

# Effect Modification of Ambient Particle Mortality by Radon: A Time Series Analysis in 108 U.S. Cities

Annelise J. Blomberg, Brent A. Coull, Iny Jhun, Carolina L. Z. Vieira, Antonella Zanobetti, Eric Garshick, Joel Schwartz and Petros Koutrakis

## SUPPLEMENTAL MATERIAL

### Table of Contents

<b>Table S1:</b> Summary statistics for all cities included in analysis, including the years of study, total number of study days, SRRS and LBL radon (Rn) values, mean two-day moving-averaged PM <sub>2.5</sub> , and mean daily number of deaths. ....	2
<b>Table S2:</b> Estimated percent change in mortality associated with a 10 µg/m <sup>3</sup> increase in PM <sub>2.5</sub> . Results are presented at the 10th and 90th percentile of radon (SRRS: 20.1 and 234.2 Bq/m <sup>3</sup> ; LBL: 18.1 and 108.0 Bq/m <sup>3</sup> ).....	5
<b>Figure S1:</b> Forest plots of city- and season-specific PM <sub>2.5</sub> effect estimates, ordered by mean city radon concentrations (SRRS).....	6
<b>Figure S2:</b> Results of the SRRS meta-regression, with and without adjustment for additional city characteristics. ....	7
<b>Figure S3:</b> Results of the LBL meta-regression, with and without adjustment for additional city characteristics.....	8

**Table S1:** Summary statistics for all cities included in analysis, including the years of study, total number of study days, SRRS and LBL radon (Rn) values, mean two-day moving-averaged PM<sub>2.5</sub>, and mean daily number of deaths.

