies evaluate the respiratory health status in elderly T2DM populations that suffer from very high level of PM air pollution.

With rapid urbanization, China have experienced intense PM air pollution caused by anthropogenic emissions, such as manufacturing, transportation, and a dependence on fossil fuels like gas and coal.[18–20] Moreover, increased ageing population and longer life spans have led to a rapid change in the health profile of the nation.[21] The Chinese Lunar New Year (CLNY) holiday is one of the most important traditional festival in China; like many other traditional festival worldwide, people celebrate the holiday by family reunite and setting off firecrackers.[22] During this holiday, there is less air pollution from traffic because high proportion of immigrant population leaving Shanghai for family reunite alleviated traffic pressure, whereas for the other side, poor air quality may be caused by setting off holiday firecrackers at particular occasion, such as the Eve of CLNY.[23,24]

In the context, we focus on the role of PM air pollution as a risk factor for elderly outpatients with T2DM, to evaluate the association of PM level and respiratory health across the entire holiday period. We hypothesized that changes in PM air pollution would be associated with changes in lung function and exhaled nitric oxide (eNO).

## METHODS

### Study Design

We conducted this study at a community hospital between December 2013 and March 2014 in Shanghai, China. The elderly outpatients with T2DM were randomly selected from the Chronic Disease Management System in the community hospital. Then, the selected outpatients were invited to participants in our study by telephone call. The participants expressing an interest were recruited and confirmed by physician. The selection criteria were as follow: local community residents who live within 2 miles around the community hospital; no history of established lung disease, such as asthma or chronic respiratory diseases; no history of coronary artery disease, congestive heart failure, or ischemic heart disease. Finally, 60 elder participants with T2DM were recruited.

The present panel study was designed in which each participant had three repeated lung function and eNO measurements, separated by 1 month, in correspond to period-specific PM exposure. The baseline health outcome examination was performed on January 9, 2014 immediately after the pre-CLNY period (December 8, 2013 to January 9, 2014), the first follow-up examination performed on February 7, 2014 after the during-CLNY period (January 10 to February 7, 2014), and the second follow-up after the after-CLNY period (February 8 to March 6, 2014). The baseline health outcome examination was carried on 3 weeks before the CLNY holiday. The first follow-up was carried on February 7, 2014, which was immediately after the CLNY holiday. Then, we arranged the second follow-up, which was 4 weeks after the CLNY holiday. During the study, the participants took their usual medication in glycemic control. This study was reviewed and approved by the Fudan University Institutional Review Board (Protocol #2012030329). All participants provided consents for interviews and health outcome examination.

### PM Exposure Measurements

Daily air pollution data, including daily average $PM_{2.5}$, $PM_{10}$, $NO_2$, $SO_2$, $O_3$, temperature and relative humidity, were obtained from the Shanghai Environmental Monitoring Center. The Shanghai Environmental Monitoring Center is the official environmental

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monitoring agency of Ministry of Environmental Protection of China. Daily concentrations for each pollutant were collected from a fixed-site station which is 2 miles from the community hospital in Xuhui District.

As the time window of PM exposure that could have effect on lung function is unknown, we evaluated the average PM concentrations during different time windows (same day, 7-day, 14-day, and 21-day previous, before the time of health outcome examination). Daily average on the health outcome examination day were surrogate for acute exposure (lag 0), with previous 1 week average (lag 7), prior 2 weeks average (lag 14), and previous 3 weeks average (lag 21) as the surrogate for short-term exposure. We use the exposure matrix to analyze per interquartile range (IQR) decrease in PM exposure with lung function changes according to different lag structures.

## Respiratory Health Measurement

Health checkup and respiratory health measurement for both baseline and follow-ups were conducted in the morning at the community hospital on appointed examination days. The baseline assessment included self-administrated questionnaire about participants' current medication and lifestyle habits, such as physical exercise (defined as regular outdoor activity daily for a minimum of 30 min), smoking history (former and never-smoker). At each visit, lung function included forced expiratory flow in 1 second ($FEV_1$), forced vital capacity (FVC), maximum mid-expiratory flow ($MMEF_{25-75}$), and peak expiratory flow (PEF) were measured. The spirometric parameters were obtained using the German Master Screen PFT (Hoechberg, Germany) pulmonary monitory instrument; the participants wore a nose clip, seated, and performed at least three maneuvers. In accordance with the American Thoracic Society/European Respiratory Society guidelines,[25] hospital technicians certified for operating Master Screen-PFT (Hoechberg, Germany) performed all tests. FVC and $FEV_1$ results were accepted as valid when the difference between the best two valid maneuvers was less than 200 mL. The eNO measurements were performed using nitric oxide analyzer (Sunvou, China).

