Lung function and air pollution exposure in adults with asthma in Beijing: a 2-year longitudinal panel study

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Methods

Validation of exposure assessment

We validated the use of inverse distance weighting (IDW) method in exposure assessment. For each of the 35 air quality monitoring stations in Beijing, China, we applied the IDW method using data of the nearest four, five, six monitors respectively to predict concentration of each monitoring station, and finally four monitors presented optimal validity. Deciles of each pollutant was chosen as samples to predict accuracy, by which was assessed calculating coefficient of determination (R^2), mean absolute error (MAE) and bias between predicted and measured concentrations using the following equations.

$$R^2 = 1 - (\sum\nolimits_{i=1}^{N} (M_i - P_i)^2) / (\sum\nolimits_{i=1}^{N} (M_i - \underline{M_i})^2)$$

$$MAE = (\sum\nolimits_{i=1}^{N} |P_i - M_i|) / N$$

$$Bias = \sum\nolimits_{i=1}^{N} (P_i - M_i) / N$$

Where M = measured concentration; $\underline{M_i}$ = mean of measured concentrations; P = predicted concentration

Table S1. Lung function of each visit during the observation period (Mean ± SD) (%)

Visit		FEV_1 (%Pred)	FVC (%Pred)	FEV_1/FVC (%)	FEF_{50} (%Pred)	FEF_{75} (%Pred)	FEF_{25-75} (%Pred)
V1 n=60	pre	79.73±17.06	98.09±13.92	67.32±11.55	49.81±23.83	34.44±19.23	45.54±22.11
	post	85.20±17.26	100.08±12.56	70.68±12.28	58.89±28.54	44.72±28.89	56.58±28.96
V2 n=104	pre	78.04±16.90	97.72±14.49	66.43±11.40	46.35±23.19	33.56±19.16	43.80±22.39
	post	84.51±14.85	100.86±13.38	70.01±11.08	54.89±24.72	42.19±24.22	52.81±24.63
V3 n=106	pre	77.53±16.84	97.37±13.90	66.09±10.91	45.22±21.73	33.25±18.57	42.88±20.46
	post	83.76±15.00	99.50±13.31	70.06±11.23	54.25±24.44	42.71±23.47	52.42±24.03
V4 n=103	pre	77.54±16.23	97.17±13.86	66.22±10.65	45.53±21.63	33.10±18.06	43.20±20.92
	post	84.59±15.03	100.03±13.50	70.50±10.76	57.02±25.67	42.97±23.99	53.77±25.08
V5 n=100	pre	78.64±17.06	97.35±14.50	66.86±10.85	47.41±22.63	34.53±19.02	44.40±21.64
	post	85.28±15.09	99.96±13.24	70.94±10.68	56.82±24.46	43.62±23.26	54.62±24.01
V6 n=89	pre	79.05±17.24	98.17±14.67	66.67±10.83	47.15±22.43	33.93±18.50	44.04±21.30
	post	85.31±16.17	100.23±14.30	70.86±11.34	57.32±25.23	43.78±23.31	54.83±24.10

V7 n=87	pre	79.09±15.74	97.76±14.03	67.20±9.80	46.77±20.59	34.84±18.48	44.50±20.19
	post	85.75±14.42	99.97±13.82	71.60±10.07	57.87±24.31	44.10±24.34	55.08±24.16
V8 n=88	pre	77.94±16.91	96.58±14.37	66.80±10.84	46.63±21.84	34.64±19.53	44.01±20.99
	post	84.65±15.36	99.17±13.60	71.01±10.84	56.58±24.09	44.17±23.67	54.42±24.82
V9 n=90	pre	78.74±15.06	97.34±13.55	67.20±9.78	46.41±19.06	33.64±17.43	43.87±19.27
	post	84.59±14.77	99.21±13.83	70.99±9.87	55.77±22.81	42.60±21.52	53.53±22.89

Abbreviations: SD: standard deviation; Other Abbreviations: see Table 2.

