SUPPLEMENTARY INFORMATION

Seasonal effect of $PM_{2.5}$ exposures in patients with COPD: a multicentre panel study

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Text S1. Inclusion and exclusion crtieria of the study

PATIENT INCLUSION CRITERIA

i) ≥ 40 years of age,

ii) Post-bronchodilator forced expiratory volume in one second (FEV_1)/forced vital capacity < 0.7

iii) Predicted FEV_1 < 80%

iv) Diagnosis of COPD by the attending physician

PATIENT EXCLUSION CRITERIA

i) Absence of respiratory symptoms

ii) Inability to understand the questionnaires and instructions for air sampler devices

Table S1. Seasonal indoor/outdoor ratio of $PM_{2.5}$.

	I/O ratio	*P*
Season		<0.001
Spring	0.918	
Summer	1.112	
Fall	1.059	
Winter	0.837	
Location		0.048
Seoul	0.850	
Gangneung	1.046	
Inchon	1.249	
Ulsan	0.903	
Income		0.036
High	0.856	
Low	1.031	
Economic status		0.009
High	0.756	
Low	0.951	
Level of education		0.006
High	0.812	
Low	0.975	

Abbreviations: I/O, indoor/outdoor ratio; $PM_{2.5}$, particulate matter with aerodynamic size ≤ 2.5 μm

Table S2. Analysis of association between patient characteristics and indoor PM2.5 concentrations using a mixed-effect model.

	Gradient	95% Confidence Interval		*P*
Age	0.212	0.002	0.422	0.050
Male	-1.030	-6.559	4.499	0.716
Smoking status				
Never smoker	-	-	-	-
Former smoker	-2.315	-6.494	1.869	0.283
Current smoker	0.269	-4.853	5.266	0.917
Monthly household income, USD				
< $875	-	-	-	-
$875 – $1750	-6.269	-10.437	-2.1200	0.005
$1750 – $3500	-6.471	-10.600	-2.342	0.003
$3500 – $5250	-6.125	-11.964	-0.287	0.046
$5250 <	-6.645	-12.751	-0.539	0.039
Education				
≤ Middle school graduation	-	-	-	-
High school graduation	-2.267	-5.916	1.399	0.234
College graduation	-2.115	-6.047	2.288	0.334
Post-graduate education	-5.763	-10.989	-0.138	0.042
Economic status				
Low	-	-	-	-
Slightly below average	-1.732	-6.687	3.298	0.512
Average	-4.063	-8.959	0.812	0.113
Slightly above average	-5.321	-11.782	1.235	0.118
High	-8.257	-16.252	0.524	0.057
Seasons				
Spring	-	-	-	-
Summer	-1.749	-2.904	-0.593	0.003
Fall	-3.739	-4.887	-2.591	<0.001
Winter	-1.226	-2.389	-0.064	0.040

Abbreviations: USD, United States dollar

Table S3. Analysis of association between patient characteristics and outdoor $PM_{2.5}$ concentrations using mixed-effect model.

	Gradient	95% Confidence Interval		*P*
Age	0.030	-0.017	0.100	0.168
Male	-0.366	-1.9312	1.558	0.640
Smoking status				
Never smoker	-	-	-	-
Former smoker	-0.390	-1.550	0.797	0.515
Current smoker	-0.651	-2.082	0.828	0.379
Monthly household income, USD				
< $875	-	-	-	-
$875 – $1750	-2.332	-3.568	-1.115	<0.001
$1750 – $3500	-1.407	-2.600	-0.211	0.022
$3500 – $5250	-1.282	-2.958	0.374	0.134
$5250 <	-1.466	-3.178	0.282	0.099
Education				
≤ Middle school graduation	-	-	-	-
High school graduation	-0.995	-2.038	0.058	0.064
College graduation	-0.290	-1.493	0.943	0.641
Post-graduate education	-0.377	-1.884	1.154	0.627
Economic status				
Low	-	-	-	-
Slightly below average	-1.335	-2.827	0.178	0.083
Average	-1.856	-3.262	-0.433	0.011
Slightly above average	-1.721	-3.591	0.176	0.075
High	-1.049	-3.415	1.379	0.392
Seasons				
Spring	-	-	-	-
Summer	-4.384	-5.249	-3.519	<0.001
Fall	-6.862	-7.719	-6.003	<0.001
Winter	-1.071	-1.935	-0.207	0.016

Abbreviations: USD, United States dollar

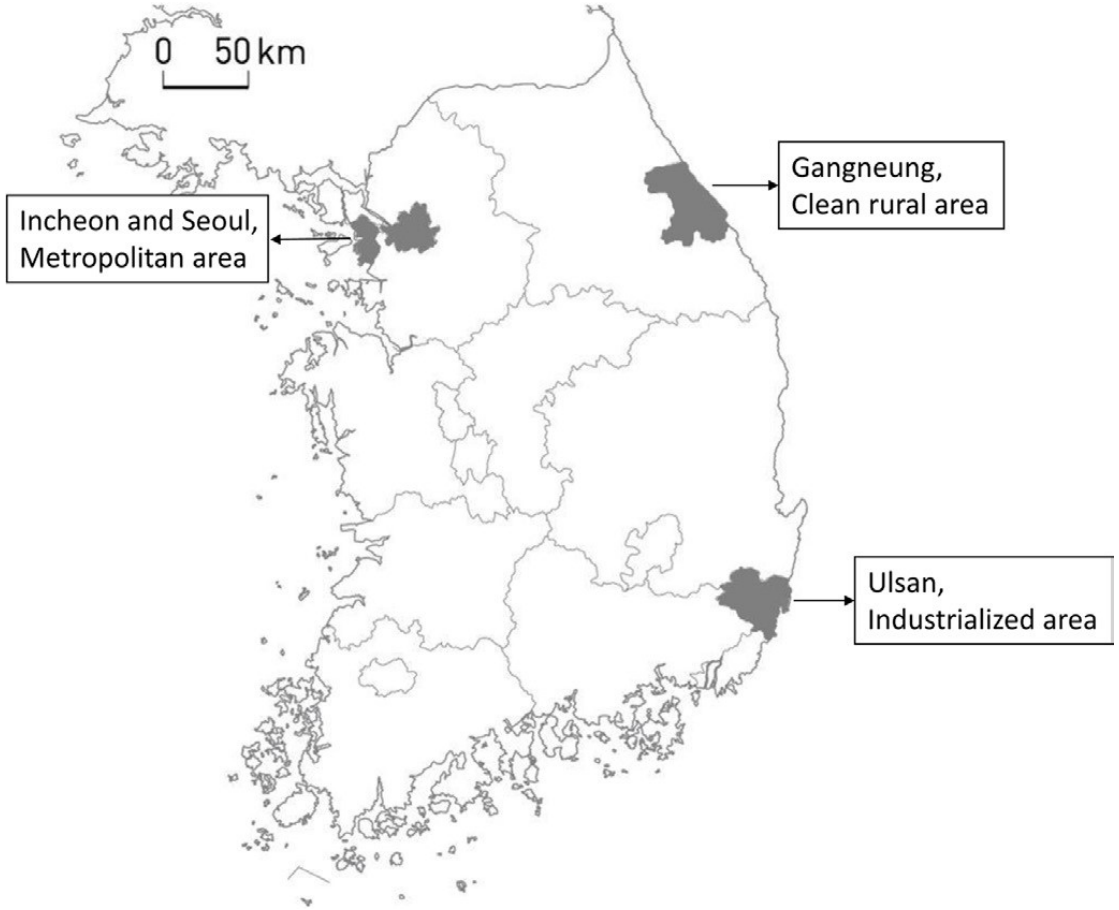

Fig. S1. Location of hospitals that participated in this study[1]

