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Supplementary Materials: Association between long-term exposure to particulate matter air pollution and mortality in a South Korean national cohort: comparison across different exposure assessment approaches

Okjin Kim, Sun-Young Kim *, Ho Kim *

Supplementary tables and figures

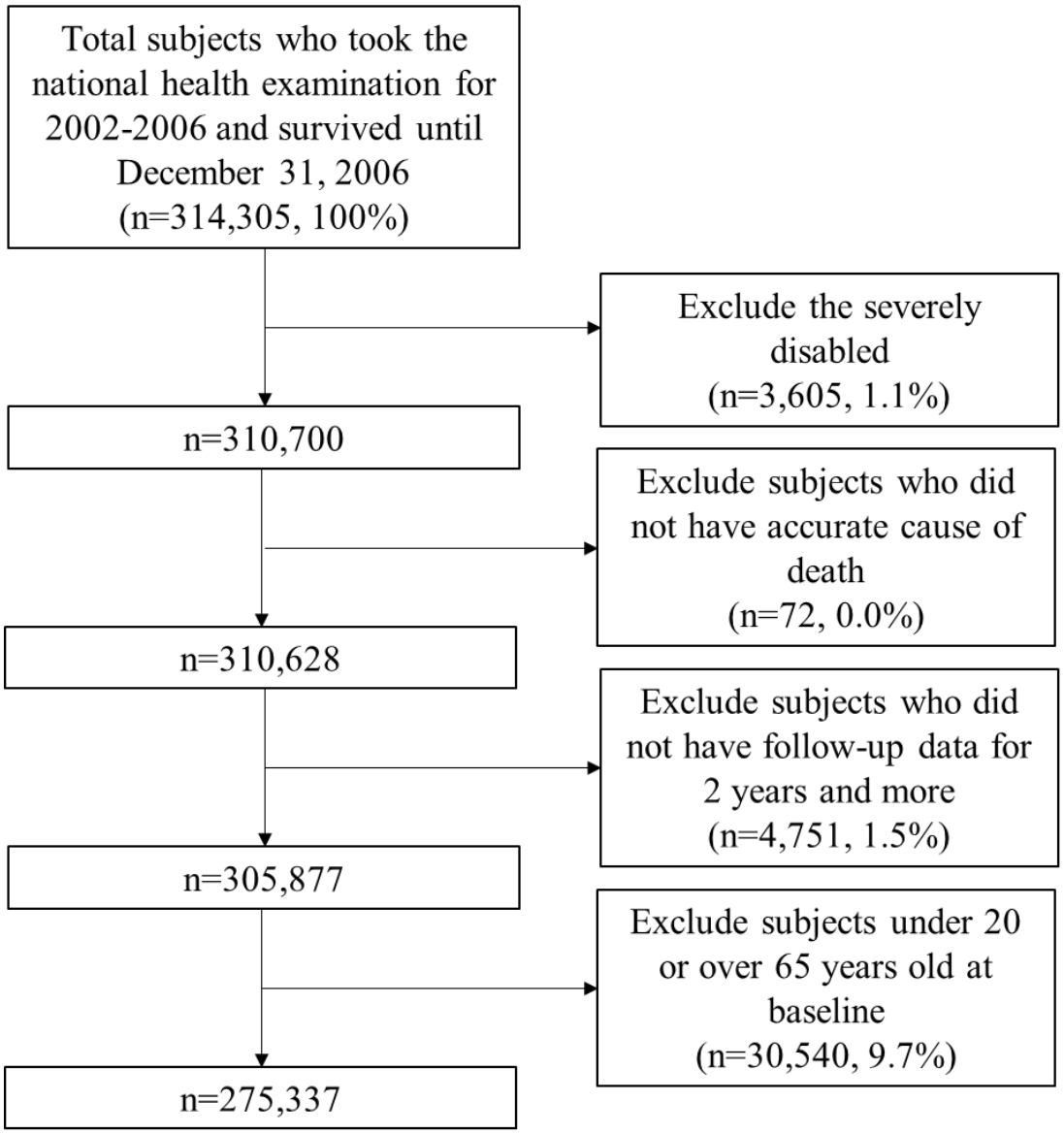

Figure S1. Schematic diagram of exclusion criteria and numbers of National Health Insurance Service- National Sample Cohort subjects included or excluded after the application of each criterion.

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Table S1. Definition of four exposure assessment (EA) approaches.

EA	Time-varying exposure	Residential mobility
EA1	O	O
EA2	O	X
EA3	X	O
EA4	X	X

Equations for individual-level 5-year PM_{10} average concentrations by the four different exposure assessment (EA) approaches.

