

THE LANCET

Planetary Health

Supplementary appendix

This appendix formed part of the original submission and has been peer reviewed.
We post it as supplied by the authors.

Supplement to: Prada D, Zhong J, Colicino E, et al. Association of air particulate pollution with bone loss over time and bone fracture risk: analysis of data from two independent studies. *Lancet Planet Health* 2017; **1**: e337–47.

SUPPLEMENTAL MATERIAL

Association of Air Particulate Pollution with Age-Related Bone Loss and Bone Fracture Risk: Two Independent Studies in the United States

Table of contents:

Supplementary Table 1. ICD-9 codes evaluated in the Medicare analysis (primary admission diagnosis), including only fractures at osteoporosis-related sites (forearm, neck of femur and vertebrae).

Supplementary Table 2. Description and sources for United States zip code level variables in the Medicare analysis.

Supplementary Table 3. Comparison on major characteristics between BACH/Bone participants with complete follow up data at year 8 and those with Inverse Probability Weighting (IPW) in the longitudinal analysis.

Supplementary Table 4. Characteristics of population and area per zip code in the North-Mid Atlantic U.S. area from 2003 to 2010.

Supplementary Table 5. Risk of hospital admissions by osteoporosis-related bone fractures associated with 1-year average increase in PM_{2.5} levels using alternative regression models.

Supplementary Figure 1. Association between 1-year average black carbon levels and percent of change in bone mineral density.

Supplementary Table 1. ICD-9 codes evaluated in the Medicare analysis (primary admission diagnosis), including only fractures at osteoporosis-related sites (forearm, neck of femur and vertebrae).

ICD-9 Code	Diagnosis
Forearm	
813	Fracture of radius and ulna
813.0	Fracture of upper end of radius and ulna closed
813.00	Closed fracture of upper end of forearm unspecified
813.01	Fracture of olecranon process of ulna closed
813.02	Fracture of coronoid process of ulna closed
813.03	Monteggia's fracture closed
813.04	Other and unspecified closed fractures of proximal end of ulna (alone)
813.05	Fracture of head of radius closed
813.06	Fracture of neck of radius closed
813.07	Other and unspecified closed fractures of proximal end of radius (alone)
813.08	Fracture of radius with ulna upper end (any part) closed
813.1	Fracture of upper end of radius and ulna open
813.10	Open fracture of upper end of forearm unspecified
813.11	Fracture of olecranon process of ulna open
813.12	Fracture of coronoid process of ulna open
813.13	Monteggia's fracture open
813.14	Other and unspecified open fractures of proximal end of ulna (alone)
813.15	Fracture of head of radius open
813.16	Fracture of neck of radius open
813.17	Other and unspecified open fractures of proximal end of radius (alone)
813.18	Fracture of radius with ulna upper end (any part) open
813.2	Fracture of shaft of radius and ulna closed
813.20	Fracture of shaft of radius or ulna unspecified closed
813.21	Fracture of shaft of radius (alone) closed
813.22	Fracture of shaft of ulna (alone) closed
813.23	Fracture of shaft of radius with ulna closed
813.3	Fracture of shaft of radius and ulna open
813.30	Fracture of shaft of radius or ulna unspecified open
813.31	Fracture of shaft of radius (alone) open
813.32	Fracture of shaft of ulna (alone) open
813.33	Fracture of shaft of radius with ulna open
813.4	Fracture of lower end of radius and ulna closed
813.40	Closed fracture of lower end of forearm unspecified
813.41	Colles' fracture closed
813.42	Other closed fractures of distal end of radius (alone)
813.43	Fracture of distal end of ulna (alone) closed
813.44	Fracture of lower end of radius with ulna closed
813.45	Torus fracture of radius (alone)
813.46	Torus fracture of ulna (alone)
813.47	Torus fracture of radius and ulna

This table continues on the next page.

This table is continued from the previous page.

813.5	Fracture of lower end of radius and ulna open
813.50	Open fracture of lower end of forearm unspecified
813.51	Colles' fracture open
813.52	Other open fractures of distal end of radius (alone)
813.53	Fracture of distal end of ulna (alone) open
813.54	Fracture of lower end of radius with ulna open
813.8	Fracture of unspecified part of radius with ulna closed
813.80	Closed fracture of unspecified part of forearm
813.81	Fracture of unspecified part of radius (alone) closed
813.82	Fracture of unspecified part of ulna (alone) closed
813.83	Fracture of unspecified part of radius with ulna closed
813.9	Fracture of unspecified part of radius with ulna open
813.90	Fracture of unspecified part of forearm open
813.91	Fracture of unspecified part of radius (alone) open
813.92	Fracture of unspecified part of ulna (alone) open
813.93	Fracture of unspecified part of radius with ulna open