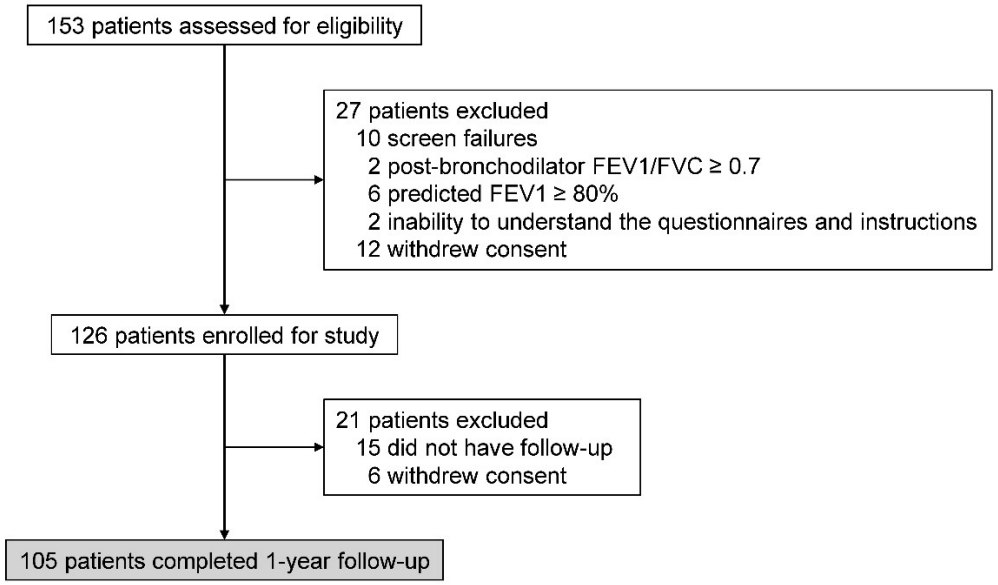

Fig. S2. Flow chart of the study.

Abbreviations: FEV_1, forced expiratory volume in one second; FVC, forced vital capacity.

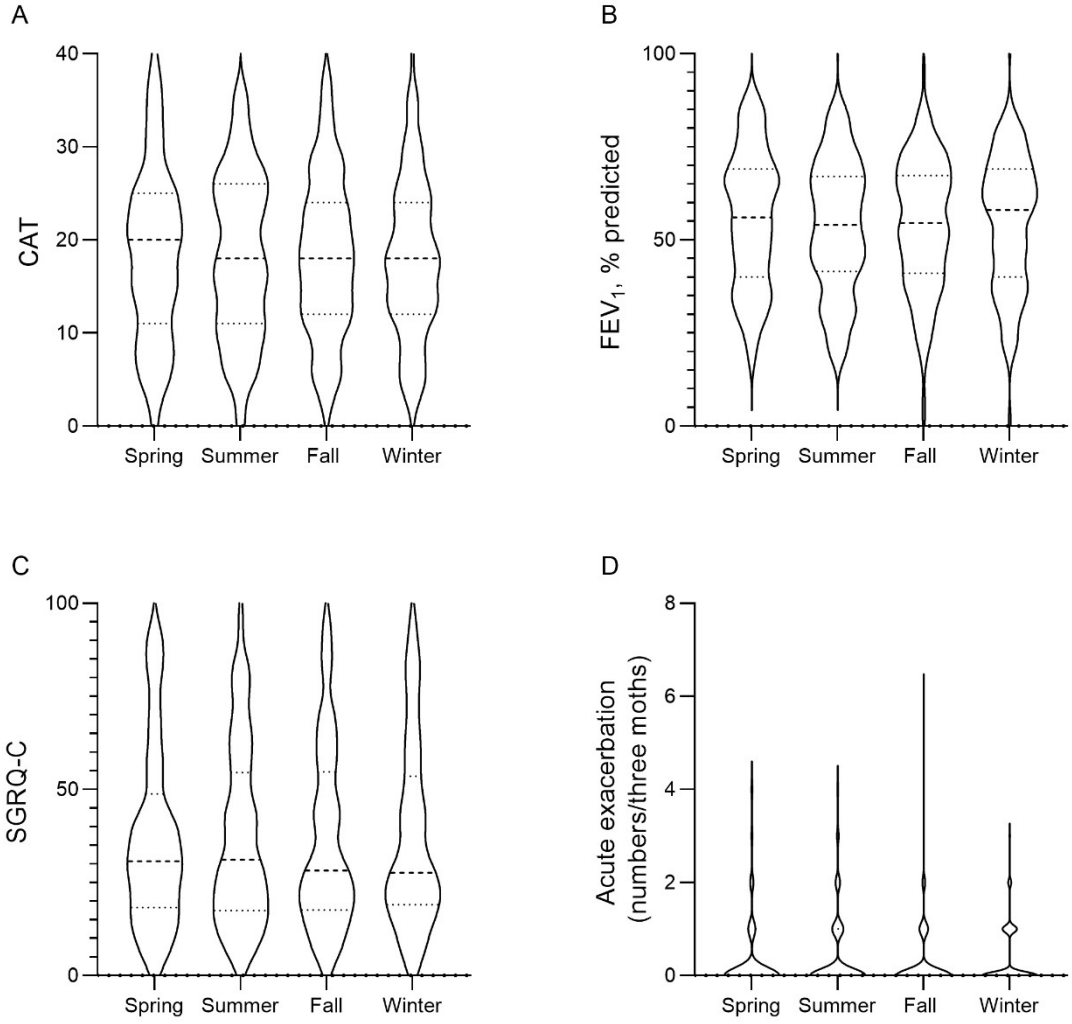

Fig. S3. Clinical outcomes in each season of the year.

The curves represent the probability density of the data at different values. The bold dotted line inside the curves illustrates the median, whereas paler dotted lines below and above the bold line are the first interquartile and the third interquartile range. (A) Mean of CAT scores. (B) FEV_1, % prediction. (C) SGRQ-C scores. (D) Total number of acute exacerbations in the three months of each season.

Abbreviations: CAT, COPD assessment test; FEV_1, forced expiratory volume in one second; SGRQ-C, Saint George's Respiratory Questionnaire for COPD