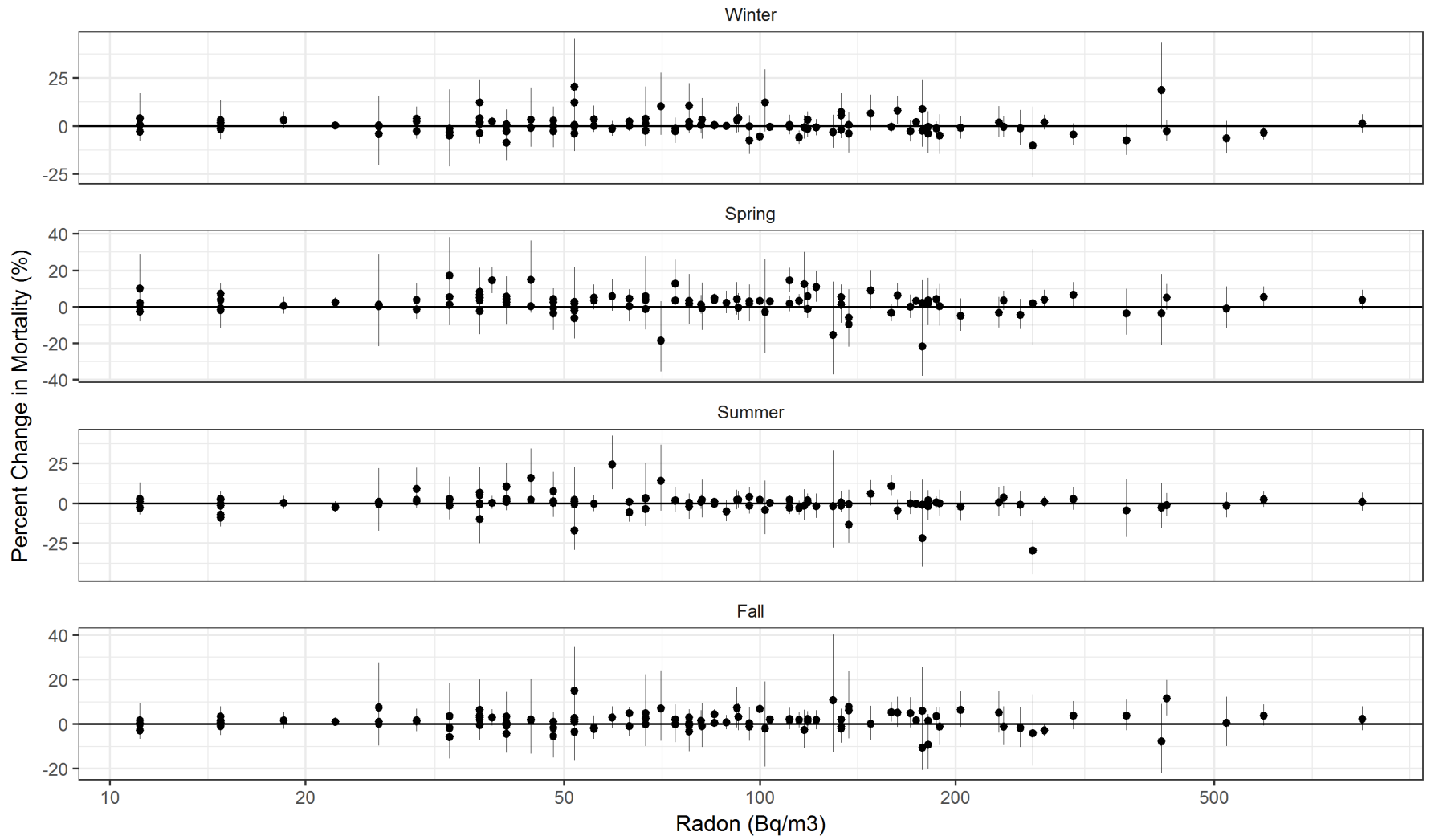
City	State	Years	Total Days	SRRS Rn (Bq/m <sup>3</sup> )	LBL Rn (Bq/m <sup>3</sup> )	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	Tot	CVD	Resp
Birmingham	AL	1999-2011	4,748	55.5	41.4	15.3	23	6	2
Montgomery	AL	2008-2010	1,096	33.3	27.8	11.6	5	1	0
Little Rock	AR	2000-2009	3,653	33.3	26.3	13.2	8	2	1
Phoenix	AZ	1999-2001	1,096	62.9	45.9	11.4	56	17	7
Tucson	AZ	2002-2006	1,826	51.8	38.9	6.1	19	5	2
Anaheim	CA	2002-2008	2,557	25.9	21.5	14.7	43	14	4
Bakersfield	CA	2005-2006	730	51.8	39.6	18.6	13	4	2
Fresno	CA	2004-2008	1,827	48.1	34.4	17.2	15	4	2
Los Angeles	CA	2000-2008	3,288	25.9	17	17.5	151	52	15
Riverside	CA	2001-2006	2,191	11.1	18.9	19.9	64	21	7
Sacramento	CA	2000-2006	2,557	37	22.2	12.4	24	7	3
San Diego	CA	1999-2008	3,653	22.2	18.1	14	50	15	5
Denver	CO	2000-2009	3,653	159.1	108.8	9.5	24	6	3
Hartford	CT	2006-2008	1,096	92.1	21.5	10.1	19	6	2
New Haven	CT	2003-2008	2,192	186.5	26.6	12.6	19	5	2
New London	CT	2007-2008	731	101.8	30.7	10.2	5	1	1
Stamford	CT	2007-2008	731	116.9	34.8	11.1	16	5	2
Wilmington	DE	2000-2007	2,922	81.2	20.4	14.8	10	3	1