PM_{t,s_t} : PM_{10} predicted annual average concentration of each person at address s_t in year t.

t : 2002 to 2006

t^* : baseline year (2002)

s^* : address in baseline year (2002)

$$EA1 = \frac{1}{5}\sum_{t=2002}^{2006} PM_{t,s_t}$$

$$EA2 = \frac{1}{5}\sum_{t=2002}^{2006} PM_{t,s^*}$$

$$EA3 = \frac{1}{5}\sum_{t=2002}^{2006} PM_{t^*,s_t}$$

$$EA4 = \frac{1}{5}\sum_{t=2002}^{2006} PM_{t^*,s^*} = PM_{t^*,s^*}$$

Table S2. Descriptive statistics and correlation coefficients of long-term PM_{10} concentrations of 275,337 National Health Insurance Service- National Sample Cohort (NHIS-NSC) subjects across four exposure assessment (EA) approaches.

EA	PM_{10} concentration ($\mu g/m^3$)				Correlation coefficient			
	Mean	SD	Min	Max	EA1	EA2	EA3	EA4
EA1	56.0	6.5	39.2	72.1	1.00			
EA2	55.9	6.6	39.2	71.2	0.96	1.00		
EA3	57.6	8.9	28.1	80.2	0.90	0.87	1.00	
EA4	57.6	9.2	28.1	80.2	0.87	0.91	0.95	1.00

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Table S3. Adjusted hazard ratios (HRs) and 95% confidence intervals (CIs) of non-accidental and cause-specific mortality for an increase of 10 μg/m^3 in the long-term concentration to PM_{10} defined by four different exposure assessment (EA) approaches.

EA[2]	HRs[1] (95% CIs)					
	Non-accidental	**Cardiovascular**	**Cerebrovascular**	**Respiratory**	**Cancer**	**Lung cancer**
EA1	1.05 (0.99,1.11)	1.02 (0.90,1.16)	1.14 (0.93,1.39)	1.19 (0.91,1.57)	1.02 (0.95,1.10)	0.96 (0.82,1.13)
EA2	1.05 (0.99,1.11)	1.02 (0.90,1.16)	1.12 (0.92,1.37)	1.23 (0.93,1.63)	1.02 (0.94,1.10)	0.96 (0.81,1.13)
EA3	1.00 (0.96,1.04)	0.99 (0.90,1.08)	1.07 (0.93,1.23)	1.05 (0.87,1.27)	0.98 (0.93,1.03)	0.92 (0.82,1.04)
EA4	1.00 (0.97,1.05)	1.00 (0.91,1.09)	1.08 (0.94,1.24)	1.05 (0.87,1.27)	0.99 (0.94,1.04)	0.94 (0.84,1.05)

[1] Effect estimates from our primary model (model 4) adjusting for sex, age, income, smoking, alcohol use, obese, exercise, and co-morbidity of cardiovascular disease, cerebrovascular disease, and diabetes, district-level percent of high school education completed or more, percent of the elderly, and gross regional domestic product.

[2] EA1: prediction and address in each year
EA2: prediction in each year and address at baseline
EA3: prediction at baseline and address in each year
EA4: prediction and address at baseline

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Table S4. Adjusted hazard ratios (HRs) and 95% confidence intervals (CIs) of mortality for an increase of 10 μg/m^3 in 12-year average PM_{10} concentrations[1] in 275,337 National Health Insurance Service- National Sample Cohort (NHIS-NSC) subjects for 2002-2013 in South Korea.

Cause of mortality	HRs[2] (95% CIs)
Non-accidental	1.07 (1.00,1.15)
Cardiovascular	1.04 (0.89,1.22)
Cerebrovascular	1.20 (0.94,1.54)
Respiratory	1.26 (0.90,1.77)
Cancer	1.04 (0.95,1.15)
Lung cancer	1.00 (0.81,1.22)

[1] 12-years average concentrations of PM_{10} at addresses at baseline in 2002.
[2] Adjusting for sex, age, income, smoking, alcohol use, obese, exercise, and co-morbidity of cardiovascular disease, cerebrovascular disease, and diabetes, district-level percent of high school education completed or more, percent of the elderly, and gross regional domestic product.

Table S5. Adjusted hazard ratios (HRs) and 95% confidence intervals (CIs) of mortality for an increase of 10 μg/m^3 in measurement-based long-term PM_{10} concentrations in 237,224[2] National Health Insurance Service- National Sample Cohort (NHIS-NSC) subjects for 2002-2013 in South Korea.