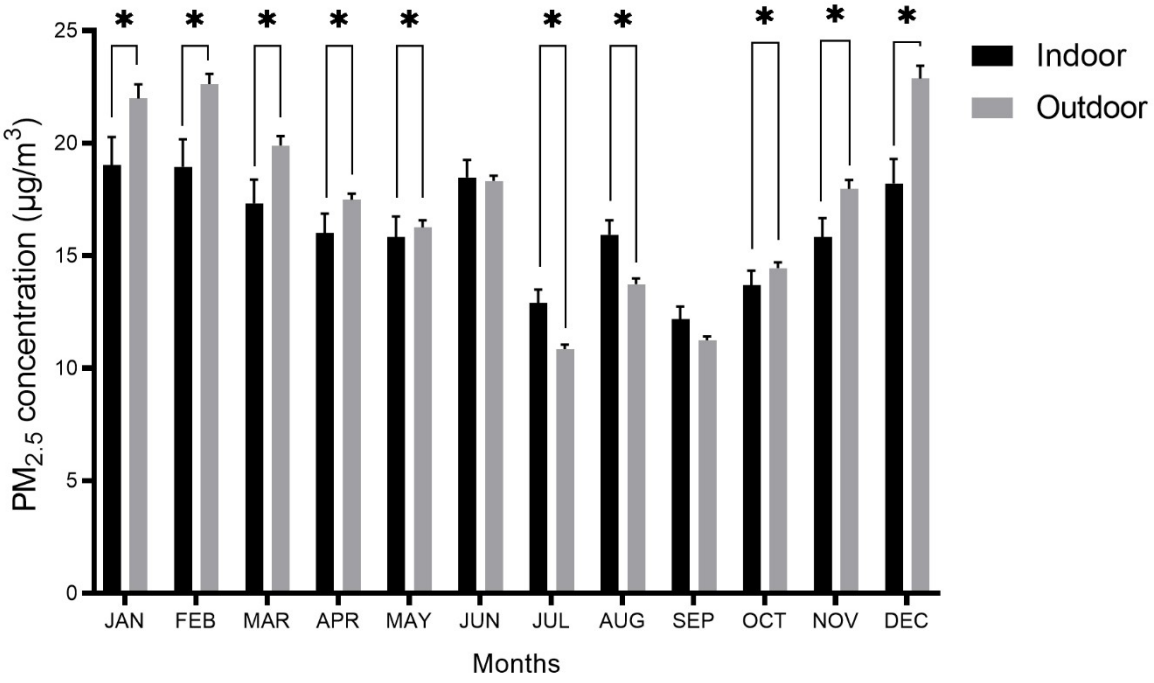

Fig. S4. Monthly mean concentration of $PM_{2.5}$ during the follow-up period. Asterisks represent statistical significance of $P < 0.05$.

Abbreviations: $PM_{2.5}$, particulate matter with aerodynamic size ≤ 2.5 μm

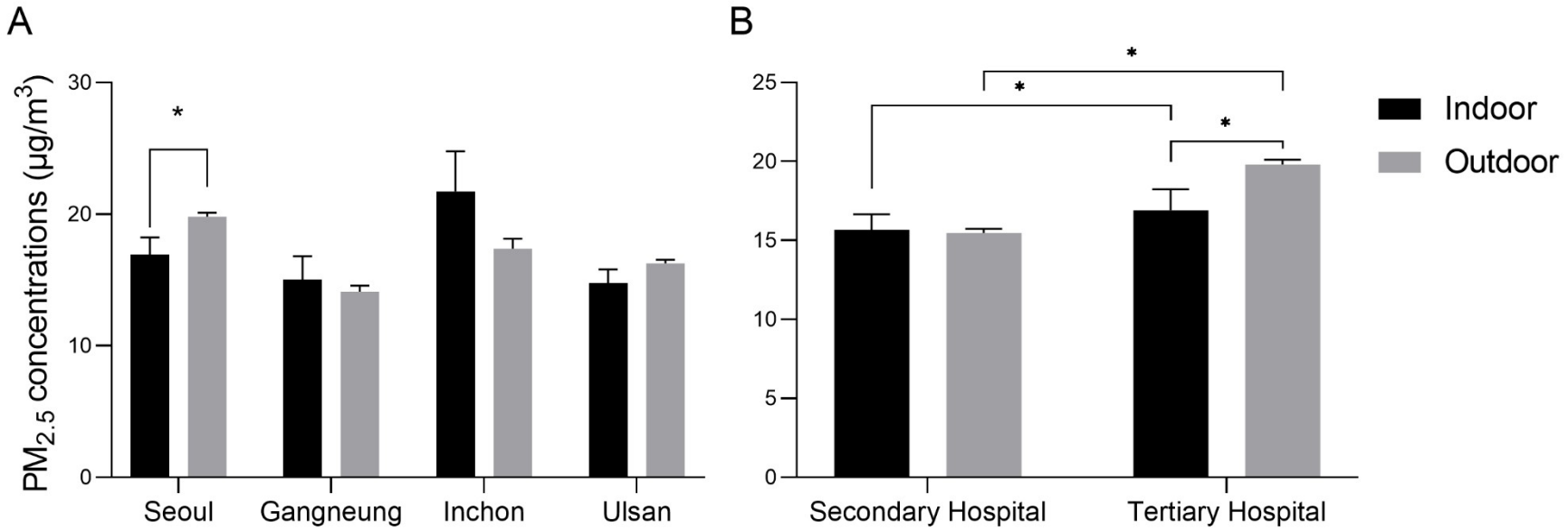

Fig. S5. Mean $PM_{2.5}$ in different locations.

(A) Mean individual $PM_{2.5}$ concentrations according to the location of the institution of each enrolled patient. (B) Mean individual $PM_{2.5}$ concentrations according to the referral status of the enrolled institution.

Asterisks represent statistical significance of $P < 0.05$.

Abbreviations: $PM_{2.5}$, particulate matter with aerodynamic size ≤ 2.5 μm

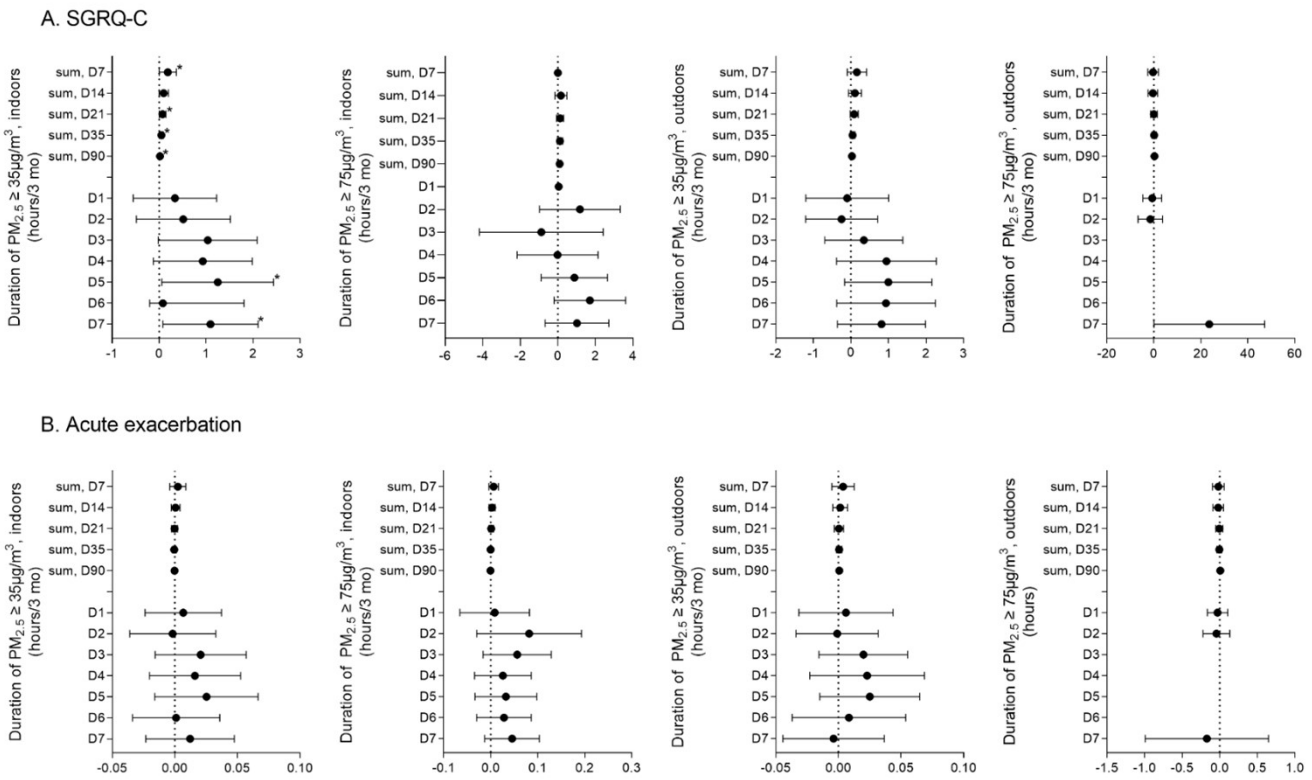

Fig. S6. Changes in SGRQ-C and acute exacerbations according to $PM_{2.5}$ concentrations, during spring.