Fort Lauderdale	FL	1999-2006	2,922	14.8	18.5	8.4	40	14	3
Jacksonville	FL	2000-2006	2,557	11.1	15.5	10.4	17	5	2
Miami	FL	1999-2002	1,461	29.6	28.5	9.7	48	18	4
Orlando	FL	1999-2006	2,922	18.5	21.8	10.2	23	7	2
Palm Beach	FL	1999-2006	2,922	14.8	18.1	8	33	11	3
Saint Petersburg	FL	1999-2006	2,922	14.8	17.4	10.4	22	7	2
Tampa	FL	1999-2002	1,461	37	27.8	12.1	22	7	2
Atlanta	GA	1999-2011	4,748	77.7	61	15.2	43	11	4
Macon-Bibb County	GA	2009-2011	1,095	44.4	40	12.8	4	1	0
Cedar Rapids	IA	2000-2005	2,192	233.1	93.6	11	4	1	1
Davenport	IA	2000-2006	2,557	303.4	125.1	12.2	7	2	1
Des Moines	IA	2000-2006	2,557	421.8	176.1	10.4	7	2	1
Chicago	IL	2000-2006	2,557	103.6	33.3	15.5	133	42	12
Gary	IN	1999-2002	1,461	48.1	30.7	16.1	12	4	1
Indianapolis	IN	2000-2008	3,288	181.3	100.6	15.7	19	5	2
Lafayette	IN	2007-2008	731	262.7	117.3	12.2	3	1	0
Kansas City	KS	1999-2002	1,461	133.2	69.9	12.5	28	8	3
Louisville	KY	2001-2009	3,287	118.4	70.7	15	17	5	2
Baton Rouge	LA	2001-2004	1,461	14.8	14.1	12.7	9	3	1
New Orleans	LA	2000-2004	1,827	11.1	11.5	12.5	23	6	2
Boston	MA	2003-2013	4,018	62.9	27	10.4	55	15	6

