

Note to readers with disabilities: *EHP* strives to ensure that all journal content is accessible to all readers. However, some figures and Supplemental Material published in *EHP* articles may not conform to [508 standards](#) due to the complexity of the information being presented. If you need assistance accessing journal content, please contact ehp508@niehs.nih.gov. Our staff will work with you to assess and meet your accessibility needs within 3 working days.

Supplemental Material

PM_{2.5} and Serum Metabolome and Insulin Resistance, Potential Mediation by the Gut Microbiome: A Population-Based Panel Study of Older Adults in China

Liang Zhao, Jianlong Fang, Song Tang, Fuchang Deng, Xiaohui Liu, Yu Shen, Yuanyuan Liu, Fanling Kong, Yanjun Du, Liangliang Cui, Wanying Shi, Yan Wang, Jiaonan Wang, Yingjian Zhang, Xiaoyan Dong, Ying Gao, Li Dong, Huichan Zhou, Qinghua Sun, Haoran Dong, Xiumiao Peng, Yi Zhang, Meng Cao, Yanwen Wang, Hong Zhi, Hang Du, Jingyang Zhou, Tiantian Li, and Xiaoming Shi

Table of Contents

Table S1. Descriptive characteristics of 76 study participant in the following four visits and repeated measurement variables in the Jinan panel from 2018 to 2019.

Table S2. Significant metabolic pathways associated to PM_{2.5} in the Jinan panel study.

Table S3. Percent change in insulin resistance-related biomarkers for a 10 µg/m³ increase in PM_{2.5} among older Chinese adults in the LME models with 95% confidence intervals.

Table S4. Percent change in insulin resistance-related biomarkers for a 10 µg/m³ increase in PM_{2.5} among older Chinese adults in the LME models with 95% confidence intervals (gender stratification).

Table S5. Kruskal-Wallis H test of featured genera amongst all study participants.

Table S6. Mediated effects of gut microbiota in the associations linking PM_{2.5} with sphingolipid metabolism among older Chinese adults in the Jinan panel study.

Table S7. Sensitivity analysis models in the Jinan panel study.

Table S8. Sensitivity analysis results in the Jinan panel study.

Figure S1. The pathway of sphingolipid metabolism.

Figure S2. Percent change in insulin resistance-related biomarkers for a 10 $\mu\text{g}/\text{m}^3$ increase in $\text{PM}_{2.5}$ among older Chinese adults in the LME models with 95% confidence intervals (gender stratification).

Figure S3. Changes in feces microbial diversities among older Chinese adults in the Jinan panel study.

Figure S4. Abundance of gut microbiota (16 genera) among older Chinese adults in the Jinan panel study.

Figure S5. Significant results of 16S rRNA associated with $\text{PM}_{2.5}$ among older Chinese adults in the Jinan panel study.

Additional File- R code for mediation analysis.txt File and Excel Document

Table S1: Descriptive characteristics of 76 study participant in the following four visits and repeated measurement variables in the Jinan panel from 2018 to 2019.

Variables	1 st (N=73)		2 nd (N=70)		3 rd (N=71)		4 th (N=71)	
	Mean ± SD (or N)	Range (or %)	Mean ± SD (or N)	Range (or %)	Mean ± SD (or N)	Range (or %)	Mean ± SD (or N)	Range (or %)
Characteristics								
Gender (M/F)	35 / 38	48 / 52	35 / 35	50 / 55	34 / 37	48 / 52	37 / 34	52 / 48
Age (years)	64.96±2.87	60-70	64.97±2.84	60-70	64.89±2.86	60-70	65.04±2.86	60-70
Height (cm)	162.48±7.79	143-178	162.89±7.98	143-176.5	162.52±7.96	143-176.5	162.83±7.93	143-176.5
Weight (kg)	66.37±9.14	44.1-85	66.78±9.26	44.1-85	66.52±8.92	44.1-84	66.49±9.13	44.1-85
BMI (kg/m ²)	25.09±2.47	17.86-28.19	25.1±2.31	18.44-28.08	25.13±2.3	18.44-28.07	25.02±2.44	18.44-28.08
Education	73	100	70	100	71	100	71	100
Below primary school	5	6.85	4	5.71	5	7.04	5	7.04
Primary school	3	4.11	2	2.86	2	2.82	1	1.41
Junior school	21	28.77	19	27.14	19	26.76	20	28.17
Senior high school	32	43.84	31	44.29	31	43.66	31	43.66
University	12	16.44	14	20	14	19.72	14	19.72
Income (10,000 RMB)	9.79±6.73	0-36	10.26±6.79	0-36	10.14±6.56	0-36	10.44±6.7	0-36
Cotinine (ng/ml)	0.55±2.5	0.03-21.48	0.58±3.41	0.01-28.69	1.27±4.97	0.03-29.55	2.31±10.86	0.03-84.38
Drink (Yes/No)	2 / 70	3 / 92	3 / 67	4 / 96	1 / 70	1 / 99	0 / 70	0 / 99
Cook (Yes/No)	62 / 10	85 / 15	61 / 9	87 / 13	64 / 7	90 / 10	63 / 8	89 / 11
Functional indicators								
Glucose (mmol/L)	6.15±0.64	5.08-7.87	6.27±0.63	5.05-8.12	6.36±0.56	4.63-7.54	8.11±2.63	5.08-13.05
TC (mmol/L)	5.51±0.87	3.42-9.08	5.43±0.78	3.86-7.21	5.67±0.78	4.12-7.5	6.99±2.26	2.82-11.39
TG (mmol/L)	1.48±0.41	0.63-3	1.61±0.51	0.88-3.67	1.5±0.46	0.86-2.4	1.83±0.74	0.77-4.28