The black circles represent the correlation between SGRQ-C score or number of acute exacerbations and PM2.5 concentrations. The x-axis illustrates the linear regression coefficients. The y-axis displays the $PM_{2.5}$ concentrations of each day or sum of $PM_{2.5}$ concentrations during the days before clinical evaluation. (A) $PM_{2.5}$ and SGRQ-C. (B) $PM_{2.5}$ and numbers of acute exacerbation in three months.

Asterisks represent statistical significance of $P < 0.05$.

Abbreviations: $PM_{2.5}$, particulate matter with aerodynamic size ≤ 2.5 μm; SGRQ-C, Saint George's Respiratory Questionnaire for COPD

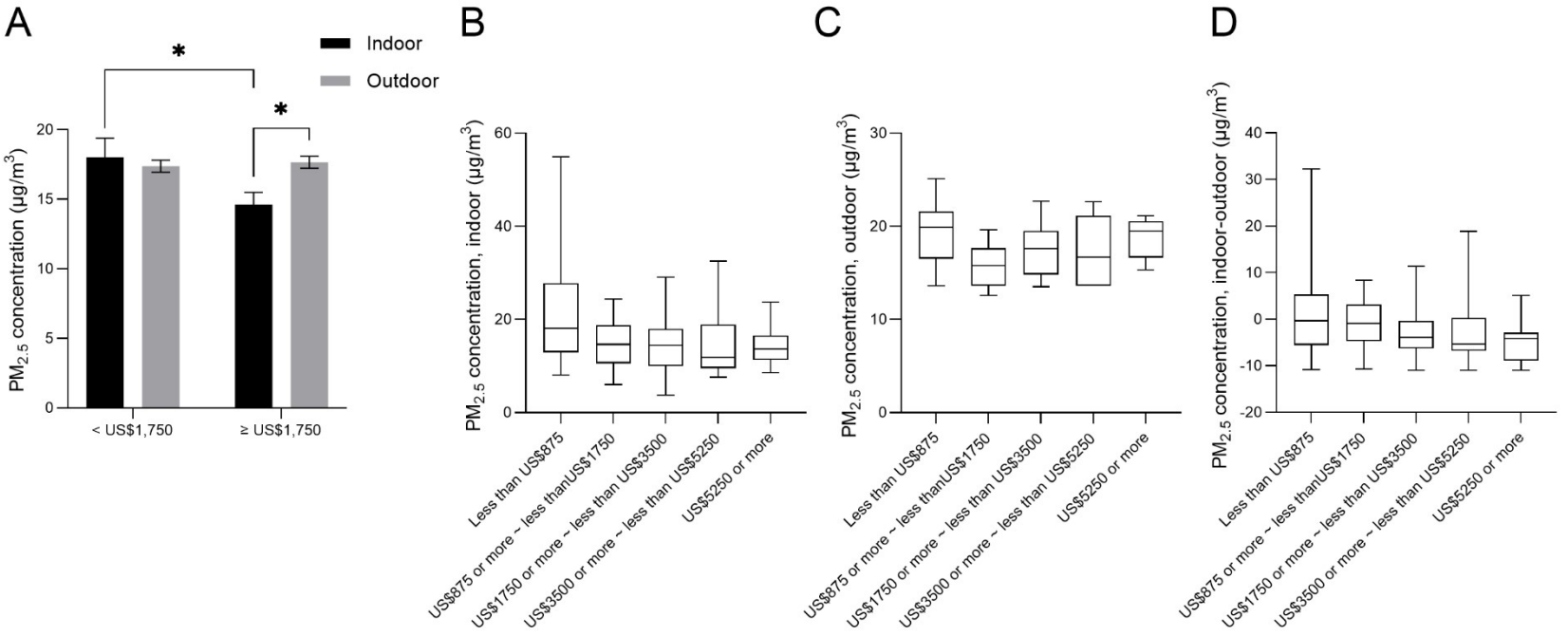

Fig. S7. Indoor and outdoor $PM_{2.5}$ concentrations in relation to participants' income status.

Participants were allocated to the low-income group if their monthly income was less than $1,750 USD.

(A) Mean individual ambient $PM_{2.5}$ concentrations of high-, and low- income groups. (B) Indoor $PM_{2.5}$ concentrations among different income groups. (C) Outdoor $PM_{2.5}$ concentrations among different income groups. (D) Difference from indoor $PM_{2.5}$ concentration to outdoor $PM_{2.5}$ concentration among different income groups.

Asterisks represent statistical significance of $P < 0.05$.

Abbreviations: $PM_{2.5}$, particulate matter with aerodynamic size ≤ 2.5 μm; USD, United States dollar