Table S2. The association of lung function and air pollution in all subjects

		change per unit(95%CI)					
		CO	NO$_2$	O$_3$	PM$_{10}$	PM$_{2.5}$	SO$_2$
FEF$_{25\text{-}75}$	pre	-1.09 (-2.96,0.78)	-0.03 (-0.10,0.03)	0.01 (0.00,0.02)	0.01 (-0.01,0.04)	0.00 (-0.04,0.03)	-0.08 (-0.21,0.06)
	post	-0.91 (-2.98,1.16)	-0.03 (-0.10,0.04)	0.01 (-0.01,0.02)	0.01 (-0.02,0.03)	-0.01 (-0.05,0.03)	-0.09 (-0.24,0.06)
FEF$_{50}$	pre	-1.81 (-3.77,0.16)	-0.05 (-0.12,0.02)	0.01* (0.00,0.03)	0.01 (-0.01,0.04)	-0.01 (-0.04,0.03)	-0.08 (-0.22,0.06)
	post	-1.42 (-3.53,0.69)	-0.03 (-0.11,0.04)	0.01 (0.00,0.03)	0.01 (-0.02,0.04)	-0.01 (-0.05,0.03)	-0.10 (-0.25,0.05)
FEF$_{75}$	pre	-1.18 (-3.00,0.63)	-0.05 (-0.11,0.02)	0.00 (-0.01,0.02)	0.01 (-0.02,0.03)	-0.01 (-0.04,0.02)	-0.08 (-0.21,0.05)
	post	0.07 (-2.32,2.46)	0.00 (-0.08,0.09)	0.00 (-0.01,0.02)	0.02 (-0.01,0.05)	0.00 (-0.04,0.05)	-0.07 (-0.24,0.10)
FEV$_1$	pre	-2.04** (-3.50,-0.58)	-0.05 (-0.10,0.01)	0.01 (0.00,0.02)	-0.01 (-0.03,0.01)	-0.03* (-0.05,0.00)	-0.07 (-0.18,0.03)
	post	-1.38* (-2.74,-0.01)	-0.02 (-0.07,0.03)	0.00 (-0.01,0.01)	-0.01 (-0.03,0.01)	-0.02 (-0.05,0.00)	-0.07 (-0.17,0.03)
FVC	pre	-1.89** (-3.09,-0.68)	-0.04 (-0.08,0.01)	0.01 (0.00,0.01)	-0.01 (-0.03,0.00)	-0.03* (-0.05,0.00)	-0.06 (-0.14,0.03)
	post	-1.33* (-2.41,-0.25)	-0.02 (-0.06,0.02)	0.00 (-0.01,0.01)	-0.01 (-0.03,0.00)	-0.02 (-0.04,0.00)	-0.05 (-0.13,0.03)
FEV$_1$/FVC	pre	-0.41 (-1.26,0.43)	-0.01 (-0.04,0.02)	0.00 (-0.01,0.01)	0.00 (-0.01,0.02)	0.00 (-0.02,0.01)	-0.01 (-0.07,0.05)
	post	-0.17 (-0.97,0.63)	0.00 (-0.03,0.03)	0.00 (-0.01,0.00)	0.00 (-0.01,0.01)	0.00 (-0.02,0.01)	-0.01 (-0.07,0.04)

Abbreviations: CI: confidence interval; Other Abbreviations: see Table 2. Notes: *P＜0.05; **P＜0.01.

Table S3. The association of lung function and air pollution in severe group

		change per unit(95%CI)					
		CO	NO_2	O_3	PM_{10}	$PM_{2.5}$	SO_2
FEF_{25-75}	pre	_	-0.09* (-0.17,-0.01)	0.01 (-0.01 ,0.02)	-0.03 (-0.06 ,0.00)	_	_
	post	_	-0.02 (-0.12,0.08)	0.00 (-0.02,0.02)	-0.02 (-0.06,0.01)	_	_
FEF_{50}	pre	_	-0.09 (-0.19,0.00)	0.01 (-0.01 ,0.03)	-0.03 (-0.06,0.00)	_	_
	post	_	-0.07 (-0.18,0.04)	0.01 (-0.01,0.03)	-0.03 (-0.07,0.01)	_	_
FEF_{75}	pre	_	-0.06 (-0.13,0.01)	-0.00 (-0.02 ,0.01)	-0.02 (-0.05,0.01)	_	_
	post	_	0.00 (-0.08,0.08)	-0.00 (-0.02,0.01)	-0.02 (-0.05,0.01)	_	_
FEV_1	pre	-9.01* (-15.92,-2.11)	-0.15 (-0.34,0.05)	0.02 (-0.02,0.05)	-0.04 (-0.11 ,0.03)	-0.13* (-0.24,-0.03)	-0.48* (-0.88,-0.07)
	post	-7.16 (-14.55,0.24)	-0.05 (-0.25,0.16)	0.00 (-0.04,0.04)	-0.03 (-0.10,0.05)	-0.10 (-0.22,0.01)	-0.43 (-0.85,0.00)
FVC	pre	-7.62* (-14.41,-0.83)	-0.10 (-0.29,0.10)	0.00 (-0.04,0.04)	-0.06 (-0.12,0.01)	-0.14* (-0.24,-0.04)	-0.45* (-0.84,-0.05)
	post	-5.19 (-11.96,1.58)	0.01 (-0.18,0.21)	-0.02 (-0.05,0.01)	-0.03 (-0.10,0.03)	-0.09 (-0.19,0.02)	-0.39 (-0.77,-0.00)
FEV_1/FVC	pre	-3.67 (-7.63,0.28)	-0.08 (-0.18,0.03)	0.01 (-0.01 ,0.03)	-0.01 (-0.05,0.03)	-0.05 (-0.11,0.02)	-0.15 (-0.38,0.09)
	post	-2.49 (-6.16,1.19)	-0.05 (-0.14,0.05)	0.01 (-0.01,0.03)	-0.00 (-0.04,0.03)	-0.03 (-0.09,0.02)	-0.11 (-0.33,0.11)