Insulin resistance indexes								
Insulin (μ IU/mL)	4.47 \pm 3.44	1.78-16.99	4.78 \pm 3.88	1.81-19.83	5.55 \pm 4.41	1.71-20.33	6.5 \pm 4.73	1.71-23.85
HOMA-IR	1.21 \pm 0.94	0.41-5.17	1.35 \pm 1.22	0.42-6.36	1.59 \pm 1.32	0.35-6.39	2.55 \pm 2.55	0.45-13.31
IAI	0.06 \pm 0.03	0.01-0.11	0.05 \pm 0.03	0.01-0.11	0.05 \pm 0.04	0.01-0.13	0.04 \pm 0.03	0-0.1
Insulin resistance related biomarkers (Inflammation)								
IL-4 (pg/ml)	175.38 \pm 106.29	11.18-514.51	328.01 \pm 217.81	16.28-1131	180.85 \pm 134	15.01-629.74	253.27 \pm 179.16	8.94-824.21
IL-6 (pg/ml)	0.78 \pm 1.59	0.04-12.58	2.02 \pm 3.34	0.04-20.41	1.34 \pm 3.03	0.09-22.29	1.81 \pm 4.10	0.05-30.73
IL-10 (pg/ml)	8.87 \pm 49	0.35-421.25	7.9 \pm 31.16	0.94-263.5	5 \pm 14.22	0.43-121.78	10.01 \pm 56.97	0.37-482.61
IL-13 (pg/ml)	2.64 \pm 2.46	0.06-12.39	6.70 \pm 3.91	0.06-16.14	3.84 \pm 2.84	0.12-11.48	4.35 \pm 3.43	0.12-13.39
IL-23 (pg/ml)	332.85 \pm 853.04	1.78-5062	312.35 \pm 653.45	7.22-4499	262.37 \pm 685.06	2.18-5018	259.59 \pm 742.6	4.13-4820
MIP.3. α (pg/ml)	19.73 \pm 73.67	3.74-616.32	13.19 \pm 28.44	2.69-242.75	12.24 \pm 22.62	2.93-193.07	13.94 \pm 23.32	3.24-190.11
TNF- α (pg/ml)	3.43 \pm 1.3	1.09-6.84	4.23 \pm 1.58	1.87-8.87	4.09 \pm 1.45	1.1-8.02	3.19 \pm 1.14	1.17-7.22
Insulin resistance related biomarkers (other)								
MCP.1 (pg/ml)	130.42 \pm 41.62	44.89-281.55	139.49 \pm 50.29	35.44-282.63	129.30 \pm 46.12	36.43-281.57	130.73 \pm 49.60	21.23-323.02
PYY (pg/ml)	12.66 \pm 19.44	8.62-170.67	11.78 \pm 13.4	7.6-109.52	10.59 \pm 13.5	7.26-113.49	14.9 \pm 15.59	7.26-91.26
CRP (μ g/ml)	5.62 \pm 2.31	1.8-15.6	7.95 \pm 17.37	0.6-123	10.36 \pm 21.08	0.4-153.6	13.45 \pm 27.01	0.2-148.8
Fetuin A (μ g/ml)	192.91 \pm 27.29	130-307.4	209.32 \pm 34.01	137.6-288.2	223.64 \pm 100.12	98.8-664.4	194.13 \pm 30	121.2-273.8
SAP (μ g/ml)	7.1 \pm 1.34	4.2-12.8	7.7 \pm 2.04	4.2-13.8	8.86 \pm 5.81	2.8-36.4	7.13 \pm 1.86	4.2-13

Table S2: Significant metabolic pathways associated to PM_{2.5} in the Jinan panel study.