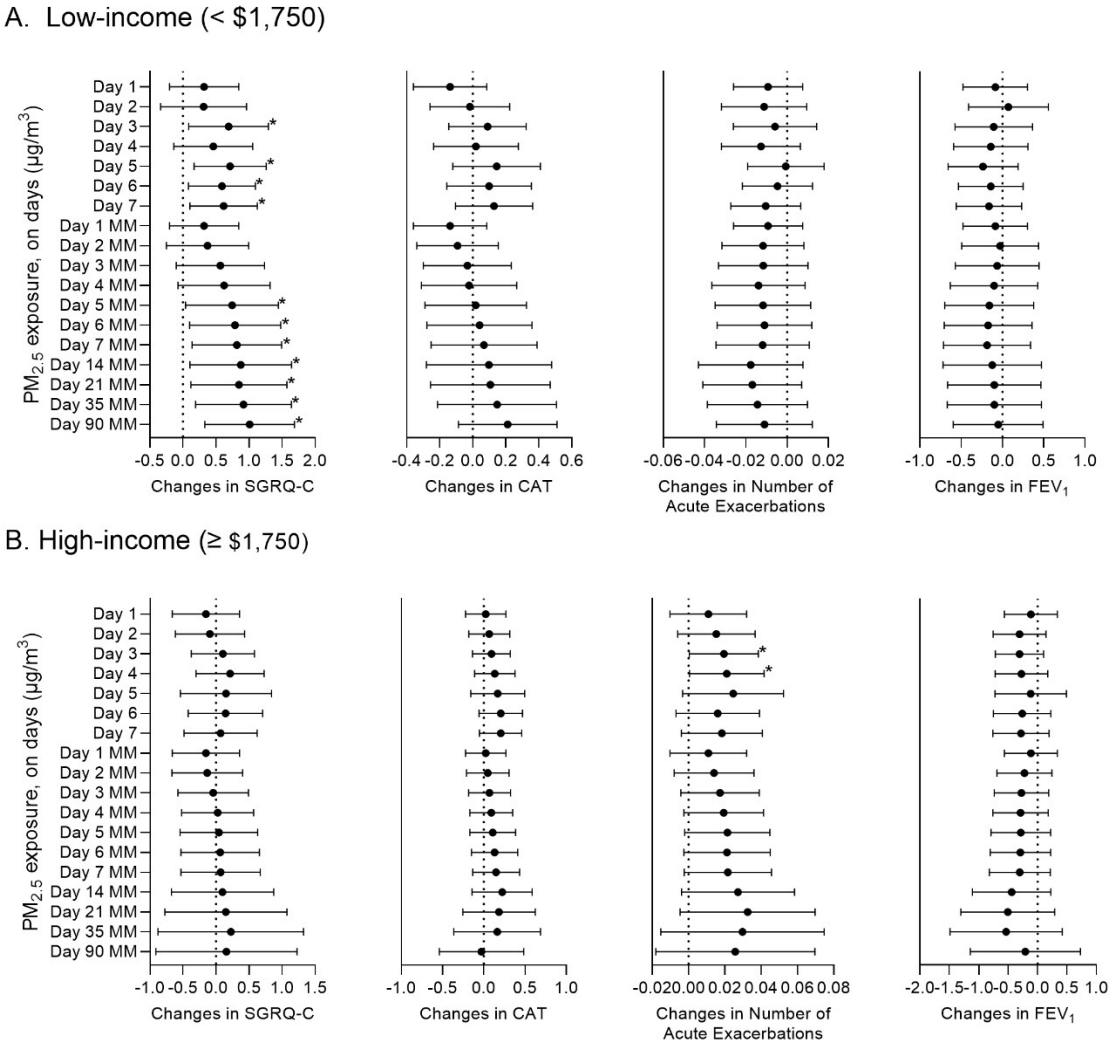

Fig. S8. Relationship between clinical outcomes and $PM_{2.5}$ concentrations according to income groups in spring.

(A) Changes of clinical parameters in low-income group. (B) Changes in clinical parameters in high-income group.

Asterisks represent statistical significance of $P < 0.05$.

Abbreviations: $PM_{2.5}$, particulate matter with aerodynamic size ≤ 2.5 μm; MM, moving mean

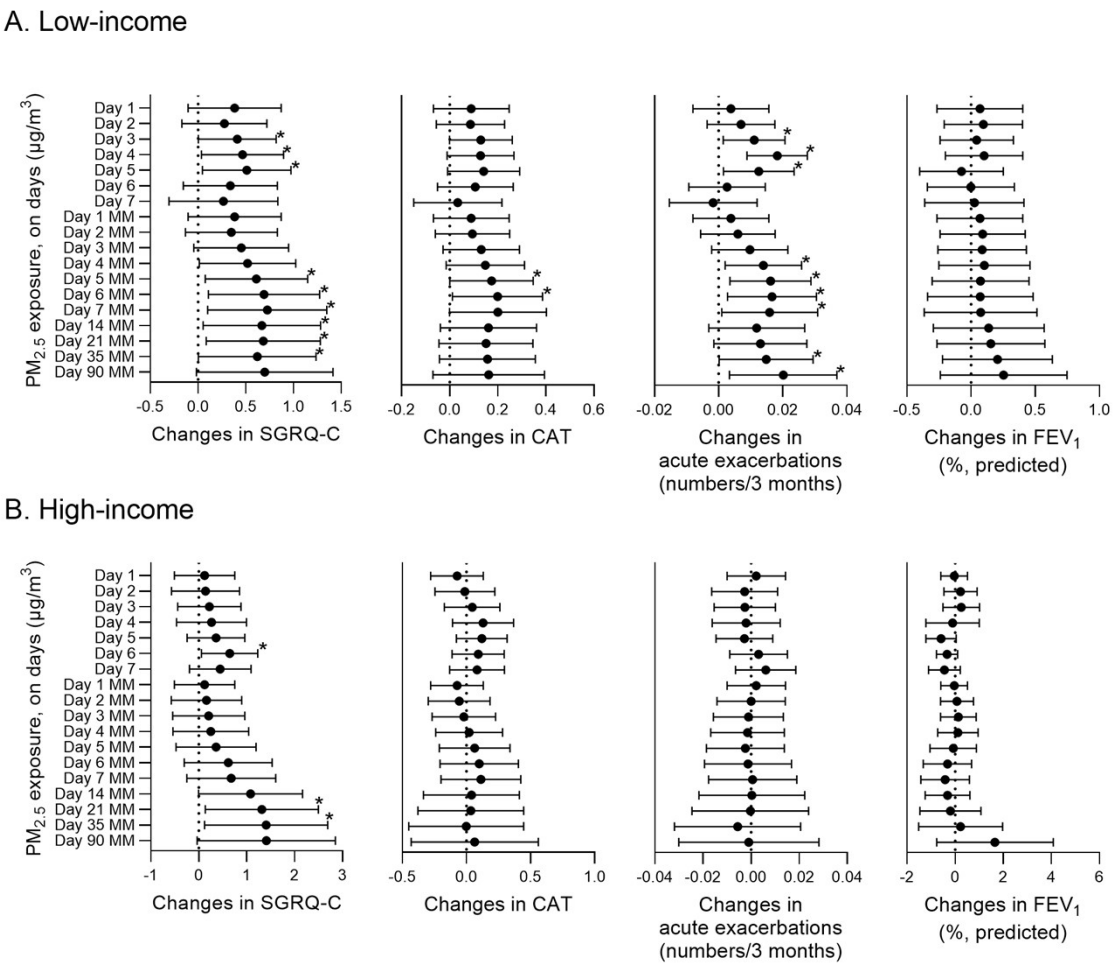

Fig. S9. Relationship between clinical outcomes and $PM_{2.5}$ concentrations according to income groups in winter.

(A) Changes of clinical parameters in the low-income group. (B) Changes in clinical parameters in the high-income group. Asterisks represent statistical significance of $P < 0.05$.

Abbreviations: $PM_{2.5}$, particulate matter with aerodynamic size ≤ 2.5 μm; MM, moving mean

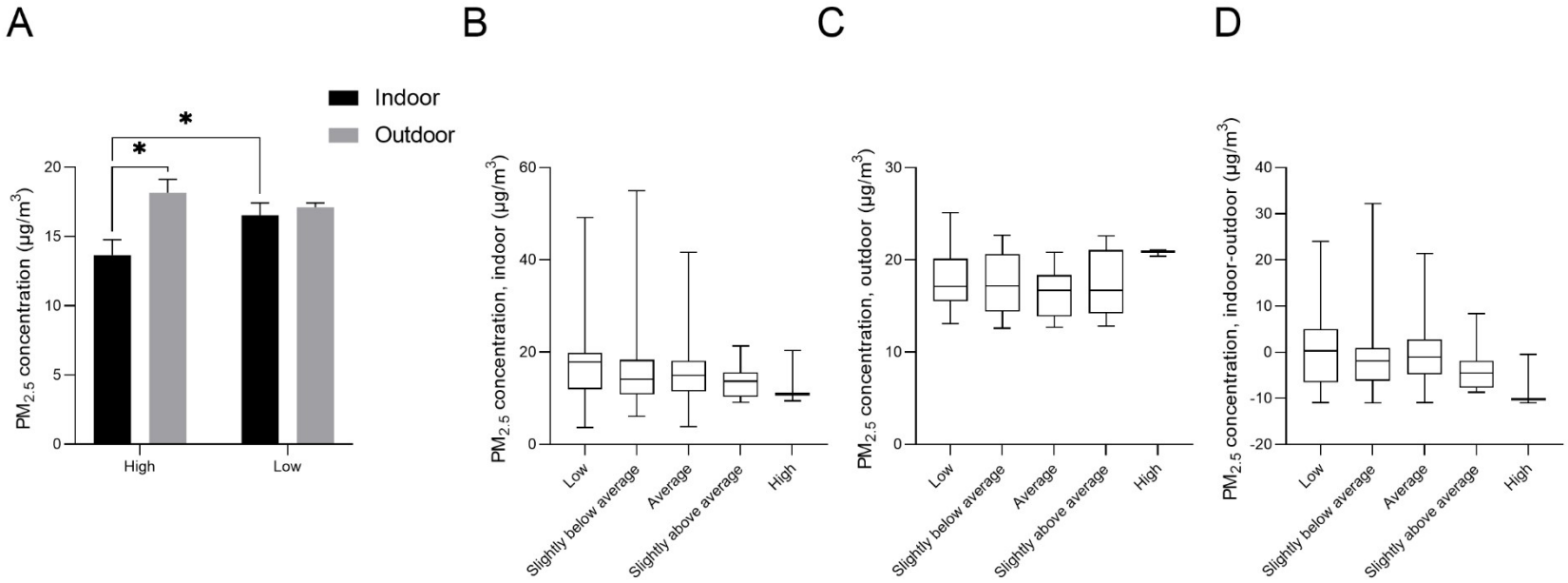

Fig. S10. Indoor and outdoor $PM_{2.5}$ concentrations in relation to participants' economic status groups.