City	State	Years	Total Days	SRRS Rn (Bq/m <sup>3</sup> )	LBL Rn (Bq/m <sup>3</sup> )	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	Tot	CVD	Resp
Springfield	MA	2001-2003	1,095	74	25.9	12.2	12	3	1
Baltimore	MD	2001-2009	3,287	77.7	20.7	14.1	37	11	3
Detroit	MI	2000-2013	5,114	48.1	29.6	13.3	90	30	8
Grand Haven	MI	2007-2008	731	66.6	36.6	11.4	4	1	0
Grand Rapids	MI	1999-2005	2,557	66.6	41.1	13.4	10	3	1
Holland	MI	2001-2005	1,826	48.1	34.8	12.2	2	1	0
Minneapolis	MN	2001-2002	730	170.2	106.2	11	30	7	3
St. Louis	MO	1999-2009	4,018	85.1	36.3	14	37	12	4
Charlotte	NC	2000-2009	3,653	40.7	21.1	14	12	3	1
Durham	NC	2002-2004	1,096	51.8	19.6	13.8	4	1	0
Greensboro	NC	2000-2005	2,192	66.6	21.8	14.4	9	2	1
Raleigh	NC	2000-2006	2,557	92.5	28.1	14.2	9	2	1
Winston-Salem	NC	1999-2004	2,192	133.2	68.5	15	7	2	1
Omaha	NE	2000-2006	2,557	236.8	118	10.2	9	2	1
Elizabeth	NJ	2001-2002	730	81.4	23.3	13.9	12	4	1
Albuquerque	NM	2000-2008	3,288	136.9	107.7	6.5	11	3	1
Las Vegas	NV	1999-2006	2,922	38.7	26.6	9.4	32	10	4
Albany	NY	2007-2009	1,096	136.9	52.2	9.1	7	2	1
Bath	NY	2005-2009	1,826	414.4	80.7	8.1	3	1	0
Buffalo	NY	2007-2009	1,096	162.8	45.5	10.5	24	7	2
New York	NY	2000-2006	2,557	51.8	48.5	13.9	148	65	12
Akron	OH	1999-2004	2,192	118.4	55.5	16.1	14	4	2
Canton	OH	2009-2012	1,461	203.5	84.7	12.7	10	3	1
Cincinnati	OH	1999-2004	2,192	77.7	43.7	17	21	6	2
Cleveland	OH	1999-2004	2,192	74	33.3	16.9	51	18	4
Columbus	OH	1999-2004	2,192	273.8	148.7	16.3	21	6	2
Middletown	OH	2000-2003	1,461	148	79.9	16.2	7	2	1
Steubenville	OH	2011-2013	1,096	70.3	64.8	11.1	3	1	0
Toledo	OH	2001-2003	1,095	96.2	55.5	14.9	11	4	1
Youngstown	OH	1999-2004	2,192	99.9	60.3	15.5	11	4	1
Oklahoma City	OK	2005-2006	730	33.3	23.3	9.8	16	5	2
Tulsa	OK	2005-2006	730	40.7	25.9	11.3	13	4	1
Eugene	OR	1999-2004	2,192	59.2	25.5	10.2	7	2	1
Medford	OR	1999-2002	1,461	37	22.6	10.6	5	1	0
Portland	OR	1999-2002	1,461	122.1	54.4	8.7	28	7	3
Allentown	PA	2000-2009	3,653	595.7	199.1	13.6	8	2	1
Erie	PA	2004-2005	731	177.6	48.5	12.8	7	2	1
Gettysburg	PA	2001-2009	3,287	251.6	77	12.7	2	1	0
Harrisburg	PA	2001-2009	3,287	843.6	161.3	14.6	6	2	1
Mercer	PA	2002-2005	1,461	181.3	52.5	13.8	4	1	0
Philadelphia	PA	2004-2009	2,192	85.1	33.7	13.1	103	29	10
Pittsburgh	PA	2000-2009	3,653	173.9	60.3	16	37	12	4