All of the participants were requested to fast overnight for 10 hour, and then 2 mL blood sample was collected into vacuum tubes containing sodium fluoride for fasting plasma glucose (FPG) measurement. All of the blood samples were transported to the certified laboratory in the community hospital for blood glucose analyses.

## Statistical Analysis

The final dataset for analysis included participants who completed all three times of health measurement. Description summaries of PM air pollution exposure were exhibit including means and median with ranges over three exposure sessions, and description summaries of respiratory health (lung function and eNO) were presented from baseline to two follow-ups.

Repeated measurements were performed to estimate associations between air pollutant exposures and changes in lung function measures using linear mixed effects models, the random participant intercept were included to account for the correlation of repeat lung function measures in linear mixed effects models.[26–28] The models were used to interpret lung function change in relation to per IQR decrease in $PM_{2.5}$ or $PM_{10}$ concentration within the exposure matrix. First order autoregressive covariance structure was used to fit correlations between repeated measurements. As age, sex, body mass index (BMI), disease group (T2DM concomitant with hypertension or T2DM only), smoking history are associated with lung function, these covariates were included as the basic models and controlled for in all models, then temperature and relative humidity were added to control the potential confounding from meteorology; finally, we only controlled ambient $NO_2$ level which served as a proxy for other copollutions, because $PM_{2.5}$ were strongly correlated with $NO_2$, $SO_2$, and CO.

To assess effect modification, we stratified our models by disease group (type 2 DM concomitant with hypertension, type 2 DM only), sex (male, female), and age (more than 65 years, less than or equal to 65 years), the association in each stratum was estimated. In addition, to evaluate the robustness of our main analysis model, sensitivity analysis was conducted by including additional covariates, such as alcohol intake, controlling for other pollutant, such as $O_3$. All analyses were conducted using Statistical Analysis Software Version 9.4 (SAS Inc, Cary, NC).

# RESULTS

## Study Population

Table 1 summarized the descriptive statistics of study participants. Of the 60 enrolled participants in the study population, we included 55 participants (40% men; 66.2 ± 7.3 years of age) with no missing information on PM exposure, outcome, and covariates. The five excluded participants did not have a noticeable difference from those included. Therefore, a total of 165 observations were obtained with data from three sessions of repeated lung function measurements. There was 38.1% participants had prior smoking history, 10.9% for alcohol history, none of them were currently smoking or alcohol users. There were 26 T2DM patients concomitant with hypertension, which comprised 47.3% of the available study population.

## PM Exposure Measurements

Table 2 described period-specific means of $PM_{2.5}$ and $PM_{10}$ exposure level among three successive exposure periods. The daily mean concentrations of $PM_{2.5}$ and $PM_{10}$ were 89.4 and 116.2 $\mu g/m^3$, respectively, in pre-CLNY period, the baseline health outcome examination was carried out on January 9, 2014. The during-CLNY period included the 7-day CLNY legal holiday, with the first follow-up of health outcome examination conducted on February 7, 2014. The PM level in during-CLNY period had somewhat decreased to 66.1 $\mu g/m^3$ for $PM_{2.5}$ and 82.1 $\mu g/m^3$ for $PM_{10}$. The post-CLNY period comprised 1 month after the CLNY holiday. The daily mean concentrations of PM were at relatively lower levels with 42.5 $\mu g/m^3$ for $PM_{2.5}$ and 51.4 $\mu g/m^3$ for $PM_{10}$, with the second follow-up of health outcome examination conducted on March 6, 2014.