No.	Pathway Name	Match Status	P	FDR	Impact (%)
1	Arginine biosynthesis	6/14	0.001383	0.078297	11.68
2	Aminoacyl-tRNA biosynthesis	12/48	0.001864	0.078297	16.67
3	Histidine metabolism	6/16	0.003110	0.087075	34.43
4	Alanine, aspartate and glutamate metabolism	8/28	0.004539	0.095313	67.15
5	Biosynthesis of unsaturated fatty acids	9/36	0.006969	0.117080	0.00
6	Sphingolipid metabolism	6/21	0.013799	0.187660	48.28
7	D-Glutamine and D-glutamate metabolism	3/6	0.015638	0.187660	50.00
8	Glycerophospholipid metabolism	8/36	0.022081	0.231860	49.65
9	Glyoxylate and dicarboxylate metabolism	7/32	0.034261	0.305080	22.75
10	Cysteine and methionine metabolism	7/33	0.039950	0.305080	32.95
11	Glycine, serine and threonine metabolism	7/33	0.039950	0.305080	53.74

Metabolic pathways were identified through the analysis modules of MetaboAnalyst website.

Table S3: Percent change in insulin resistance-related biomarkers for a 10 $\mu\text{g}/\text{m}^3$ increase in $\text{PM}_{2.5}$ among older Chinese adults in the LME models with 95% confidence intervals.

Adjusted covariates included age (continuous), sex (female or male), BMI (continuous), annual income (continuous), education status, smoking status, alcohol consumption status, cooking status, day of the week of the clinical visit, temperature and relative humidity.

Variables	Lag (h)	ER(95%CI)
Sphingolipid Metabolism		
L-serine	lag06	-0.16(-0.29,-0.03)
	lag012	-0.38(-0.54,-0.21)
	lag024	-0.50(-0.67,-0.33)
	lag036	-0.49(-0.68,-0.30)
	lag048	-0.48(-0.69,-0.28)
	lag072	-0.45(-0.68,-0.22)
O-phosphoethanolamine	lag06	0.73(0.24,1.21)
	lag012	1.42(0.80,2.03)
	lag024	1.93(1.30,2.56)
	lag036	2.03(1.34,2.72)
	lag048	2.25(1.52,2.99)
	lag072	2.15(1.34,2.96)
sphingasine	lag06	-1.18(-1.90,-0.47)
	lag012	-2.28(-3.16,-1.40)
	lag024	-3.03(-3.93,-2.11)
	lag036	-2.84(-3.85,-1.81)
	lag048	-2.71(-3.80,-1.61)
	lag072	-2.14(-3.36,-0.90)
sphingomyelin	lag06	0.0002(-0.11,0.10)
	lag012	-0.11(-0.24,0.02)
	lag024	-0.17(-0.31,-0.03)
	lag036	-0.20(-0.35,-0.04)
	lag048	-0.23(-0.40,-0.07)
	lag072	-0.25(-0.43,-0.07)
sphingosine	lag06	-1.28(-2.09,-0.45)
	lag012	-2.56(-3.57,-1.55)
	lag024	-3.43(-4.47,-2.39)
	lag036	-3.15(-4.31,-1.96)
	lag048	-2.92(-4.19,-1.65)
	lag072	-2.04(-3.44,-0.61)
ceramide	lag06	0.02(-0.27,0.30)
	lag012	-0.36(-0.72,0)
	lag024	-0.63(-1.01,-0.25)
	lag036	-0.71(-1.12,-0.29)
	lag048	-0.84(-1.29,-0.39)