Neck of femur

820	Fracture of neck of femur
820.0	Transcervical fracture closed
820.01	Fracture of unspecified intracapsular section of neck of femur closed
820.02	Fracture of midcervical section of femur closed
820.03	Fracture of base of neck of femur closed
820.09	Other transcervical fracture of femur closed
820.1	Transcervical fracture open
820.10	Fracture of unspecified intracapsular section of neck of femur open
820.11	Fracture of epiphysis (separation) (upper) of neck of femur open
820.12	Fracture of midcervical section of femur open
820.13	Fracture of base of neck of femur open
820.19	Other transcervical fracture of femur open
820.2	Petrochanteric fracture of femur closed
820.20	Fracture of unspecified trochanteric section of femur closed
820.21	Fracture of intertrochanteric section of femur closed
820.22	Fracture of subtrochanteric section of femur closed
820.3	Petrochanteric fracture of femur open
820.30	Fracture of unspecified trochanteric section of femur open
820.31	Fracture of intertrochanteric section of femur open
820.32	Fracture of subtrochanteric section of femur open
820.8	Fracture of unspecified part of neck of femur closed
820.9	Fracture of unspecified part of neck of femur open

Vertebrae

823	Fracture of vertebral column without mention of spinal cord injury
805.0	Closed fracture of cervical vertebra without mention of spinal cord injury
805.00	Closed fracture of cervical vertebra unspecified level
805.01	Closed fracture of first cervical vertebra
805.02	Closed fracture of second cervical vertebra

This table continues on the next page.

This table is continued from the previous page.

805.03	Closed fracture of third cervical vertebra
805.04	Closed fracture of fourth cervical vertebra
805.05	Closed fracture of fifth cervical vertebra
805.06	Closed fracture of sixth cervical vertebra
805.07	Closed fracture of seventh cervical vertebra
805.08	Closed fracture of multiple cervical vertebrae
805.1	Open fracture of cervical vertebra without mention of spinal cord injury
805.10	Open fracture of cervical vertebra unspecified level
805.11	Open fracture of first cervical vertebra
805.12	Open fracture of second cervical vertebra
805.13	Open fracture of third cervical vertebra
805.14	Open fracture of fourth cervical vertebra
805.15	Open fracture of fifth cervical vertebra
805.16	Open fracture of sixth cervical vertebra
805.17	Open fracture of seventh cervical vertebra
805.18	Open fracture of multiple cervical vertebrae
805.2	Closed fracture of dorsal (thoracic) vertebra without spinal cord injury
805.3	Open fracture of dorsal (thoracic) vertebra without spinal cord injury
805.4	Closed fracture of lumbar vertebra without spinal cord injury
805.5	Open fracture of lumbar vertebra without spinal cord injury
805.6	Closed fracture of sacrum and coccyx without spinal cord injury
805.7	Open fracture of sacrum and coccyx without spinal cord injury
805.8	Closed fracture of unspecified part of vertebral column without spinal cord injury
805.9	Open fracture of unspecified part of vertebral column without spinal cord injury
806	Fracture of vertebral column with spinal cord injury
806.0	Closed fracture of cervical vertebra with spinal cord injury
806.00	Closed fracture of c1-c4 level with unspecified spinal cord injury
806.01	Closed fracture of c1-c4 level with complete lesion of cord
806.02	Closed fracture of c1-c4 level with anterior cord syndrome
806.03	Closed fracture of c1-c4 level with central cord syndrome
806.04	Closed fracture of c1-c4 level with other specified spinal cord injury
806.05	Closed fracture of c5-c7 level with unspecified spinal cord injury
806.06	Closed fracture of c5-c7 level with complete lesion of cord
806.07	Closed fracture of c5-c7 level with anterior cord syndrome
806.08	Closed fracture of c5-c7 level with central cord syndrome
806.09	Closed fracture of c5-c7 level with other specified spinal cord injury
806.1	Open fracture of cervical vertebra with spinal cord injury
806.10	Open fracture of c1-c4 level with unspecified spinal cord injury
806.11	Open fracture of c1-c4 level with complete lesion of cord
806.12	Open fracture of c1-c4 level with anterior cord syndrome
806.13	Open fracture of c1-c4 level with central cord syndrome
806.14	Open fracture of c1-c4 level with other specified spinal cord injury
806.15	Open fracture of c5-c7 level with unspecified spinal cord injury
806.16	Open fracture of c5-c7 level with complete lesion of cord

This table continues on the next page.