As expected, there was an air-pollution peak on January 30, 2014 (the Eve of CLNY), with 192.0 $\mu g/m^3$ for daily mean concentration $PM_{2.5}$, 195.0 $\mu g/m^3$ for $PM_{10}$. The result was consistent with our hypothesis that widespread usage of firecrackers would cause extremely high PM concentration. After the Eve and Day of the CLNY, there was a sharp decrease ensued from January 31, 2014 to February 6, 2014. The minimum daily level for $PM_{2.5}$ had dropped to 8.0 $\mu g/m^3$ on February 6, 2014. There was a less demand

**TABLE 1.** Characteristic of Study Participants ($n = 55$)

| Characteristic | Mean ± SD or *n* (%) |
|---|---|
| Male, No. (%) | 22 (40) |
| Age (yrs) | 66.9 ± 7.3 |
| BMI (kg/m$^2$) | 25.9 ± 3.9 |
| Low physical activity (<1 time/week) | 7 (12.7) |
| Smoking status | |
| Former | 21 (38.1) |
| Never | 34 (61.9) |
| Alcohol use | |
| Former | 6 (10.9) |
| Never | 49 (89.1) |
| Concomitant hypertension | 26 (47.3) |

BMI, body mass index; SD, standard deviation.

**TABLE 2.** Description of Particulate Matter Air Pollution Across Study Period from December 2013 to March 2014 (μg/$m^3$)

| | Mean ± SD | IQR | Minimum/Maximum |
|---|---|---|---|
| Before the CNLY | | | |
| $PM_{2.5}$ | 89.4 ± 50.5 | 61.0 | 13.0–224.0 |
| $PM_{10}$ | 116.2 ± 62.9 | 93.0 | 14.0–269.0 |
| $NO_2$ | 74.6 ± 24.2 | 35.0 | 35.0–119.0 |
| During the CNLY | | | |
| $PM_{2.5}$ | 66.1 ± 55.2 | 72.0 | 8.0–195.0 |
| $PM_{10}$ | 82.1 ± 59.2 | 76.0 | 6.0–261.0 |
| $NO_2$ | 47.2 ± 19.6 | 20.0 | 14.0–101.0 |
| After the CNLY | | | |
| $PM_{2.5}$ | 42.5 ± 29.2 | 32.0 | 8.0–128.0 |
| $PM_{10}$ | 51.4 ± 30.3 | 46.0 | 11.0–134.0 |
| $NO_2$ | 40.2 ± 16.2 | 20.0 | 14.0–85.0 |

CNLY, Chinese Lunar New Year; $NO_2$, nitrogen dioxide; $PM_{10}$, particulate matter with aerodynamic diameter less than 10 μm; $PM_{2.5}$, particulate matter with aerodynamic diameter less than 2.5 μm; SD, standard deviation.

for energy as the numbers of people using public transportation decreased while a lot of people returned their hometown during the Festival. Factories and constructions sites were also stop operating during the 7-day CLNY legal holiday. The trend was in line with our hypothesis that urban PM air pollution would be influenced by less traffic and commute during the holiday. Spearman correlation analysis showed that daily mean of $PM_{2.5}$ was highly related with $NO_2$, $SO_2$, CO ($r = 0.78$, $P < 0.001$; $r = 0.79$, $P < 0.001$; $r = 0.95$, $P < 0.001$), whereas inversely related with $O_3$ ($r = -0.27$, $P < 0.001$).

Table 3 described the lung function parameters and eNO in three repeated measurements across the study period. The average $FEV_1$ had increased from 2.4 L (baseline) to 2.6 L (the second follow-up) in man group. The average $FEV_1$ had increased from 1.8 L (baseline) to 1.9 L (the first follow-up) and then 2.0 L (the second follow-up) in women group. The average FVC had increased from 3.2 L (baseline) to 3.9 L (the second follow-up) in man group. The average FVC had increased from 2.4 L (baseline) to 2.7 L (the first follow-up) and then 2.8 L (the second follow-up) in woman group. There was a slightly decrease in eNO level in both man and woman groups. Generally, the PEF or $MMEF_{25-75}$ had shown no consistent change over three repeated measurements.

