

Supplemental Material

Manuscript Title:

Associations between recent exposure to ambient fine particulate matter and blood pressure in The Multi-Ethnic Study of Atherosclerosis (MESA)

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Supplemental Material, Table 1. Description of gaseous pollutants, traffic-related variables, weather, and, Spearman correlations between each variable* and PM_{2.5} -- stratified by temperature, Multi-Ethnic Study of Atherosclerosis, 2000-2002.

Environmental variables		Tertiles of temperature			
		Median † (25th - 75th percentile)	cool (17-<50 F.)	moderate (50-<62 F.)	warm (62-80 F.)
No. *			1705	1708	1699
			Correlations with PM_{2.5} averaged for prior 30 days (values >0.50 are in bold)‡		
Co-pollutants §	Ozone, ppm †	0.071 (0.050-0.093)	-0.67	-0.30	0.23
	Carbon monoxide, ppm	0.957 (0.783-1.367)	0.20	0.71	0.25
	Sulfur dioxide, ppm	0.004 (0.003-0.007)	0.36	-0.17	-0.11
	Nitrogen dioxide, ppm	0.026 (0.019-0.033)	0.55	0.66	0.32
Traffic related	Distance to highways, km	0.638 (0.259-1.234)	-0.19	0.02	0.11
	Density of road length near home (within 400 meters of home, km)	1.903 (0.905-3.445)	0.17	-0.08	-0.15
Weather	Temperature, F.	57.6 (44.5-66.1)	-0.37	0.14	0.19
	Atmospheric pressure (sea level, inches Hg)	30.065 (30.005-30.124)	0.37	-0.18	-0.15

* Measures represent averages for the prior 30 days.

† Ozone has fewer observations than the other measures: No. =1149, 1640, 1699 in cool, moderate, and warm temperatures, respectively.

‡ P-values all <0.0000 except between distance to highways and PM_{2.5} for moderate temperature, p=0.5.

§ The 2006 National Ambient Air Quality Standards are: NO₂ 0.053 ppm for annual mean; SO₂ 0.03 ppm for annual mean and 0.14 ppm for 24-hour value; CO 9 ppm for 8-hour average; O₃ 0.08 ppm for 8-hour average.{U.S. EPA, 2006 #851}

Supplemental Material, Table 2. Adjusted mean differences (with 95% confidence intervals) in diastolic blood pressure (mm Hg) and in mean arterial pressure (mm Hg) per 10 $\mu\text{g}/\text{m}^3$ in $\text{PM}_{2.5}$ averaged for the prior 1-30 days and prior 1-60 days (n= 5112), Multi-Ethnic Study of Atherosclerosis, 2000-2002.

$\text{PM}_{2.5}$ exposures	Model No.	Adjustment variables	Diastolic blood pressure				Mean arterial pressure*			
			Mean difference	95% low	95% high	P-value	Mean difference	95% low	95% high	P-value
Prior 30-days	1	Person-level covariates†	-0.38	-0.92	0.16	0.168	-0.03	-0.69	0.63	0.927
	2	Person-level covariates†, weather variables‡	-0.13	-0.70	0.44	0.657	0.24	-0.46	0.95	0.496
	2a	Person-level covariates†, weather variables‡, gaseous pollutants§	0.14	-0.57	0.86	0.698	1.03	0.15	1.90	0.022
	3	Person-level covariates†, study site	-0.07	-0.73	0.59	0.833	0.24	-0.57	1.05	0.564
	3a	Person-level covariates†, study site, weather variables‡	0.20	-0.55	0.96	0.600	0.57	-0.35	1.50	0.225
	3b	Person-level covariates†, study site, weather variables‡, gaseous pollutants§	0.18	-0.67	1.03	0.676	0.63	-0.41	1.67	0.237
Prior 60-days	1	Person-level covariates†	-0.40	-1.02	0.22	0.203	-0.05	-0.82	0.71	0.888
	2	Person-level covariates†, weather variables‡	-0.25	-0.90	0.41	0.463	0.12	-0.69	0.92	0.779
	2a	Person-level covariates†, weather variables‡, gaseous pollutants§	0.02	-0.84	0.88	0.964	1.04	-0.01	2.09	0.053
	3	Person-level covariates†, study site	0.05	-0.78	0.88	0.911	0.35	-0.67	1.36	0.501
	3a	Person-level covariates†, study site, weather variables‡	-0.05	-1.05	0.94	0.916	0.30	-0.92	1.52	0.635
	3b	Person-level covariates†, study site, weather variables‡, gaseous pollutants§	-0.08	-1.19	1.03	0.890	0.35	-1.01	1.70	0.616

* Mean arterial pressure is $[(2 * \text{diastolic}) + \text{systolic}]/3$

† Person-level covariates: age, sex, race/ethnicity, income, education, BMI, diabetes status, cigarette smoking status, environmental tobacco smoke, alcohol use, physical activity, medication use.