Participants were allocated to the high-economic status group if they answered their economic status to be high or very high in the questionnaire.

(A) Mean individual ambient $PM_{2.5}$ concentrations of high-, and low- economic status groups. (B) Boxplot of indoor $PM_{2.5}$ concentrations among different economic status groups. (C) Boxplot of outdoor $PM_{2.5}$ concentrations among different economic status groups. (D) Difference from indoor $PM_{2.5}$ concentration to outdoor $PM_{2.5}$ concentration among different economic status groups.

Asterisks represent statistical significance of $P < 0.05$.

Abbreviations: $PM_{2.5}$, particulate matter with aerodynamic size ≤ 2.5 μm

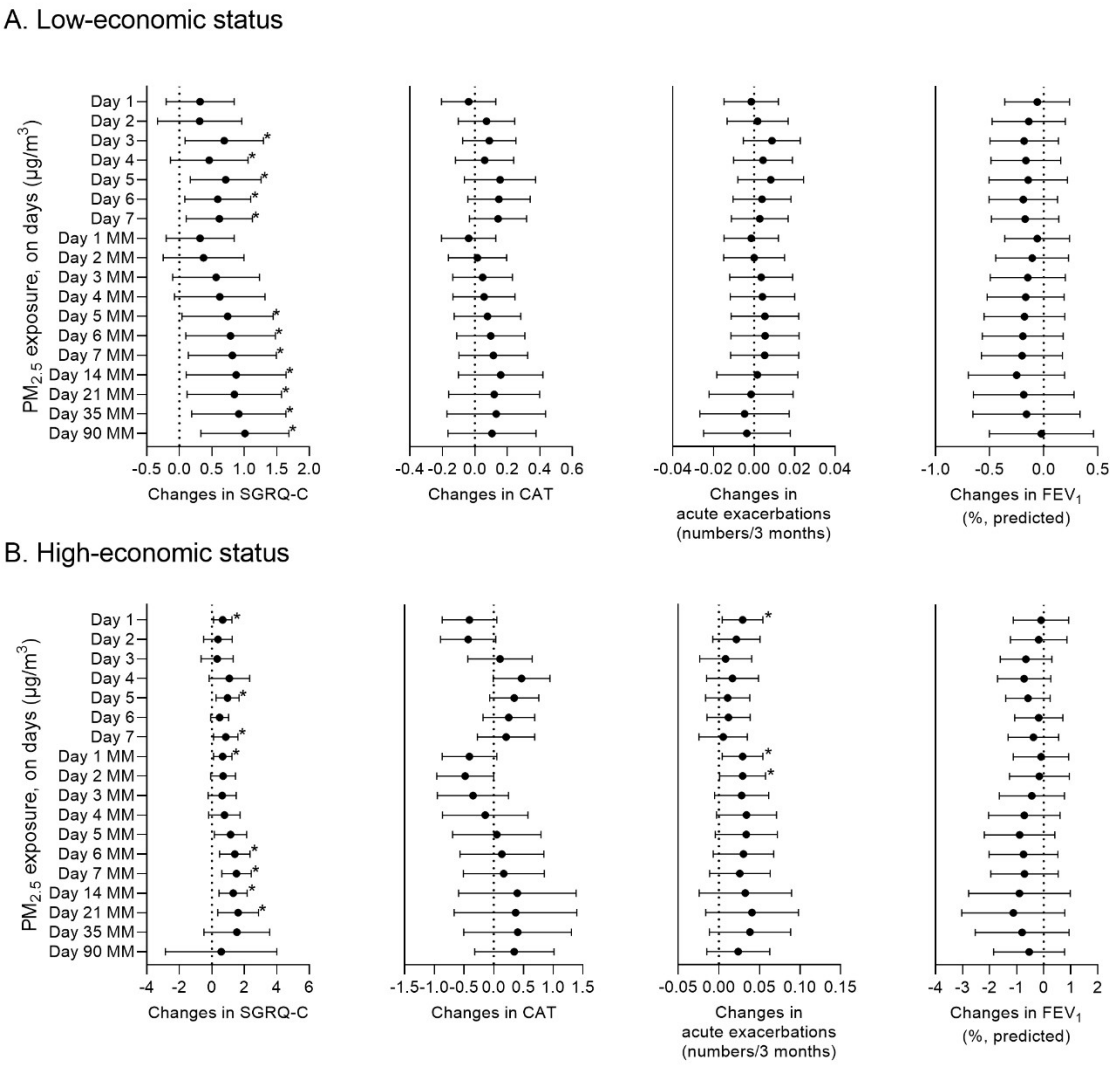

Fig. S11. Relationship between clinical outcomes and $PM_{2.5}$ concentrations according to economic status groups in spring.

(A) Changes of clinical parameters in the low-economic status group. (B) Changes in clinical parameters in the high-economic status group.

Asterisks represent statistical significance of $P < 0.05$.

Abbreviations: $PM_{2.5}$, particulate matter with aerodynamic size ≤ 2.5 μm; MM, moving mean