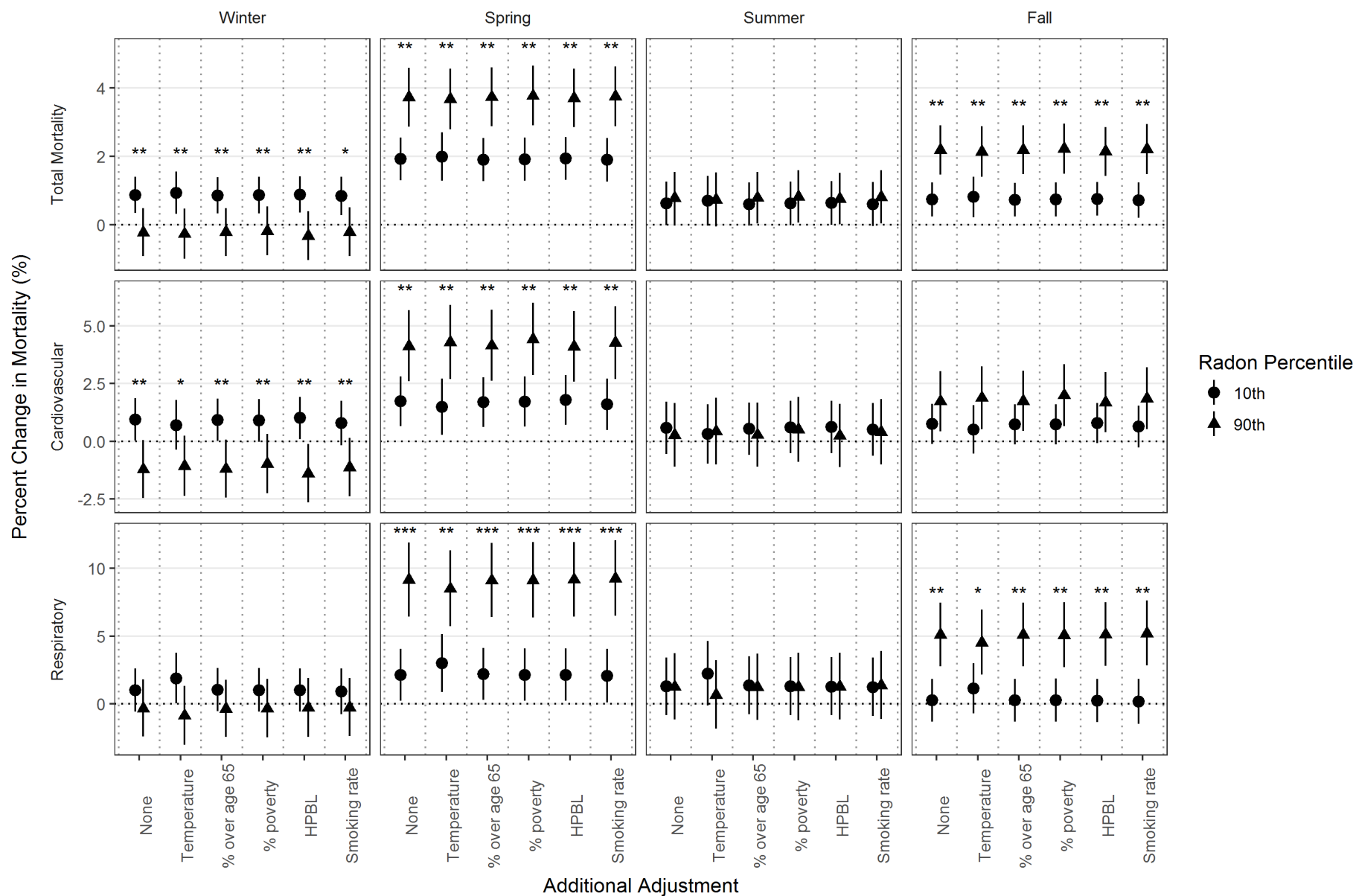
City	State	Years	Total Days	SRRS Rn (Bq/m <sup>3</sup> )	LBL Rn (Bq/m <sup>3</sup> )	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	Tot	CVD	Resp
Scranton	PA	2000-2009	3,653	111	49.2	11.5	18	6	2
State College	PA	2003-2009	2,557	521.7	143.9	12	3	1	0
Washington	PA	2003-2009	2,557	133.2	57.4	13.4	6	2	1
Columbia	SC	2007-2009	1,096	37	22.2	11.9	11	3	1
Greenville	SC	2000-2009	3,653	111	48.1	14.2	8	2	1
Spartanburg	SC	1999-2009	4,018	55.5	40.3	13.5	6	2	1
Knoxville	TN	2003-2006	1,461	96.2	68.8	15.4	12	3	1
Memphis	TN	2001-2005	1,826	37	32.6	13.4	19	6	2
Nashville	TN	2004-2005	731	188.7	90.7	13.5	12	4	1
Austin	TX	2000-2002	1,096	51.8	32.2	10.4	10	3	1
Corpus Christi	TX	2006-2007	730	25.9	17.4	9.8	7	2	1
Dallas	TX	2000-2009	3,653	44.4	32.9	11.8	35	10	3
El Paso	TX	2000-2002	1,096	37	24.8	9.6	10	3	1
Fort Worth	TX	2000-2007	2,922	40.7	30.7	11.9	25	7	2
Houston	TX	2000-2009	3,653	14.8	14.4	12.9	53	15	4
Port Arthur	TX	2001-2004	1,461	11.1	12.2	11	7	2	1
San Antonio	TX	2001-2002	730	40.7	27.8	9.1	26	8	2
Ogden	UT	2008-2009	731	129.5	101.4	9.6	4	1	0
Salt Lake City	UT	1999-2009	4,018	88.8	103.6	11.4	13	3	1
Annandale	VA	2007-2009	1,096	77.7	43.3	11.3	11	3	1
Norfolk	VA	2004-2009	2,192	29.6	12.2	11.4	25	7	3
Richmond	VA	2000-2009	3,653	51.8	31.4	12.8	15	4	2
Seattle	WA	1999-2005	2,557	14.8	14.4	9.5	29	8	3
Spokane	WA	2000-2002	1,096	366.3	232	9.8	9	3	1
Tacoma	WA	1999-2002	1,461	29.6	20.4	11.2	13	4	1
Beaver Dam	WI	2004-2005	731	177.6	109.9	11	2	1	0
Milwaukee	WI	1999-2001	1,096	114.7	66.2	13.7	30	9	3