Cause of mortality	HRs[1] (95% CIs)	
	Measurement-based PM_{10}	EA1[2]
Non-accidental	1.04 (0.99,1.08)	1.07 (1.00,1.14)
Cardiovascular	1.02 (0.92,1.13)	1.05 (0.91,1.22)
Cerebrovascular	1.05 (0.90,1.24)	1.10 (0.87,1.39)
Respiratory	0.98 (0.79,1.22)	1.05 (0.76,1.45)
Cancer	1.01 (0.95,1.07)	1.02 (0.94,1.11)
Lung cancer	0.98 (0.86,1.12)	0.98 (0.81,1.19)

[1] Adjusting for sex, age, income, smoking, alcohol use, obese, exercise, and co-morbidity of cardiovascular disease, cerebrovascular disease, and diabetes, district-level percent of high school education completed or more, percent of the elderly, and gross regional domestic product.
[2] Subjects who lived in the districts where there are regulatory air pollution monitoring sites.

Table S6. Adjusted hazard ratios (HRs) and 95% confidence intervals (CIs) of mortality for an increase of 10 μg/m^3 in the long-term PM_{10} concentrations from time-dependent Cox proportional hazards models.

Cause of mortality	HRs[1] (95% CIs)
Non-accidental	1.03 (0.96 ,1.11)
Cardiovascular	0.91 (0.77,1.06)
Cerebrovascular	1.07 (0.84,1.36)
Respiratory	1.01 (0.71,1.45)
Cancer	1.05 (0.96,1.16)
Lung cancer	1.00 (0.81,1.22)

[1] Adjusting for sex, age, income, smoking, alcohol use, obese, exercise, and co-morbidity of cardiovascular disease, cerebrovascular disease, and diabetes, district-level percent of high school education completed or more, percent of the elderly, and gross regional domestic product.

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Table S7. Adjusted hazard ratio (HRs) and 95% confidence interval (CIs) of mortality for an increase of 10 μg/m^3 in the long-term PM_{10} concentrations from Cox proportional hazards model incorporating random effects for subjects' residential districts at baseline.

Cause of mortality	HRs[1] (95% CIs)
Non-accidental	1.05 (0.99, 1.11)
Cardiovascular	1.02 (0.90, 1.16)
Cerebrovascular	1.14 (0.93, 1.39)
Respiratory	1.19 (0.89, 1.58)
Cancer	1.02 (0.95, 1.10)
Lung cancer	0.96 (0.82, 1.13)

[1] Adjusting for sex, age, income, smoking, alcohol use, obese, exercise, and co-morbidity of cardiovascular disease, cerebrovascular disease, and diabetes, district-level percent of high school education completed or more, percent of the elderly, and gross regional domestic product.