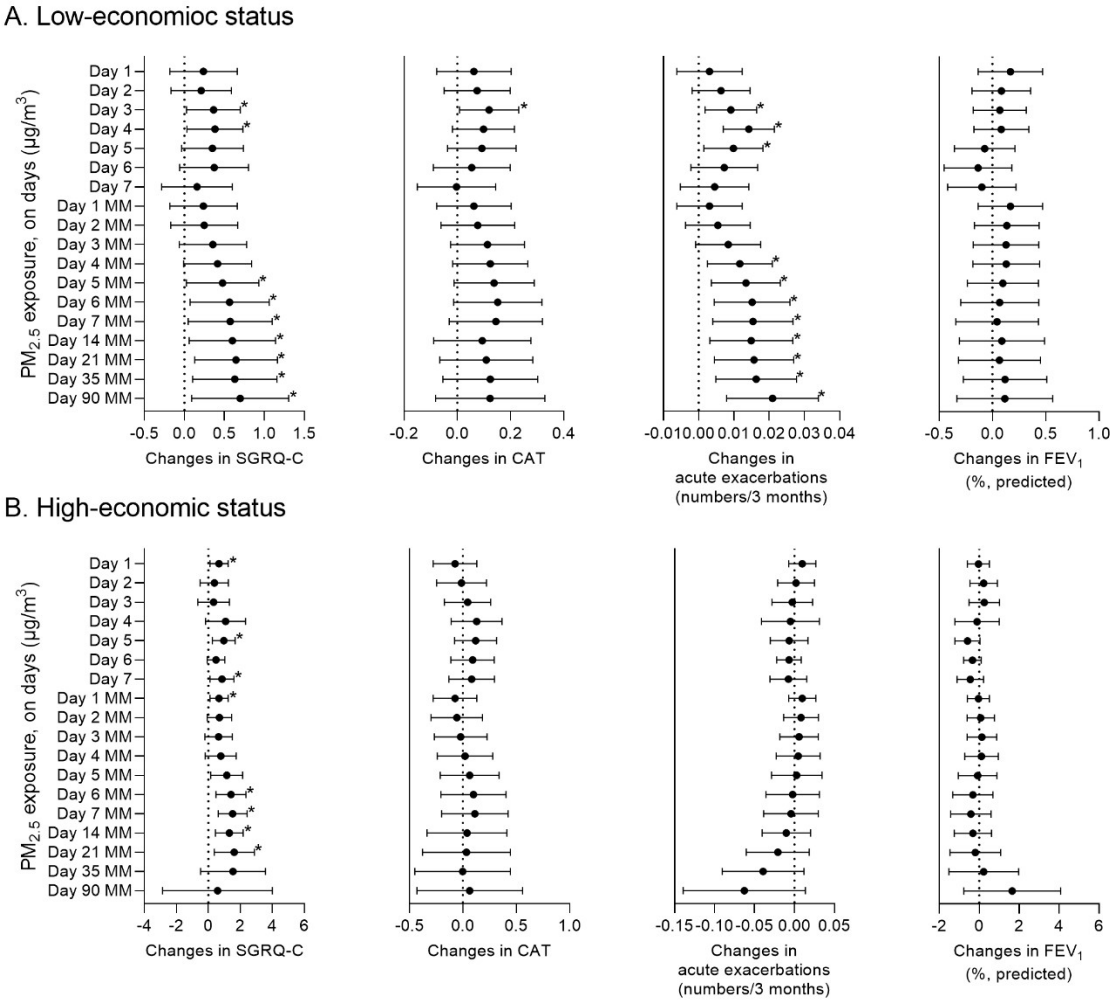

Fig. S12. Relationship between clinical outcomes and $PM_{2.5}$ concentrations according to economic status groups in winter.

(A) Changes of clinical parameters in the low-economic status group. (B) Changes in clinical parameters in the high-economic status group.

Asterisks represent statistical significance of $P < 0.05$.

Abbreviations: $PM_{2.5}$, particulate matter with aerodynamic size ≤ 2.5 μm; MM, moving mean

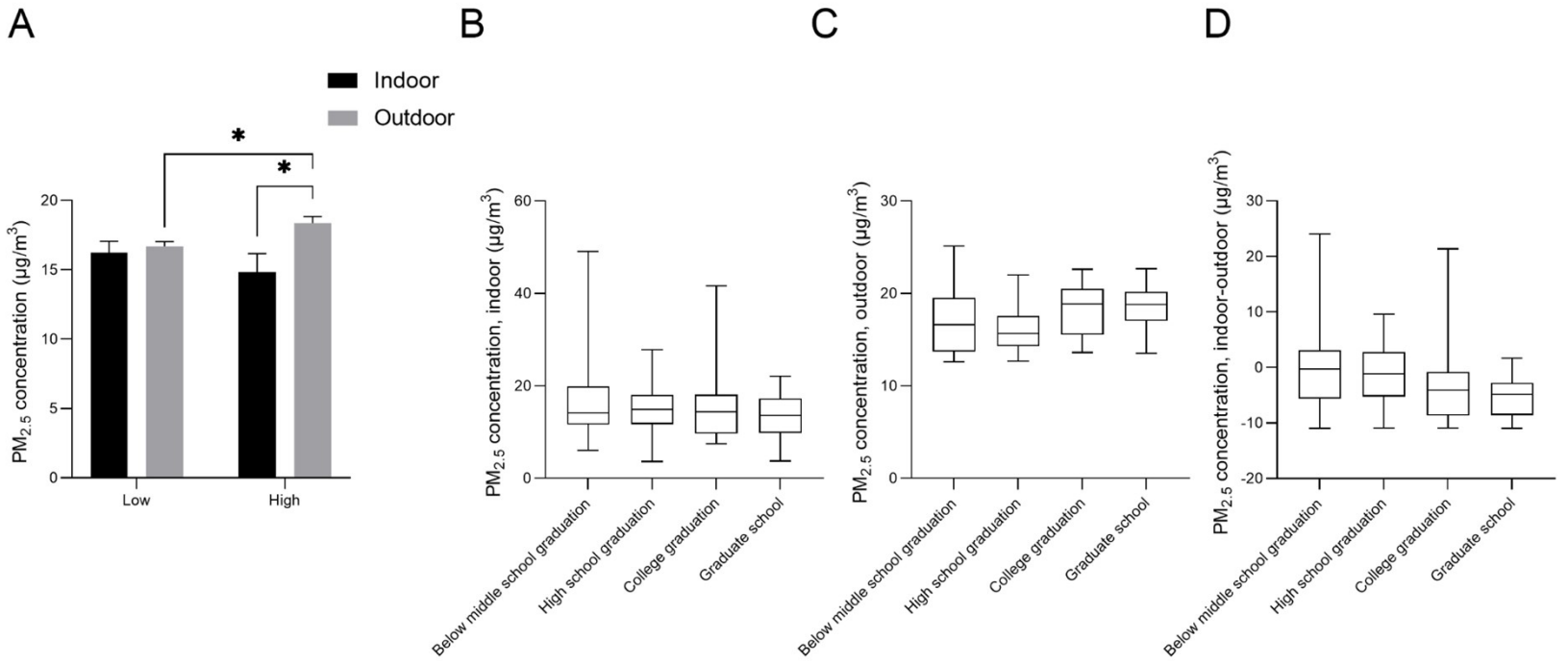

Fig. S13. Indoor and outdoor $PM_{2.5}$ concentrations in relation to participants' educational status groups.

Participants were allocated to the high-education group if they graduated college or had any higher education.

(A) Mean individual ambient $PM_{2.5}$ concentrations of high-, and low- educational achievement groups. (B) Boxplot of indoor $PM_{2.5}$ concentrations among different education groups. (C) Boxplot of outdoor $PM_{2.5}$ concentrations among different education groups. (D) Difference from indoor $PM_{2.5}$ concentration to outdoor $PM_{2.5}$ concentration among different education groups.

Asterisks represent statistical significance of $P < 0.05$.