‡ Weather variables: prior 30-day mean for temperature and sea-level pressure

§ Gaseous copollutants were: NO_2 , SO_2 , and CO. Ozone was not included due to having incomplete information in the winter. Cumulative exposures for weather and co-pollutants corresponded to the averaging period for $\text{PM}_{2.5}$ (e.g., copollutants were averaged for prior 30-days to correspond to prior 30-day average $\text{PM}_{2.5}$). Adjusted relationships between blood pressure and temperature and SO_2 were fit using piecewise linear splines due to being positive for lower values and negative for higher values (breaks at 45 F. for temperature and 0.004 ppm for SO_2).

Supplemental Material, Table 3. Adjusted mean differences (with 95% confidence intervals) in blood pressure (mm Hg) (diastolic, systolic, pulse, mean arterial) for gaseous co-pollutants averaged for prior 1-30 days (n= 5112), Multi-Ethnic Study of Atherosclerosis, 2000-2002.

Exposure	Model No.	Adjustment variables	Pulse pressure				Systolic pressure				Diastolic blood pressure				Mean arterial pressure*			
			Mean difference	95% low	95% high	P-value	Mean difference	95% low	95% high	P-value	Mean difference	95% low	95% high	P-value	Mean difference	95% low	95% high	P-value
Averaging period Prior 30-days																		
Nitrogen dioxide (ppb)																		
	2a	Person-level covariates*, weather†, other gaseous co-pollutants‡	-0.170	-0.230	-0.111	0.000	-0.247	-0.327	-0.166	0.000	-0.076	-0.117	-0.036	0.000	-0.133	-0.183	-0.084	0.000
	3b	+ study site	-0.008	-0.089	0.073	0.849	-0.051	-0.161	0.058	0.358	-0.044	-0.099	0.012	0.123	-0.046	-0.114	0.022	0.182
Carbon monoxide (ppm)																		
	2a	Person-level covariates*, weather†, other gaseous co-pollutants‡	0.441	-0.464	1.345	0.340	1.072	-0.153	2.296	0.086	0.631	0.016	1.246	0.044	0.778	0.023	1.533	0.044
	3b	+ study site	-0.436	-1.442	0.569	0.395	-0.194	-1.555	1.167	0.780	0.242	-0.443	0.928	0.488	0.097	-0.744	0.937	0.821
Sulfur dioxide (ppb)																		
Lower§	2a	Person-level covariates*, weather†, other gaseous co-pollutants‡	0.283	-0.215	0.782	0.266	0.482	-0.193	1.157	0.162	0.199	-0.140	0.538	0.251	0.293	-0.123	0.709	0.168
Higher	2a	Person-level covariates*, weather†, other gaseous co-pollutants‡	0.363	-0.346	1.071	0.315	0.511	-0.448	1.471	0.296	0.149	-0.334	0.632	0.546	0.270	-0.323	0.862	0.372
Lower§	3b	model 2a + study site	-0.353	-0.498	-0.209	0.000	-0.276	-0.472	-0.080	0.006	0.078	-0.021	0.176	0.122	-0.040	-0.161	0.080	0.513
Higher	3b	model 2a + study site	-0.104	-0.297	0.089	0.291	-0.032	-0.294	0.229	0.808	0.072	-0.060	0.203	0.287	0.037	-0.125	0.198	0.654

* Person-level covariates: age, sex, race/ethnicity, income, education, BMI, diabetes status, cigarette smoking status, environmental tobacco smoke, alcohol use, physical activity, medication use.

† Weather variables: prior 60-day mean for temperature and sea-level pressure.

‡ The other gaseous co-pollutants are nitrogen dioxide, carbon monoxide, and sulfur dioxide. Spearman bivariate rank correlations were 0.56 between NO₂ and CO, and ≈0.25 between the other gaseous pollutants

§ The adjusted relationship between blood pressure and sulfur dioxide (SO₂) was fit using piecewise linear splines due to being positive for lower values and negative for higher value (break at 0.004 ppm for SO₂).