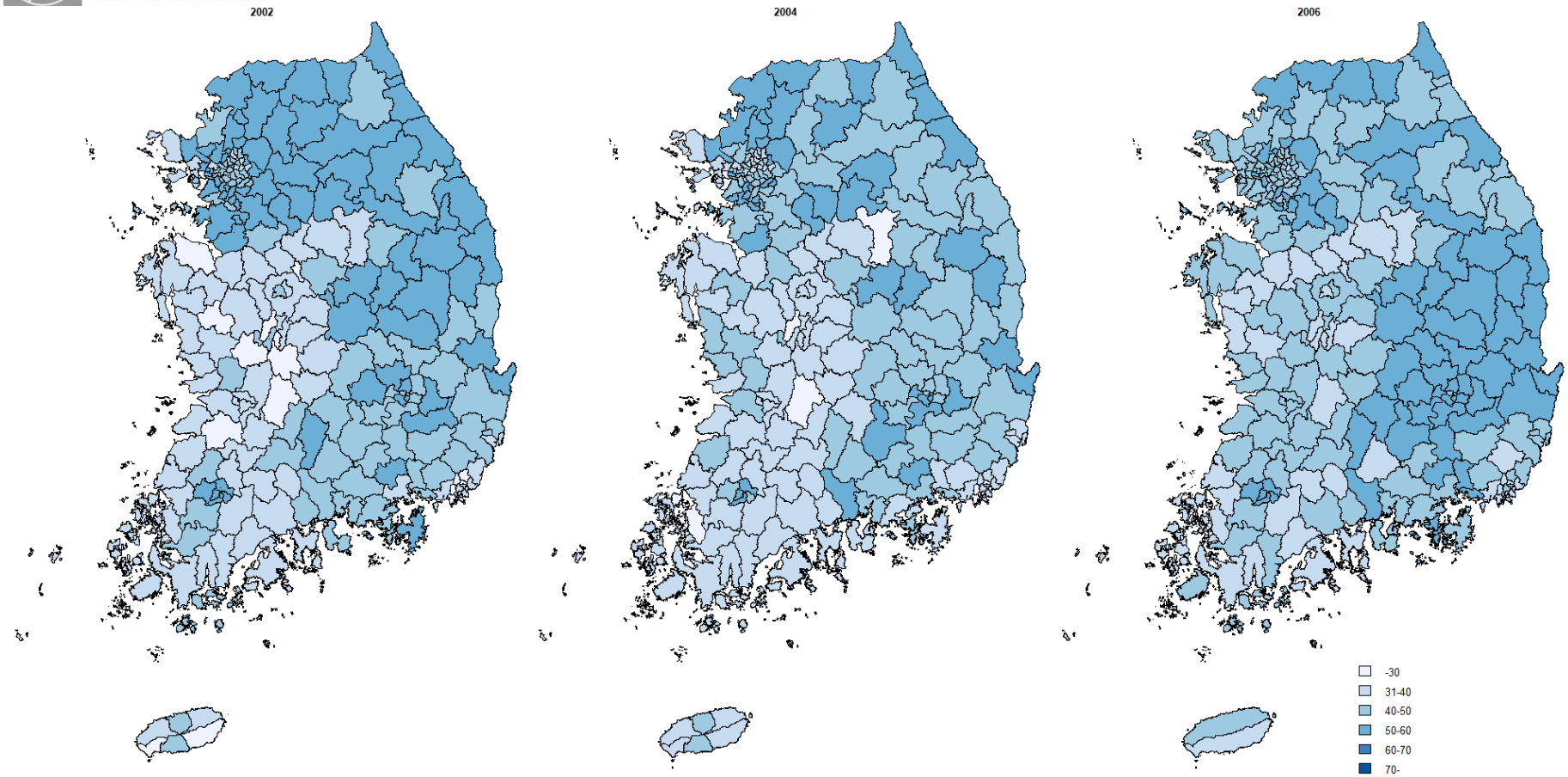

Figure S2. Maps of predicted district-specific annual concentrations of PM_{10} in 2010, South Korea.

Table S8. Summaries of previous cohort studies of the association between long-term exposure to PM_{10} and mortality.

Study	Cohort	N of subjects	Measurements/ predictions	Time	Space	Percent change in mortality risk (95% confidence interval per 10 μg/m³ increase in PM_{10}				
						All-causes	Non-accidental	Cardiovascular *[cerebrovascular]*	Respiratory	Lung cancer
Ueda et al, 2011 [1]	Japan ≥ 30 years nationwide	7,250	Measurements	24 year average	District	-2 (-8, 4)		-14 (-26, 1)		
Fisher et al, 2015 [2]	Netherland, ≥ 30 years, nationwide	7,218,363	Predictions	1 year average	100m x 100m grid		8 (7, 9)	6 (4, 8)	13 (10, 17)	26 (21, 30)
Zhang et al, 2011 [3]	China 35-103 years, 5 districts	9,941	Measurements	1 year average	District			55 (51, 60)		
Zhou et al, 2014 [4]	China ≥ 40 years 25 urban cities	71,431	Measurements	10 year average	City	0.4 (-0.1, 1)		1 (0.4, 1.7)	-0.2 (-0.9, 0.6)	0.3 (-0.2, 0.9)
Carey et al, 2013 [5]	England 40-89 years nationwide	835,607	Predictions	1 year average	1kmx1km grid	7 (-1, 16)		7 (-0.3, 18)	42 (29, 55)	7 (0, 14)
Bentayeb et al, 2015 [6]	France average 43.7 ages nationwide	20,327	Predictions	20 year average	zip code area		17 (0, 37)	17 (-26, 84)	0 (-32, 48)	
Heinrich et al, 2013 [7]	German, ≥ 55 years 10 areas in 7 cities	4,750	Measurements	1 year average	geocoded address		22 (6, 41)	60 (25, 105)	-6 (-52, 85)	139 (34, 325)
Beelen et al, 2014 [8]	Europe ESCAPE cohort	367,251	Predictions	2.5 year average			4 (0, 9)			
Beelen et al ,2014 [9]	Europe, ESCAPE cohort	367,383	Predictions	2.5 year average				2 (-8, 14) *[22 (-9, 63)]*		

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