**Table S2:** Estimated percent change in mortality associated with a 10  $\mu\text{g}/\text{m}^3$  increase in  $\text{PM}_{2.5}$ . Results are presented at the 10th and 90th percentile of radon (SRRS: 20.1 and 234.2  $\text{Bq}/\text{m}^3$ ; LBL: 18.1 and 108.0  $\text{Bq}/\text{m}^3$ )

<b>Radon Data</b>	<b>Outcome</b>	<b>Percentile</b>	<b>Winter</b>	<b>Spring</b>	<b>Summer</b>	<b>Fall</b>
SRRS	Total Mortality	10 <sup>th</sup>	0.86 (0.33, 1.4) **	1.92 (1.29, 2.55) **	0.62 (-0.02, 1.25)	0.73 (0.24, 1.23) **
		90 <sup>th</sup>	-0.23 (-0.93, 0.48) **	3.73 (2.87, 4.59) **	0.78 (0.03, 1.54)	2.18 (1.47, 2.9) **
	Cardiovascular	10 <sup>th</sup>	0.94 (0.03, 1.86) **	1.73 (0.65, 2.81) **	0.58 (-0.55, 1.72)	0.75 (-0.12, 1.62)
		90 <sup>th</sup>	-1.21 (-2.46, 0.04) **	4.12 (2.59, 5.68) **	0.26 (-1.11, 1.65)	1.73 (0.43, 3.04)
	Respiratory	10 <sup>th</sup>	1.01 (-0.56, 2.61)	2.13 (0.24, 4.07) ***	1.28 (-0.82, 3.43)	0.26 (-1.3, 1.84) **
		90 <sup>th</sup>	-0.32 (-2.4, 1.81)	9.14 (6.45, 11.9) ***	1.26 (-1.16, 3.74)	5.09 (2.79, 7.45) **
LBL	Total Mortality	10 <sup>th</sup>	0.93 (0.39, 1.48) **	2.40 (1.73, 3.06)	0.51 (-0.12, 1.15)	1.00 (0.47, 1.53)
		90 <sup>th</sup>	-0.46 (-1.24, 0.33) **	3.19 (2.17, 4.23)	0.96 (0.05, 1.87)	1.88 (1.04, 2.72)
	Cardiovascular	10 <sup>th</sup>	0.91 (0.03, 1.8) **	2.10 (1, 3.21)	0.06 (-1.03, 1.16)	0.83 (-0.04, 1.72)
		90 <sup>th</sup>	-1.45 (-2.81, -0.07) **	3.75 (1.93, 5.59)	1.11 (-0.51, 2.76)	1.65 (0.17, 3.15)
	Respiratory	10 <sup>th</sup>	0.87 (-0.66, 2.43)	3.01 (1.07, 4.99) **	0.37 (-1.63, 2.41)	0.44 (-1.14, 2.05) **
		90 <sup>th</sup>	-0.22 (-2.46, 2.08)	8.52 (5.37, 11.77) **	2.78 (-0.08, 5.72)	5.28 (2.66, 7.97) **