This table is continued from the previous page.

806.17	Open fracture of c5-c7 level with anterior cord syndrome
806.18	Open fracture of c5-c7 level with central cord syndrome
806.19	Open fracture of c5-c7 level with other specified spinal cord injury
806.2	Closed fracture of dorsal vertebra with spinal cord injury
806.20	Closed fracture of t1-t6 level with unspecified spinal cord injury
806.21	Closed fracture of t1-t6 level with complete lesion of cord
806.22	Closed fracture of t1-t6 level with anterior cord syndrome
806.23	Closed fracture of t1-t6 level with central cord syndrome
806.24	Closed fracture of t1-t6 level with other specified spinal cord injury
806.25	Closed fracture of t7-t12 level with unspecified spinal cord injury
806.26	Closed fracture of t7-t12 level with complete lesion of cord
806.27	Closed fracture of t7-t12 level with anterior cord syndrome
806.28	Closed fracture of t7-t12 level with central cord syndrome
806.29	Closed fracture of t7-t12 level with other specified spinal cord injury
806.3	Open fracture of dorsal vertebra with spinal cord injury
806.30	Open fracture of t1-t6 level with unspecified spinal cord injury
806.31	Open fracture of t1-t6 level with complete lesion of cord
806.32	Open fracture of t1-t6 level with anterior cord syndrome
806.33	Open fracture of t1-t6 level with central cord syndrome
806.34	Open fracture of t1-t6 level with other specified spinal cord injury
806.35	Open fracture of t7-t12 level with unspecified spinal cord injury
806.36	Open fracture of t7-t12 level with complete lesion of cord
806.37	Open fracture of t7-t12 level with anterior cord syndrome
806.38	Open fracture of t7-t12 level with central cord syndrome
806.39	Open fracture of t7-t12 level with other specified spinal cord injury
806.4	Closed fracture of lumbar spine with spinal cord injury
806.5	Open fracture of lumbar spine with spinal cord injury
806.6	Closed fracture of sacrum and coccyx with spinal cord injury
806.60	Closed fracture of sacrum and coccyx with unspecified spinal cord injury
806.61	Closed fracture of sacrum and coccyx with complete cauda equina lesion
806.62	Closed fracture of sacrum and coccyx with other cauda equina injury
806.69	Closed fracture of sacrum and coccyx with other spinal cord injury
806.7	Open fracture of sacrum and coccyx with spinal cord injury
806.70	Open fracture of sacrum and coccyx with unspecified spinal cord injury
806.71	Open fracture of sacrum and coccyx with complete cauda equina lesion
806.72	Open fracture of sacrum and coccyx with other cauda equina injury
806.79	Open fracture of sacrum and coccyx with other spinal cord injury
806.8	Closed fracture of unspecified vertebra with spinal cord injury
806.9	Open fracture of unspecified vertebra with spinal cord injury

Supplementary Table 2. Description and sources for United States zip code level variables in the Medicare analysis

Variable	Description	Source
Population	Number of people ≥ 65 years old living in a zip code in 2000	2000 Census
Education	Percent of high school graduates	2000 Census
Socioeconomic status	Median income Percent of non-Hispanic whites	2000 Census
Obesity prevalence	Average age-adjusted percentage of population that is obese (data from 2004–2010)	Centers for Disease Control and Prevention
Sex	Percent of females	2000 Census
Age	Percent of population 65-74 and ≥ 75 years old	2000 Census
Temperature	Number of days with freezing temperatures ($< 0^{\circ}\text{C}$)	National Oceanic and Atmospheric Administration
Location	Urban or rural area	U.S. Department of Agriculture

Supplementary Table 3. Comparison on major characteristics between BACH/Bone participants with complete follow up data at year 8 and those with Inverse Probability Weighting (IPW) in the longitudinal analysis.