	lag072	-0.82(-1.31,-0.33)
Insulin Resistance Indexes		
Insulin	lag06	-0.13(-0.98,0.73)
	lag012	0.58(-0.53,1.70)
	lag024	1.38(0.20,2.57)
	lag036	1.40(0.09,2.72)
	lag048	1.58(0.18,3.00)
	lag072	1.64(0.12,3.19)
HOMA-IR	lag06	-0.10(-1.07,0.87)
	lag012	0.97(-0.31,2.26)
	lag024	2.30(0.90,3.73)
	lag036	2.33(0.80,3.89)
	lag048	2.74(1.08,4.43)
	lag072	2.78(0.94,4.66)
IAI	lag06	0.11(-0.86,1.08)
	lag012	-0.96(-2.21,0.32)
	lag024	-2.25(-3.60,-0.89)
	lag036	-2.28(-3.74,-0.79)
	lag048	-2.66(-4.24,-1.06)
	lag072	-2.71(-4.45,-0.93)
Inflammations		
IL-4	lag06	-0.68(-1.41,0.05)
	lag012	-1.17(-2.10,-0.23)
	lag024	-1.62(-2.59,-0.65)
	lag036	-1.88(-2.94,-0.82)
	lag048	-1.88(-3.02,-0.73)
	lag072	-1.63(-2.87,-0.37)
IL-6	lag06	-0.74(-2.36,0.91)
	lag012	-1.04(-3.13,1.09)
	lag024	-1.08(-3.27,1.17)
	lag036	-1.10(-3.55,1.40)
	lag048	-0.84(-3.47,1.85)
	lag072	0.03(-2.86,3.00)
IL-10	lag06	-0.98(-1.79,-0.16)
	lag012	-1.84(-2.86,-0.81)
	lag024	-2.34(-3.40,-1.27)
	lag036	-2.42(-3.61,-1.22)
	lag048	-2.49(-3.77,-1.18)
	lag072	-2.18(-3.60,-0.75)
IL-13	lag06	-1.26(-2.58,0.07)
	lag012	-1.86(-3.57,-0.11)
	lag024	-2.02(-3.82,-0.19)
	lag036	-2.06(-4.04,-0.04)

	lag048	-1.61(-3.74,0.58)
	lag072	-0.69(-3.06,1.73)
IL-23	lag06	-1.36(-2.33,-0.37)
	lag012	-2.49(-3.72,-1.24)
	lag024	-3.33(-4.59,-2.05)
	lag036	-3.51(-4.93,-2.08)
	lag048	-3.48(-5.01,-1.92)
	lag072	-2.98(-4.68,-1.24)
MIP-3 α	lag06	0.34(-0.46,1.13)
	lag012	0.37(-0.65,1.40)
	lag024	0.68(-0.40,1.76)
	lag036	0.63(-0.56,1.83)
	lag048	0.68(-0.61,1.98)
	lag072	0.87(-0.53,2.29)
TNF- α	lag06	-0.93(-1.37,-0.49)
	lag012	-1.50(-2.06,-0.94)
	lag024	-1.77(-2.36,-1.19)
	lag036	-1.95(-2.59,-1.30)
	lag048	-2.03(-2.73,-1.33)
	lag072	-1.94(-2.72,-1.15)

Other biomarkers

MCP.1	lag06	0.12(-0.27,0.51)
	lag012	-0.04(-0.55,0.47)
	lag024	-0.33(-0.86,0.21)
	lag036	-0.31(-0.90,0.28)
	lag048	-0.33(-0.97,0.30)
	lag072	-0.32(-1.01,0.37)
PYY	lag06	-0.14(-0.84,0.56)
	lag012	-0.25(-1.14,0.66)
	lag024	-0.03(-0.98,0.93)
	lag036	-0.22(-1.28,0.84)
	lag048	-0.29(-1.42,0.85)
	lag072	-0.64(-1.86,0.59)
CRP	lag06	1.15(-0.71,3.05)
	lag012	1.69(-0.69,4.13)
	lag024	1.81(-0.71,4.39)
	lag036	1.87(-0.90,4.73)
	lag048	1.58(-1.39,4.65)
	lag072	1.33(-1.90,4.67)
Fetuin A	lag06	0.58(0.17,1.00)
	lag012	0.59(0.06,1.12)
	lag024	0.43(-0.14,1.00)