Supplemental Material, Table 4. Adjusted mean differences (with 95% confidence intervals) in pulse pressure (mm Hg) and in systolic blood pressure (mm Hg) per 10 ug/m³ in PM_{2.5} averaged for the prior 1-60 days (n= 5112), Multi-Ethnic Study of Atherosclerosis, 2000-2002.

PM _{2.5} exposures	Model No.	Adjustment variables	Pulse Pressure				Systolic Blood Pressure			
			Mean difference	95% low	95% high	P-value	Mean difference	95% low	95% high	P-value
Prior 60-days	1	Person-level covariates*	1.04	0.13	1.96	0.026	0.64	-0.60	1.88	0.310
	2	Person-level covariates*, weather†	1.08	0.11	2.05	0.029	0.84	-0.47	2.15	0.210
	2a	Person-level covariates*, weather†, gaseous co-pollutants‡	3.05	1.79	4.31	0.000	3.07	1.37	4.77	0.000
	3	Person-level covariates*, study site	0.90	-0.31	2.12	0.144	0.95	-0.69	2.60	0.256
	3a	Person-level covariates*, study site, weather†	1.05	-0.41	2.51	0.159	1.00	-0.98	2.97	0.324
	3b	Person-level covariates*, study site, weather†, gaseous co-pollutants‡	1.27	-0.35	2.90	0.124	1.20	-1.00	3.40	0.286

* Person-level covariates: age, sex, race/ethnicity, income, education, BMI, diabetes status, cigarette smoking status, environmental tobacco smoke, alcohol use, physical activity, medication use.

† Weather variables: prior 60-day mean for temperature and sea-level pressure.

‡ Gaseous copollutants were: NO₂, SO₂, and CO. Ozone was not included due to having incomplete information in the winter. Cumulative exposures for weather and co-pollutants corresponded to the averaging period for PM_{2.5} (e.g., copollutants were averaged for prior 60-days to correspond to prior 60-day average PM_{2.5}). Adjusted relationships between blood pressure and temperature and SO₂ were fit using piecewise linear splines due to being positive for lower values and negative for higher values (breaks at 45 F. for temperature and 0.004 ppm for SO₂).

Supplemental Material, Table 5. Adjusted mean differences (with 95% confidence intervals) in blood pressure (mm Hg) (diastolic, systolic, pulse, mean arterial) for traffic-related variables (n= 5112), Multi-Ethnic Study of Atherosclerosis, 2000-2002.

Exposure	Model No.	Adjustment variables	Pulse pressure				Systolic pressure				Diastolic blood pressure				Mean arterial pressure*			
			Mean difference	95% low	95% high	P-value	Mean difference	95% low	95% high	P-value	Mean difference	95% low	95% high	P-value	Mean difference	95% low	95% high	P-value
Ambient nitrogen dioxide (ppb)	2	Person-level covariates†, weather§	-0.109	-0.154	-0.064	0.000	-0.147	-0.208	-0.086	0.000	-0.036	-0.066	-0.005	0.022	-0.072	-0.110	-0.035	0.000
	3a	Person-level covariates†, study site, weather§	0.007	-0.064	0.078	0.842	-0.021	-0.117	0.075	0.669	-0.003	-0.049	0.042	0.886	0.003	-0.053	0.058	0.919
Residing close to a highway*	2	Person-level covariates†, weather§	-1.643	-2.487	-0.799	0.000	-1.434	-2.575	-0.293	0.014	0.178	-0.084	0.439	0.182	0.529	0.208	0.850	0.001
	3a	Person-level covariates†, study site, weather§	-0.361	-1.245	0.523	0.423	-0.047	-1.243	1.149	0.939	0.009	-0.280	0.298	0.950	0.072	-0.282	0.426	0.688
Density of road length around the home† (km)	2	Person-level covariates†, weather§	-0.615	-0.813	-0.416	0.000	-0.601	-0.869	-0.333	0.000	0.018	-0.117	0.152	0.798	-0.187	-0.352	-0.022	0.027
	3a	Person-level covariates†, study site, weather§	-0.064	-0.298	0.169	0.590	-0.024	-0.340	0.292	0.880	0.031	-0.128	0.190	0.703	0.009	-0.186	0.204	0.929

* Residences within 300 meters of a major road were defined as being 'close to a highway'. Major roads were identified from census feature class codes for primary roads (CFCC= A1 or A2). (Primary roads are interstate highways, limited access roads, secondary roads, US highways not classified, and state roads.) The roadway file, obtained from Environmental Systems Research Institute Inc., was a modified version of the 1990 Census TIGER/Line™ file.