Abbreviations: CI: confidence interval; Other Abbreviations: see Table 2.Notes: *P＜0.05; "_": see Figure 2.

Table S4. The association of lung function and air pollution in moderate group

		change per unit(95%CI)					
		CO	NO_2	O_3	PM_{10}	$PM_{2.5}$	SO_2
FEF_{25-75}	pre	-0.69 (-3.04,1.66)	0.03 (-0.05,0.11)	-0.01 (-0.03,0.01)	0.00 (-0.03,0.03)	-0.02 (-0.06,0.02)	0.01 (-0.15,0.17)
	post	-0.21 (-2.71,2.28)	0.01 (-0.07,0.09)	-0.01 (-0.03,0.00)	-0.01 (-0.04,0.02)	-0.02 (-0.06,0.03)	0.01 (-0.16,0.18)
FEF_{50}	pre	-1.48 (-4.24,1.28)	0.02 (-0.07,0.10)	-0.01 (-0.02,0.01)	-0.00 (-0.04,0.03)	-0.03 (-0.08,0.02)	-0.03 (-0.22,0.16)
	post	-1.03 (-3.58,1.52)	0.03 (-0.06,0.11)	-0.02* (-0.03,0.00)	-0.01 (-0.04,0.02)	-0.03 (-0.07,0.02)	-0.02 (-0.20,0.15)
FEF_{75}	pre	-1.12 (-3.26,1.03)	-0.01 (-0.08,0.06)	-0.01 (-0.02,0.01)	-0.01 (-0.04,0.02)	-0.03 (-0.07,0.01)	-0.02 (-0.16,0.12)
	post	-0.06 (-2.86,2.75)	-0.01 (-0.10,0.08)	-0.01 (-0.03,0.01)	-0.03 (-0.07,0.00)	-0.03 (-0.08,0.02)	-0.07 (-0.26,0.12)
FEV_1	pre	-2.01 (-4.89,0.87)	0.02 (-0.07,0.11)	-0.01 (-0.03,0.01)	0.01 (-0.03,0.04)	-0.03 (-0.08,0.02)	0.04 (-0.15,0.24)
	post	-1.05 (-3.58,1.49)	0.01 (-0.07,0.10)	-0.02 (-0.03,0.00)	-0.02 (-0.06,0.01)	-0.03 (-0.08,0.02)	-0.01 (-0.18,0.16)
FVC	pre	-2.04 (-4.70,0.63)	0.00 (-0.08,0.09)	0.00 (-0.01,0.02)	0.01 (-0.02,0.05)	-0.01 (-0.06,0.03)	0.08 (-0.10,0.26)
	post	-1.38 (-3.63,0.88)	0.01 (-0.07,0.08)	-0.01 (-0.02,0.01)	-0.02 (-0.04,0.01)	-0.02 (-0.06,0.02)	-0.04 (-0.19,0.11)
FEV_1/FVC	pre	-0.25 (-1.86,1.36)	0.02 (-0.03,0.07)	-0.01 (-0.02,0.00)	0.00 (-0.02,0.02)	-0.01 (-0.04,0.02)	0.02 (-0.09,0.13)
	post	0.19 (-1.16,1.54)	0.01 (-0.03,0.05)	-0.01* (-0.02,0.00)	-0.01 (-0.02,0.01)	-0.01 (-0.03,0.02)	0.03 (-0.06 ,0.12)

Abbreviations: CI: confidence interval; Other Abbreviations: see Table 2. Notes: *P＜0.05.