	lag036	0.54(-0.09,1.17)
	lag048	0.46(-0.22,1.15)
	lag072	0.26(-0.48,1.01)
SAP	lag06	0.69(0.15,1.24)
	lag012	0.53(-0.18,1.23)
	lag024	0.18(-0.57,0.93)
	lag036	0.32(-0.52,1.16)
	lag048	0.18(-0.73,1.10)
	lag072	0.02(-0.97,1.02)
Functional factors		
Glucose	lag06	0.15(-0.16,0.46)
	lag012	0.54(0.14,0.95)
	lag024	0.88(0.45,1.31)
	lag036	0.92(0.46,1.39)
	lag048	1.06(0.57,1.56)
	lag072	1.19(0.65,1.74)
TC	lag06	0.25(-0.09,0.59)
	lag012	0.86(0.42,1.31)
	lag024	1.51(1.03,1.99)
	lag036	1.62(1.10,2.14)
	lag048	1.91(1.36,2.46)
	lag072	2.09(1.48,2.70)
TG	lag06	0.07(-0.33,0.47)
	lag012	0.36(-0.18,0.91)
	lag024	0.74(0.13,1.36)
	lag036	0.74(0.07,1.41)
	lag048	0.87(0.15,1.60)
	lag072	0.93(0.14,1.72)

Table S4: Percent change in insulin resistance-related biomarkers for a 10 $\mu\text{g}/\text{m}^3$ increase in $\text{PM}_{2.5}$ among older Chinese adults in the LME models with 95% confidence intervals (gender stratification).

Adjusted covariates included age (continuous), sex (female or male), BMI (continuous), annual income (continuous), education status, smoking status, alcohol consumption status, cooking status, day of the week of the clinical visit, temperature and relative humidity.

Variables	Lag (h)	ER(95%CI)	
		Female	Male
Sphingolipid Metabolism			
L-serine	lag06	-0.07(-0.19,0.06)	-0.99(-1.43,-0.54)
	lag012	-0.17(-0.35,0)	-0.84(-1.19,-0.50)
	lag024	-0.37(-0.58,-0.16)	-0.65(-0.93,-0.37)
	lag036	-0.31(-0.54,-0.08)	-0.71(-1.04,-0.38)
	lag048	-0.32(-0.57,-0.06)	-0.66(-1.00,-0.31)
	lag072	-0.27(-0.56,0.03)	-0.63(-1.00,-0.25)
O-phosphoethanolamine	lag06	0.45(-0.10,1.00)	3.13(1.57,4.71)
	lag012	0.99(0.18,1.80)	2.43(1.30,3.58)
	lag024	1.80(0.82,2.78)	2.14(1.25,3.03)
	lag036	1.68(0.61,2.76)	2.49(1.51,3.49)
	lag048	1.95(0.78,3.14)	2.59(1.59,3.59)
	lag072	1.96(0.61,3.32)	2.31(1.26,3.38)
sphingasine	lag06	-0.75(-1.53,0.04)	-5.91(-8.08,-3.69)
	lag012	-1.68(-2.79,-0.56)	-3.95(-5.60,-2.28)
	lag024	-2.88(-4.19,-1.55)	-3.41(-4.76,-2.04)
	lag036	-2.69(-4.15,-1.20)	-3.39(-4.93,-1.83)
	lag048	-2.74(-4.36,-1.10)	-3.04(-4.64,-1.41)
	lag072	-2.16(-4.02,-0.27)	-2.28(-4.01,-0.52)
sphingomyelin	lag06	0.02(-0.10,0.13)	-0.39(-0.74,-0.03)
	lag012	-0.06(-0.22,0.11)	-0.41(-0.68,-0.15)
	lag024	-0.14(-0.34,0.07)	-0.32(-0.53,-0.10)
	lag036	-0.14(-0.36,0.08)	-0.40(-0.64,-0.16)
	lag048	-0.19(-0.43,0.06)	-0.40(-0.65,-0.15)
	lag072	-0.18(-0.45,0.10)	-0.39(-0.65,-0.12)
sphingosine	lag06	-0.73(-1.61,0.17)	-6.81(-9.25,-4.31)
	lag012	-1.81(-3.06,-0.54)	-4.57(-6.45,-2.65)
	lag024	-3.30(-4.79,-1.79)	-3.81(-5.34,-2.25)
	lag036	-2.95(-4.60,-1.28)	-3.60(-5.35,-1.83)
	lag048	-2.99(-4.82,-1.13)	-3.14(-4.95,-1.29)
	lag072	-2.09(-4.21,0.07)	-2.37(-4.31,-0.40)
ceramide	lag06	0.04(-0.26,0.34)	-0.81(-1.85,0.23)
	lag012	-0.18(-0.61,0.25)	-1.12(-1.89,-0.34)
	lag024	-0.56(-1.08,-0.03)	-0.95(-1.57,-0.33)