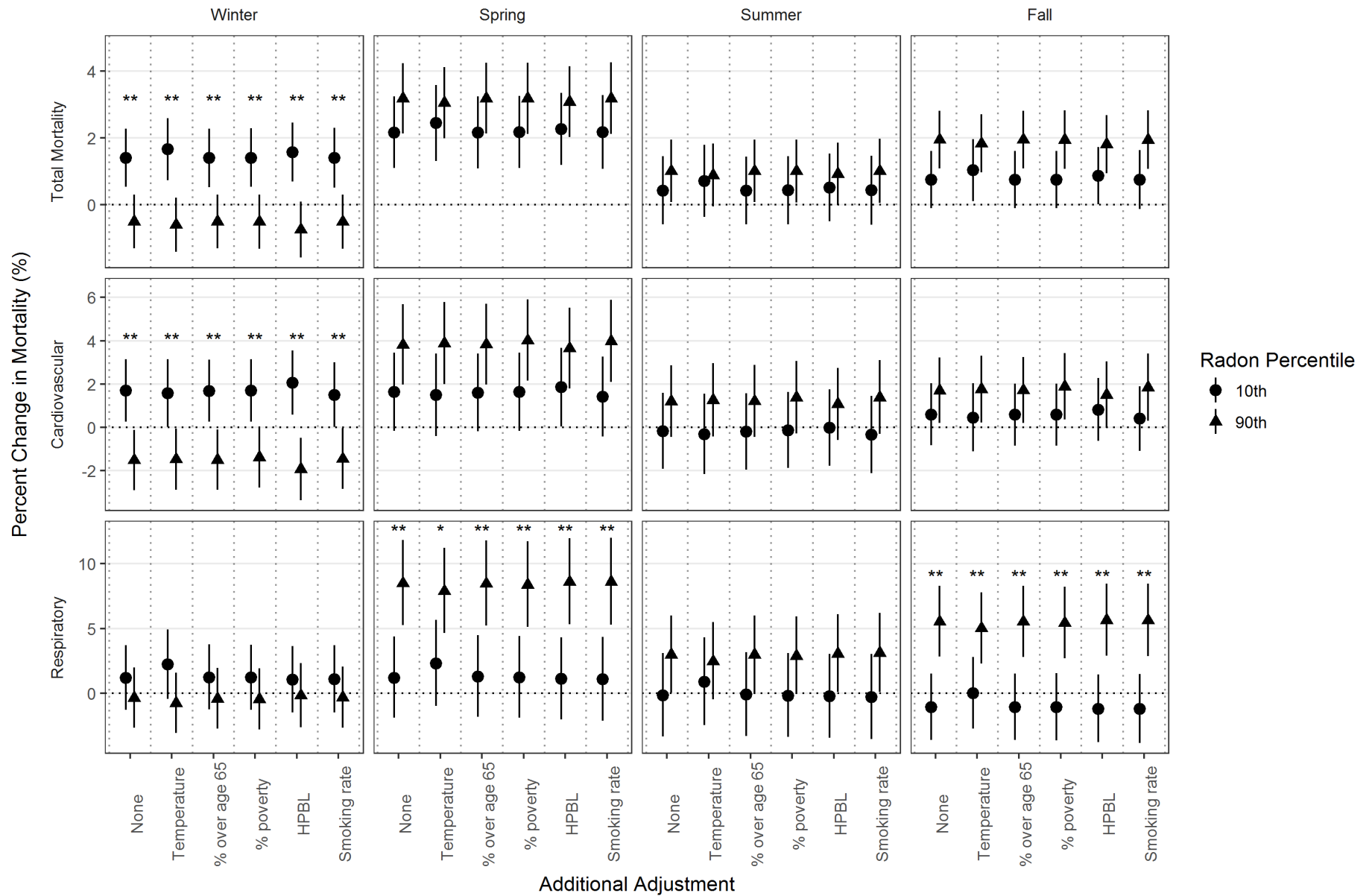


**Figure S1:** Forest plots of city- and season-specific  $PM_{2.5}$  effect estimates, ordered by mean city radon concentrations (SRRS).



**Figure S2:** Results of the SRRS meta-regression, with and without adjustment for additional city characteristics. Results are presented as the estimated percent change in mortality associated with a 10  $\mu\text{g}/\text{m}^3$  increase in  $\text{PM}_{2.5}$  at the 10<sup>th</sup> and 90<sup>th</sup> percentile of radon and the median value of other spatial variables (if included).

Significance for the  $\ln(\text{radon})$  term: \* p<0.1; \*\* p<0.05; \*\*\* p<0.001



**Figure S3:** Results of the LBL meta-regression, with and without adjustment for additional city characteristics. Results are presented as the estimated percent change in mortality associated with a 10  $\mu\text{g}/\text{m}^3$  increase in  $\text{PM}_{2.5}$  at the 10<sup>th</sup> and 90<sup>th</sup> percentile of radon and the median value of other spatial variables (if included).

Significance for the  $\ln(\text{radon})$  term: \*  $p < 0.1$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.001$