Abbreviations: $PM_{2.5}$, particulate matter with aerodynamic size ≤ 2.5 μm

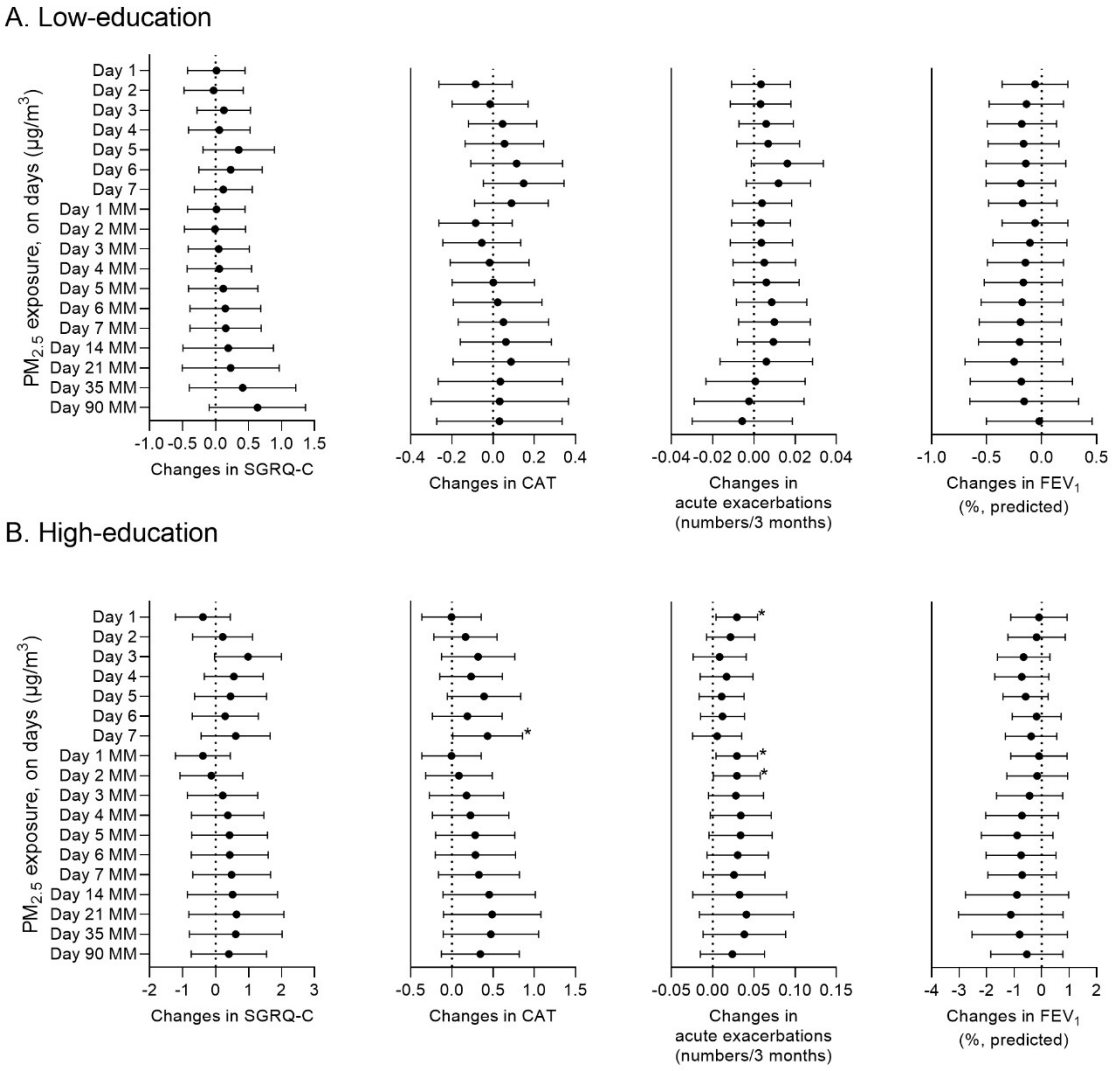

Fig. S14. Relationship between clinical outcomes and $PM_{2.5}$ concentrations according to educational status groups in spring.

(A) Changes of clinical parameters in the low-educational achievement group. (B) Changes in clinical parameters in the high-educational achievement group.

Asterisks represent statistical significance of $P < 0.05$.

Abbreviations: $PM_{2.5}$, particulate matter with aerodynamic size ≤ 2.5 μm; MM, moving mean

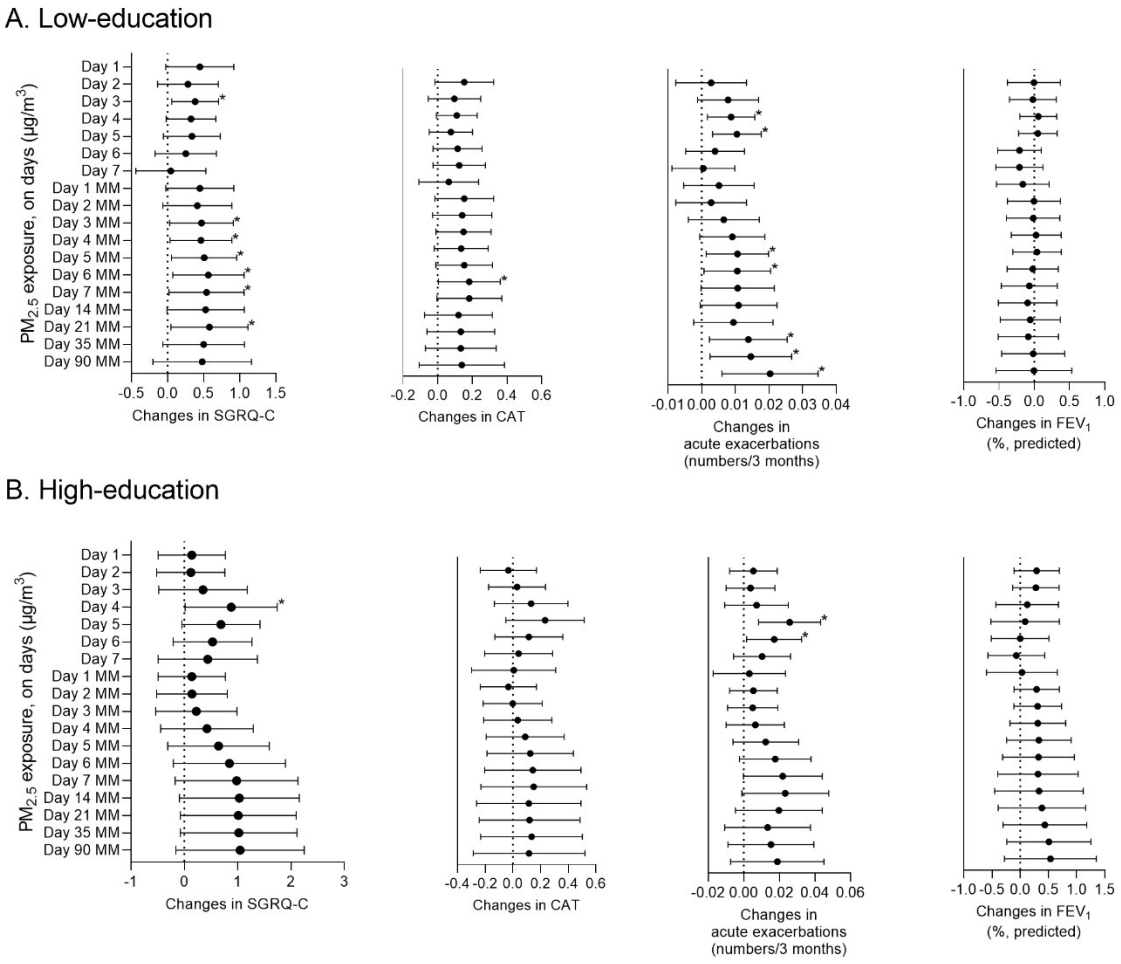

Fig. S15. Relationship between clinical outcomes and $PM_{2.5}$ concentrations according to educational status groups in winter.

(A) Changes of clinical parameters in the low-educational achievement group. (B) Changes in clinical parameters in the high-educational achievement group.

Asterisks represent statistical significance of $P < 0.05$.

Abbreviations: $PM_{2.5}$, particulate matter with aerodynamic size ≤ 2.5 μm; MM moving mean

1. S. Park, S. W. Ra, S. Y. Kang, H. C. Kim and S. W. Lee, Effect of particulate matter exposure on patients with COPD and risk reduction through behavioural interventions: the protocol of a prospective panel study, *BMJ Open*, 2020, **10**, e039394.