Table S5. The association of lung function and air pollution in mild group

		change per unit(95%CI)					
		CO	NO$_2$	O$_3$	PM$_{10}$	PM$_{2.5}$	SO$_2$
FEF$_{25-75}$	pre	-1.65 (-4.00,0.71)	-0.06 (-0.14,0.03)	0.02* (0.00,0.04)	0.01 (-0.02,0.05)	-0.00 (-0.05,0.04)	_
	post	-1.64 (-3.85,0.57)	-0.04 (-0.12,0.04)	0.02** (0.01 ,0.04)	0.01 (-0.02 ,0.04)	-0.01 (-0.05,0.03)	_
FEF$_{50}$	pre	-2.26 (-4.64,0.13)	-0.08 (-0.17,0.00)	0.03** (0.01,0.05)	0.01 (-0.03,0.04)	-0.01 (-0.05,0.04)	_
	post	-2.01 (-4.31,0.29)	-0.06 (-0.14,0.02)	0.03*** (0.02,0.05)	0.02 (-0.01,0.05)	-0.01 (-0.05 ,0.03)	_
FEF$_{75}$	pre	-1.70 (-4.15,0.76)	-0.06 (-0.15,0.03)	0.01 (-0.01,0.03)	0.01 (-0.03,0.04)	-0.01 (-0.06,0.03)	_
	post	-0.51 (-3.54,2.52)	0.02 (-0.09,0.13)	0.02 (-0.01,0.04)	0.04 (-0.00,0.08)	0.01 (-0.04,0.07)	_
FEV$_1$	pre	_	_	0.02** (0.01 ,0.03)	_	_	_
	post	_	_	0.01** (0.00 ,0.02)	_	_	_
FVC	pre	_	_	0.01* (0.00 ,0.02)	_	_	_
	post	_	_	0.01 (-0.00,0.02)	_	_	_
FEV$_1$/FVC	pre	_	_	0.01* (0.00,0.01)	_	_	_
	post	_	_	0.01 * (0.00 ,0.01)	_	_	_

Abbreviations: CI: confidence interval; Other Abbreviations: see Table 2. Notes: *P＜0.05; **P＜0.01; ***P＜0.001; "_": see Figure 3-4.

Table S6. The adjusted association of lung function and chronic exposure to pollutants

		CO	SO$_2$	PM$_{2.5}$	PM$_{10}$	NO$_2$	O$_3$
total	preFEV$_1$	-1.91 (-3.38,-0.44)					
	postFEV$_1$	-1.38 (-2.74,-0.01)					
	preFVC	-1.89 (-3.09,-0.68)					
	postFVC	-1.33 (-2.41,-0.25)					
severe	preFEV$_1$			-0.13* (-0.24, -0.03)			
	preFVC			-0.14* (-0.24, -0.04)			
	preFEF$_{50}$			-0.08** (-0.13, -0.03)			
	postFEF$_{50}$		-0.34** (-0.55, -0.12)				
	preFEF$_{75}$			-0.05* (-0.09, -0.01)			
	postFEF$_{75}$		-0.19* (-0.36, -0.02)				
	preFEF$_{25-75}$			-0.08** (-0.12, -0.03)			
	postFEF$_{25-75}$		-0.24* (-0.44, -0.03)				
moderate	Post FEV$_1$/FVC						-0.01* (-0.02, 0.00)

	postFEF$_{50}$					-0.02* (-0.04, -0.00)
mild	preFEV$_1$				-0.09*** (-0.14, -0.04)	
	postFEV$_1$	-0.13** (-0.21, -0.05)				
	preFVC		-0.03*** (-0.04, -0.02)			
	postFVC		-0.02** (-0.03, -0.01)			
	Pre FEV$_1$/FVC					0.01** (0.00, 0.01)
	Post FEV$_1$/FVC					0.01** (0.00, 0.01)
	preFEF$_{50}$					0.03*** (0.02, 0.05)
	postFEF$_{50}$	-0.18* (-0.36, -0.01)				
	preFEF$_{25-75}$					0.02** (0.01, 0.04)
	postFEF$_{25-75}$	-0.21* (-0.37, -0.05)				

Abbreviations: CI: confidence interval; Other Abbreviations: see Table 2. Notes: The insignificant associations are not presented, and only the best predictive factor

was adjusted and presented. *P<0.05；**P<0.01；***P<0.001.

References

Liu, Y., et al., *Short-Term Exposure to Ambient Air Pollution and Asthma Mortality.* Am J Respir Crit Care Med, 2019. 200(1): 24-32.