## Regression Analysis

After adjusting for temperature, relative humidity, and individual risk factors, we observed statistically significant increase in $FEV_1$ from 136.8 mL (95%CI, 24.3 to 249.3 mL) to 22.7 mL (95%CI, 5.2 to 40.2 mL) associated with per IQR decrease in $PM_{2.5}$ exposure at lag 0 and lag 14, respectively (Table 4). The estimate effect on $FEV_1$ shows substantial decrease with longer time window of PM exposure from lag 0 to previous 3 weeks (lag 21), with the strongest association on the same day of the visit (lag 0). Similar patterns for FVC (110.6 mL 95% CI: 47.8 to 173.3 mL in lag 0; 17 mL 95% CI: 7.2 to 26.8 mL in lag 14). In our analysis model, we estimated positive associations between eNO and per IQR decrease in same day PM exposure (−4.7 ppb lower eNO; 95% CI: −11.86, −1.32) and the association had become nonsignificant with longer window time. However, there were no significant estimated associations between PM air pollution and PEF or $MMEF_{25-75}$ throughout all time windows in our study. Overall, the associations of health outcomes with $PM_{10}$ were similar but relatively small, which were about 60% smaller than the effects of $PM_{2.5}$. We did not find indication of effect modification by disease group (T2DM concomitant with hypertension or T2DM only), age, or sex. In sensitivity analysis, we adjusted for the additional dichotomous variable (alcohol intake) and $O_3$ level to rule out the potential confounding. These adjustments did not affect the final results.

## DISCUSSION

This study indicated that decreased $PM_{2.5}$ and $PM_{10}$ levels were associated with increased $FEV_1$ and FVC in elderly with T2MD resided in the Shanghai metropolitan area. There were significantly associations between PM exposure and lung function in acute (Lag 0) and short-term (Lag 7 and Lag 14), but not for longer lag time, indicated that health effects of PM exposure on lung function may occur within 2 weeks.

Numerous studies have examined the association between increased PM air pollution and impaired lung function.[5,6,17,29] The multi-cohort European meta-analysis (ESCAPE study) found that long-term exposure to $PM_{10}$ was associated with small decrease in $FEV_1$ and FVC.[30] This is consistent with the results concluded from the Framingham Offspring or Third Generation studies, which found each 2 mg/$m^3$ increase in average of $PM_{2.5}$ was associated with a 13.5 (95% CI, 0.3 to 26.6) mL lower $FEV_1$.[2] In comparison with increase PM exposure, Gauderman et al[31] reported that long-term improvements in air quality had significant positive effects on $FEV_1$ and FVC in children. Evidence for short-term PM air pollution and lung function changes were also found.[4] Between June 15 and July 27 in 2008, Baccarelli et al[5] found reduced lung function associated with personal $PM_{2.5}$ of 126.8 μg/$m^3$ (IQR: 73.9–160.5) in truck drivers. These findings may suggested that the lung function might have discernible changes, such as declined $FEV_1$ and FVC, but only observed under very high level of $PM_{2.5}$ exposure. We have also estimated the associations between particulate matter air pollution and PEF or $MMEF_{25-75}$ over three repeated measurements, no significant were apparent in our research, which is consistent with the PM air pollution were less likely to associate with airflow obstruction.[32] The biologic mechanisms of PM

**TABLE 3.** The Lung Function Parameters and eNO in Three Repeated Measurements Across Study Period

| Health Outcome | Baseline | | First Follow-up | | Second Follow-up | |
|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female |
| $FEV_1$ (L) | 2.4 ± 0.5 | 1.8 ± 0.4 | 2.4 ± 0.6 | 1.9 ± 0.4 | 2.6 ± 0.5 | 2.0 ± 0.4 |
| FVC (L) | 3.2 ± 0.6 | 2.4 ± 0.5 | 3.2 ± 0.8 | 2.7 ± 1.0 | 3.9 ± 1.4 | 2.8 ± 0.8 |
| PEF (L/sec) | 6.7 ± 1.2 | 4.9 ± 1.1 | 6.1 ± 2.1 | 4.9 ± 1.3 | 6.4 ± 1.4 | 4.9 ± 1.1 |
| $MMEF_{25-75}$ (L/sec) | 2.1 ± 0.7 | 1.6 ± 0.6 | 2.0 ± 0.8 | 1.7 ± 0.8 | 1.7 ± 0.8 | 1.8 ± 0.7 |
| eNO (ppb) | 17.6 ± 7.2 | 17.5 ± 10.7 | 15.3 ± 11.1 | 15.5 ± 7.8 | 14.5 ± 7.8 | 15.7 ± 7.3 |

eNO, exhaled nitric oxide; $FEV_1$, forced expiratory flow in 1 second; FVC, forced vital capacity; $MMEF_{25-75}$, maximum mid-expiratory flow; PEF, peak expiratory flow.