† Density of road length around the home

‡ Person-level covariates: age, sex, race/ethnicity, income, education, BMI, diabetes status, cigarette smoking status, environmental tobacco smoke, alcohol use, physical activity, medication use.

§ Weather variables: prior 30-day mean for temperature and sea-level pressure.

Supplemental Material, Table 6. Stratified estimates of the difference in pulse pressure (PP) and systolic blood pressure (SBP) per 10 µg/m³ PM_{2.5} prior 30-day average, adjusted for model 2 covariates.* (Results for DBP can be derived by subtracting PP from SBP.)

	Pooled estimate*	No.	PP				SBP			
			Mean difference	95% low	95% high	Interaction P†	Mean difference	95% low	95% high	Interaction P†
		2026	1.12	0.28	1.97		0.99	-0.15	2.13	
Stratification	Levels									
Aged ≥60 years	No	2131	0.82	-0.19	1.83	0.21	0.55	-0.94	2.05	0.16
	Yes	2981	1.40	0.13	2.67		1.37	-0.28	3.02	
Sex	Female	2646	0.85	-0.43	2.13	0.44	0.58	-1.12	2.29	0.66
	Male	2466	1.38	0.28	2.47		1.47	-0.03	2.97	
Hypertension	No	2837	0.53	-0.22	1.27	0.04	0.41	-0.57	1.38	0.01
	Yes	2275	1.80	0.42	3.18		1.65	-0.08	3.38	
Diabetes	No	4412	0.87	-0.04	1.77	0.20	0.63	-0.61	1.86	0.18
	Yes	700	2.50	0.12	4.89		2.76	-0.29	5.81	
Cigarette use	Never	2621	1.60	0.48	2.73	0.38	1.25	-0.27	2.77	0.69
	Former	1883	0.44	-1.09	1.97		1.35	-0.69	3.38	
	Current	608	0.97	-1.31	3.25		-0.34	-3.66	2.98	
Blood pressure medications	No	3171	0.73	-0.23	1.70	0.04	0.57	-0.77	1.90	0.004
	Yes	1941	1.97	0.39	3.56		2.10	0.02	4.17	
Study site	Baltimore, MD	851	2.54	-0.94	6.03	0.27	2.57	-2.00	7.14	0.44
	Chicago, IL	1024	4.17	1.38	6.95		4.67	0.76	8.59	
	Forsyth, NC	814	0.17	-4.50	4.83		2.19	-4.06	8.44	
	Los Angeles, CA	1123	0.26	-1.39	1.91		0.42	-1.78	2.62	
	Northern Manhattan & Bronx, NY	912	2.50	-1.14	6.15		3.56	-1.44	8.55	
	St. Paul, MN	388	2.04	-5.21	9.30		4.16	-5.86	14.18	
High ambient carbon monoxide	Low-medium	3840	0.98	-0.19	2.15	0.59	0.85	-0.75	2.44	0.79
	High (≥1.367 ppm, top quartile)	1272	2.28	0.92	3.63		2.08	0.28	3.88	
High ambient sulfur dioxide	Low-medium	3835	1.14	0.24	2.04	0.55	0.99	-0.24	2.22	0.80
	High (≥0.007 ppm, top quartile)	1277	-0.49	-3.55	2.57		-0.09	-4.13	3.94	
High ambient nitrogen dioxide	Low-medium	3821	1.06	-0.17	2.29	0.04	1.09	-0.57	2.75	0.07
	High (≥0.033 ppm, top quartile)	1291	2.45	1.12	3.78		2.43	0.63	4.23	
Close to a highway, ≤300m of a major road	No	3615	0.70	-0.26	1.67	0.08	0.72	-0.58	2.01	0.25
	Yes	1497	2.24	0.43	4.05		2.18	-0.30	4.67	
Close to a highway, ≤400m of a major road	No	3249	0.78	-0.24	1.80	0.19	0.69	-0.68	2.06	0.28
	Yes	1863	1.72	0.17	3.27		1.87	-0.25	3.99	
Surrounded by a high density of roads‡	No	2539	0.17	-0.96	1.31	0.00	0.14	-1.38	1.67	0.01
	Yes	2573	2.07	0.78	3.36		1.93	0.17	3.68	

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Supplemental Material, Table 6. Stratified estimates of the difference in pulse pressure (PP) and systolic blood pressure (SBP) per 10 µg/m³ PM_{2.5} prior 30-day average, adjusted for model 2 covariates.* (Results for DBP can be derived by subtracting PP from SBP.)