Characteristic	Participants with complete follow up data at year 8 ^a n (%) or mean (SE)	Participants with IPW in the longitudinal analysis ^b n (%) or mean (SD)
Age		
<40	139 (29%)	146 (28%)
40-49	206 (32%)	134 (25%)
50-59	183 (20%)	102 (19%)
>=60	164 (19%)	145 (28%)
Race		
Black	214 (28%)	153 (29%)
Hispanic	204 (13%)	197 (37%)
White	274 (59%)	177 (34%)
Smoking status		
Never	301 (47%)	187 (36%)
Former	196 (28%)	179 (34%)
Current	195 (25%)	159 (30%)
Household income		
0- \$6,000	146 (13%)	131 (26%)
\$6001 - \$30,000	377 (54%)	263 (53%)
>\$30,000	169 (33%)	106 (21%)
Physical activity (PASE score)		
Low (0-99)	191 (25%)	170 (32%)
Middle (100-249)	348 (51%)	239 (46%)
High (250+)	153 (24%)	116 (22%)
Height (cm)	175.64 (0.35)	172.9 (0.33)
Weight (kg)	88.13 (0.82)	85.5 (0.75)
Serum 25(OH)D (ng/ml)	33.15 (0.80)	32.7 (0.74)
Bone Mineral Density (BMD, g/cm ²)		
Femoral neck	0.88 (0.01)	0.9 (0.01)
Total hip	1.03 (0.01)	1.0 (0.01)
L1-L4	1.05 (0.01)	1.0 (0.01)
1/3 Distal radius	0.77 (0.00)	0.8 (0.00)
Ultra distal radius	0.53 (0.00)	0.5 (0.00)
Black Carbon 1-year average (µg/m ³)	0.77 (0.01)	0.81 (0.01)

a. Unweighted n. b. Weighted % for those with Bone 1 and Bone 2

Supplementary Table 4. Characteristics of population and area per zip code in the North-Mid Atlantic U.S. area from 2003 to 2010.

	Mean	SD	Max	Min
Population	12,136.45	15,460.31	106,154	23
Area (Km ²)	87.18	122.88	3298.27	0.01
PM _{2.5} levels (µg/m ³)	10.18	2.73	22.68	2.91
Median income (k)	51.64	21.33	200.00	12.15
% white, non-Hispanic	85.60	21.00	100.00	0.00
% female	53.28	6.78	66.15	45.22
% of population that are 75 yrs or older	44.50	6.40	56.25	32.75

SES=Socioeconomic status. PM_{2.5} = fine particulate matter <2.5µm.

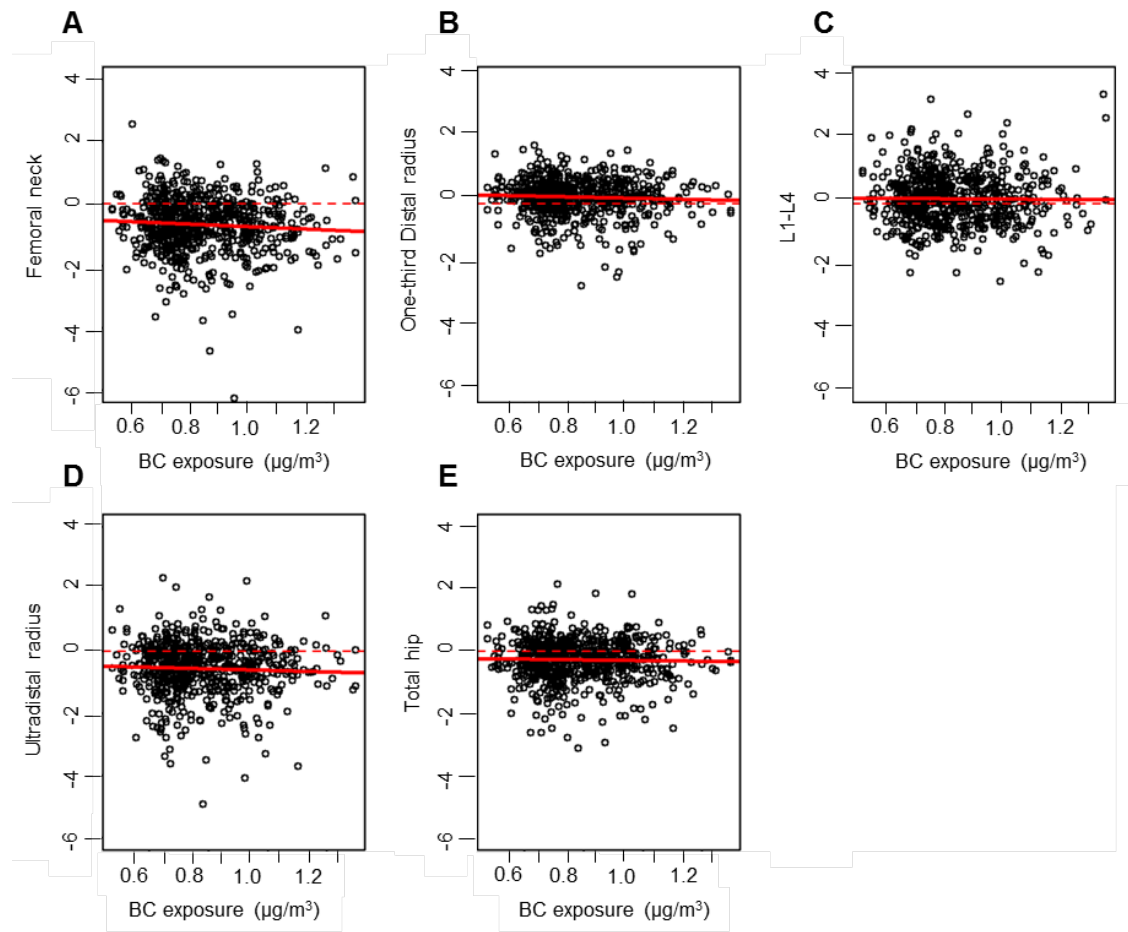
Supplementary Table 5. Risk of hospital admissions by osteoporosis-related bone fractures associated with 1-year average increase in PM_{2.5} levels using alternative regression models^a