**TABLE 4.** Estimates Change in Lung Function and eNO (With 95%CI) per Corresponding Interquartile Range Reduce of Exposure to $PM_{2.5}$ and $PM_{10}$

| | Time Window | Estimate | 95%CI | P |
|---|---|---|---|---|
| $FEV_1$ (mL) | | | | |
| $PM_{2.5}$ | Same day | 136.8 | 24.3–249.3 | <0.0001 |
| | 7-day | 32.0 | 7.0–57.1 | <0.0001 |
| | 14-day | 22.7 | 5.2–40.2 | 0.03 |
| | 21-day | −9.0 | −21.7–3.6 | 0.07 |
| $PM_{10}$ | Same day | 39.7 | 7.1–72.5 | <0.0001 |
| | 7-day | 25.2 | 5.5–45.1 | 0.03 |
| | 14-day | 11.3 | 2.6–20.1 | <0.0001 |
| | 21-day | 7.8 | −3.0–18.9 | 0.12 |
| FVC (mL) | | | | |
| $PM_{2.5}$ | Same day | 110.6 | 47.8–173.3 | 0.01 |
| | 7-day | 24.6 | 10.6–38.6 | <0.0001 |
| | 14-day | 17.0 | 7.2–26.8 | 0.01 |
| | 21-day | 9.2 | 2.3–16.2 | 0.07 |
| $PM_{10}$ | Same day | 32.1 | 13.9–50.4 | <0.0001 |
| | 7-day | 19.4 | 8.4–30.5 | 0.02 |
| | 14-day | 8.5 | 3.6–13.4 | 0.04 |
| | 21-day | 8.0 | 1.9–14.2 | 0.01 |
| PEF (mL/sec) | | | | |
| $PM_{2.5}$ | Same day | 58.3 | −118.3–126.0 | 0.12 |
| | 7-day | 108.9 | −24.3–242.1 | 0.08 |
| | 14-day | 65.7 | −27.4–158.9 | 0.35 |
| | 21-day | 86.3 | −19.1–153.5 | 0.34 |
| $PM_{10}$ | Same day | 170.1 | −3.7–344.0 | 0.12 |
| | 7-day | 85.9 | −19.2–192.0 | 0.08 |
| | 14-day | 32.8 | −13.7–79.4 | 0.41 |
| | 21-day | 75.4 | −16.7–134.2 | 0.39 |
| $MMEF_{25to75}$ (mL/sec) | | | | |
| $PM_{2.5}$ | Same day | 51.6 | −20.6–103.1 | 0.61 |
| | 7-day | −18.1 | −36.3–7.3 | 0.44 |
| | 14-day | 4.5 | −9.1–18.2 | 0.67 |
| | 21-day | −17.2 | −68.6–34.3 | 0.77 |
| $PM_{10}$ | Same day | 27.7 | −7.1–35.3 | 0.61 |
| | 7-day | −22.5 | −45.0–90.2 | 0.12 |
| | 14-day | 4.1 | −8.2–16.5 | 0.64 |
| | 21-day | −16.7 | −66.7–33.3 | 0.36 |
| eNO (ppb) | | | | |
| $PM_{2.5}$ | Same day | −4.7 | −11.86 to −1.32 | <0.0001 |
| | 7-day | 0.9 | −5.87–6.59 | 0.14 |
| | 14-day | 0.1 | −3.11–2.96 | 0.17 |
| | 21-day | 2.4 | −1.24–6.40 | 0.14 |
| $PM_{10}$ | Same day | −1.1 | −6.32 to −0.44 | <0.0001 |
| | 7-day | 0.20 | −0.72–1.14 | 0.12 |
| | 14-day | 1.4 | −0.08–0.13 | 0.15 |
| | 21-day | 0.7 | −0.21–0.30 | 0.12 |