		PP					SBP			
		No.	Mean difference	95% low	95% high	Interaction P†	Mean difference	95% low	95% high	Interaction P†
Pooled estimate*		2026	1.12	0.28	1.97		0.99	-0.15	2.13	
Stratification	Levels									
<i>(Continued from previous page.)</i>										
Temperature	Cool (17-<50 F.)	1705	-0.44	-2.23	1.35	0.21	-0.92	-3.34	1.50	0.10
	Moderate (50-<62 F.)	1708	1.52	0.29	2.75		1.21	-0.47	2.89	
	Warm (62-80 F.)	1699	1.26	-0.29	2.81		1.79	-0.28	3.87	
Barometric pressure	Low (29.87-<30.02 inches HG)	1704	0.61	-0.81	2.03	0.74	0.67	-1.25	2.60	0.94
	Moderate (30.02 -< 30.10 inches HG)	1705	1.61	0.36	2.85		1.06	-0.64	2.76	
	High (30.10-30.34 inches HG)	1703	0.54	-1.12	2.20		0.32	-1.91	2.54	
Season§	Oct - Dec	1133	1.70	-0.60	4.01	0.33	0.71	-2.38	3.80	0.73
	Jan - Mar	1427	0.66	-1.56	2.88		0.51	-2.51	3.54	
	Apr - June	1573	1.23	-1.60	4.06		1.33	-2.48	5.15	
	Jul - Sep	979	2.36	-2.11	6.83		4.50	-1.56	10.56	

* Models were adjusted for model 2 covariates: age, sex, race/ethnicity, income, education, BMI, diabetes status, cigarette smoking status, environmental tobacco smoke, alcohol use, physical activity, medication use, and weather variables (prior 30-day mean for temperature and sea-level pressure). However, if the stratification variable was included in model 2 covariates, the stratification variable was removed from the covariate list; stratified estimates for age are the exception to this rule (continuous age was controlled for in the model).

† P values for interactions tested whether the interaction parameter in regression was different from zero.

‡ Surrounded by a high density of roads was defined as ≥3.5 km (top quartile) of road length within 400m of the residence.

§ Estimates for season are site-adjusted in addition to being adjusted for model 2 variables (this is because seasons vary in our study sites e.g., Jan-Mar is not the same in St. Paul as in Los Angeles).

Supplemental Material, Table 7. Additional sensitivity analyses to site adjustment and to autocorrelation between months. Adjusted mean differences (with 95% confidence intervals) in pulse pressure (mm Hg) and in systolic blood pressure (mm Hg) per 10 ug/m³ in PM_{2.5} averaged for the prior 1-30 days.

PM _{2.5} exposures	Model No.	Adjustment variables	Pulse Pressure				Systolic Blood Pressure			
			Mean difference	95% low	95% high	P-value	Mean difference	95% low	95% high	P-value
Prior 30-days										
Models used a random intercept for each city.										
	1	Person-level covariates*	0.92	-0.03	1.88	0.059	0.84	-0.46	2.13	0.206
	2	Person-level covariates*, weathert†	1.09	0.01	2.18	0.048	1.27	-0.20	2.73	0.089
	2a	Person-level covariates*, weathert†, gaseous co-pollutants‡	1.45	0.22	2.67	0.021	1.64	-0.01	3.30	0.052
Models used a covariance structure that allowed for autocorrelation between months										
	1	Person-level covariates*	1.04	0.23	1.85	0.012	0.65	-0.44	1.75	0.242
	2	Person-level covariates*, weathert†	1.12	0.26	1.98	0.011	0.98	-0.18	2.14	0.099
	3a	Person-level covariates*, weathert†, study site	1.12	0.00	2.23	0.049	1.31	-0.19	2.82	0.087

* Person-level covariates: age, sex, race/ethnicity, income, education, BMI, diabetes status, cigarette smoking status, environmental tobacco smoke, alcohol use, physical activity, medication use.

† Weather variables: prior 30-day mean for temperature and sea-level pressure.

‡ Gaseous copollutants were: NO₂, SO₂, and CO averaged for prior 30-days.