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
PM _{2.5}	1.117 (1.109, 1.126)	1.213 (1.204, 1.223)	1.052 (1.040, 1.064)	1.061 (1.049, 1.072)	1.078 (1.066, 1.090)	1.041 (1.030, 1.051)
% white, non-Hispanic	1.034 (1.025, 1.043)	1.037 (1.028, 1.046)	1.071 (1.061, 1.080)	1.056 (1.046, 1.066)	1.101 (1.089, 1.112)	1.045 (1.038, 1.052)
% high school graduate	1.076 (1.055, 1.096)	1.074 (1.053, 1.095)	1.063 (1.040, 1.085)	1.048 (1.026, 1.070)	1.064 (1.039, 1.088)	1.035 (0.998, 1.072)
Median income	1.011 (0.976, 1.046)	1.009 (0.995, 1.023)	0.999 (0.989, 1.009)	0.994 (0.984, 1.005)	0.983 (0.963, 1.003)	0.998 (0.992, 1.004)
% obese	1.010 (0.960, 1.059)	1.012 (0.963, 1.062)	0.847 (0.794, 0.900)	1.074 (1.020, 1.127)	0.852 (0.792, 0.912)	0.973 (0.935, 1.011)
% female	1.088 (1.041, 1.134)	1.081 (1.035, 1.127)	1.178 (1.128, 1.228)	1.073 (1.027, 1.120)	1.153 (1.101, 1.205)	1.087 (1.047, 1.127)
% ≥75 years old ^b	1.480 (1.388, 1.573)	1.471 (1.379, 1.564)	1.311 (1.211, 1.411)	1.472 (1.379, 1.565)	1.266 (1.163, 1.370)	1.096 (1.087, 1.105)
Number of days below 0°C	-	-	-	-	1.009 (1.008, 1.009)	1.011 (1.010, 1.011)
Urban (vs. rural) ^c	-	-	-	-	-	0.998 (0.925, 1.071)
Year variable	Linear	Linear and square	Indicator variable	Indicator variable	Indicator variable	Indicator variable
State indicator	No	No	No	Yes	Yes	Yes
AIC	145223.8	144934.9	144622.9	143863.8	143823.9	141994.9

a. Estimated risk of hospital admissions with primary diagnosis of bone fracture (N=832,622 cases) for an interquartile range (4.18 μg/m³) increase in 1-year average in fine particulate matter <2.5μm (PM_{2.5}) across 3,974 zip code areas in the U.S. North/Mid-Atlantic area in the period 2003-2010. b. Age was categorized in percentage of population that are 65 to 74 years old and percentage of population that are 75 years old or older per zip code area. c. Rural areas included large, small, and isolated rural categories.

RR= risk ratio. 95% CI= 95% confidence interval. AIC= Akaike information criterion.

Model 1: Model for the association between PM_{2.5} (1-year average) and number of cases by zip code, fitting a random intercept for zip code to account for correlation of rates of fractures across years within each zip code, and using years as a continuous variable. Model 2: As in Model 1, but using years and years² (both as continuous variables). Model 3: As in Model 1, plus controlling for time using an indicator variable for each year in the data. Model 4: As in Model 3, plus adjusting for difference between states, using an indicator variable for each state. Model 5: As in Model 4, plus adjusting for number of days below 0°C. Model 6: As in Model 5, plus adjusting for urban vs. rural location.



Supplementary Figure 1. Association between 1-year average black carbon levels and percent of change in bone mineral density.

A. Femoral neck; B. One-third distal radius; C. L1-L4; D. Ultradistal radius; E. Total hip; Continuous red line=Unadjusted regression line; Dotted red line=No change.