Results were adjusted for: age, sex, BMI, disease group (T2DM and hypertension or TADM only), smoking history, temperature, relative humidity, and $NO_2$ as the surrogate for other airborne pollutants.

eNO, exhaled nitric oxide; $FEV_1$, forced expiratory flow in 1 second; FVC, forced vital capacity; $MMEF_{25-75}$, maximum mid-expiratory flow; PEF, peak expiratory flow; $PM_{10}$, particulate matter with aerodynamic diameter less than 10 μm; $PM_{2.5}$, particulate matter with aerodynamic diameter less than 2.5 μm.

exposure on the lung function are not very clear, the accumulated studies suggest that PM exposures result in pulmonary oxidative stress and inflammation.[33] Our finding should be interpreted with caution. Considering the associations of PM air pollution exposure, these results suggested that the effect of $PM_{10}$ was largely reflects its $PM_{2.5}$ component.

The CLNY is the most solemn and traditional celebration run from the CLNY Eve to the Lantern Festival on the 15th day of the Chinese calendar's first month.[24] We observed that daily concentrations of $PM_{2.5}$ varied dramatically, from 195.0 μg/m$^3$ on the eve of CLNY (January 30, 2014) to 8.0 μg/m$^3$ on February 6, 2014 during the 7-day CLNY legal holiday period. This phenomenon was consistent with studies about the CLNY in China. Feng et al[23] found greatly decrease in anthropogenic emissions during the CLNY period in China. The whole city almost shuts down as people travel to be with their families for the 7-day legal holiday, this ''annual human migration'' would have great impact on the air condition in Shanghai, with decreased traffic-specific exposure and declining emission from industries.[34]

We had considered many factors to address potential confounding. Dietary intake would be a confounder in the estimation of the association between PM air pollution and lung function change in T2DM participants,[35] all the participants were required to 3-day food recall questionnaire before each visit, and we had performed fasting plasma glucose (FPG) measurements at each visit, we found there were no statistically significant differences among the average FPG, which was 7.05 mmol/L at the baseline, and 6.61 mmol/L at the first follow-up, and then 6.66 mmol/L 1 month afterwards. The blood glucose information convinced that our participants had high level of awareness in healthy dietary intake through the study period,[36] herein potential nutrition confounding could be excluded. Furthermore, while hypertension and T2DM are concurrent at a great high frequency,[37] we only found the level of eNO was slightly higher in T2DM participants who concomitant with hypertension. As eNO is an established surrogate biomarker of airway inflammation,[38,39] our results suggested that participants with complex cardiometabolic disease would be more vulnerable. Consistent with previous studies in adults, short-term PM exposures were linked with eNO in both healthy and asthmatic subject.[4,40] We found 4.7 ppb reduce in eNO associated with per IQR decrease in $PM_{2.5}$ exposure on the same day of the visit with statistical significance. This supports our hypothesis that eNO would be served as biomarker of acute response to air pollution.

Our study is subjected to a number of limitations. For example, we cannot exclude bias in PM exposure level due to the exposure data were collected from fixed monitoring sites, rather than personal exposure data. In addition, our findings are limited to elderly T2DM outpatients who were residing in Shanghai, as we known, community hospitals in Shanghai are the most efficient in providing the primary healthcare service, which limits generalization to the T2DM patients who have difficulty to access sufficient health service. This study has several strengths, including its repeated measure design among local residents in community hospital, which provided more reliable and more precise information about the individual risks factors. Furthermore, each participant acted as his/her own control is more efficient for studying health effects of short-term PM air pollutant, especially in relatively small sample.

## CONCLUSION

In conclusion, our study supports the hypothesis that improvement of air quality was associated with increased lung function in elderly with T2DM. With growing diabetes population and severe PM air pollution in China, there is increasing needs for risk assessments on vulnerable subpopulation. Moreover, additional studies are also needed to investigate the specific component which reflected the toxicity of PM. Our study advocates rigorous restrictions on bursting firecrackers on the grounds that they aggravate air pollution and pose a threat on human health.

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