	lag036	-0.58(-1.15,-0.02)	-1.20(-1.90,-0.49)
	lag048	-0.80(-1.42,-0.18)	-1.22(-1.95,-0.48)
	lag072	-0.68(-1.38,0.02)	-1.17(-1.94,-0.40)
Insulin Resistance Indexes			
Insulin	lag06	-0.49(-1.50,0.54)	2.13(-0.42,4.74)
	lag012	-0.15(-1.61,1.34)	1.99(0.02,4.00)
	lag024	1.17(-0.67,3.04)	1.56(-0.02,3.17)
	lag036	0.92(-1.03,2.91)	1.74(-0.10,3.61)
	lag048	1.19(-0.97,3.39)	1.64(-0.27,3.58)
	lag072	1.78(-0.62,4.24)	1.20(-0.78,3.22)
HOMA-IR	lag06	-0.43(-1.53,0.68)	3.22(-0.31,6.88)
	lag012	0.20(-1.44,1.87)	2.77(0.25,5.35)
	lag024	1.98(-0.17,4.18)	2.57(0.56,4.61)
	lag036	1.74(-0.50,4.03)	2.92(0.63,5.27)
	lag048	2.29(-0.21,4.85)	2.90(0.52,5.34)
	lag072	2.75(-0.10,5.68)	2.56(0.04,5.16)
IAI	lag06	0.44(-0.67,1.56)	-3.12(-6.43,0.31)
	lag012	-0.20(-1.83,1.47)	-2.70(-5.08,-0.25)
	lag024	-1.94(-4.01,0.17)	-2.50(-4.41,-0.56)
	lag036	-1.71(-3.87,0.51)	-2.84(-5.01,-0.63)
	lag048	-2.24(-4.63,0.21)	-2.82(-5.07,-0.52)
	lag072	-2.67(-5.37,0.10)	-2.50(-4.90,-0.04)
Inflammations			
IL-4	lag06	-0.39(-1.17,0.41)	-2.10(-4.55,0.42)
	lag012	-0.97(-2.09,0.17)	-1.50(-3.42,0.47)
	lag024	-1.77(-3.13,-0.38)	-1.65(-3.16,-0.12)
	lag036	-2.00(-3.44,-0.55)	-1.87(-3.60,-0.11)
	lag048	-2.18(-3.76,-0.58)	-1.71(-3.50,0.13)
	lag072	-2.39(-4.15,-0.61)	-1.16(-3.05,0.78)
IL-6	lag06	-1.47(-3.15,0.24)	1.19(-4.49,7.21)
	lag012	-2.76(-5.11,-0.35)	1.46(-3.01,6.13)
	lag024	-3.23(-6.07,-0.30)	0.63(-2.95,4.34)
	lag036	-3.73(-6.81,-0.55)	0.53(-3.55,4.77)
	lag048	-3.67(-7.07,-0.13)	0.28(-3.90,4.65)
	lag072	-3.01(-6.91,1.06)	1.23(-3.15,5.81)
IL-10	lag06	-0.71(-1.63,0.21)	-3.95(-6.58,-1.25)
	lag012	-1.83(-3.10,-0.55)	-2.37(-4.44,-0.26)
	lag024	-3.20(-4.69,-1.68)	-1.77(-3.43,-0.08)
	lag036	-3.36(-4.97,-1.71)	-1.68(-3.62,0.29)
	lag048	-3.91(-5.66,-2.13)	-1.35(-3.38,0.72)
	lag072	-3.88(-5.86,-1.86)	-0.91(-3.05,1.27)
IL-13	lag06	-0.62(-2.00,0.78)	-5.47(-9.91,-0.81)
	lag012	-1.02(-3.02,1.01)	-3.51(-7.13,0.25)

	lag024	-1.04(-3.50,1.48)	-3.05(-5.97,-0.04)
	lag036	-0.98(-3.63,1.75)	-3.47(-6.75,-0.07)
	lag048	-0.65(-3.57,2.37)	-2.92(-6.35,0.64)
	lag072	-0.14(-3.43,3.27)	-1.94(-5.56,1.82)
IL.23	lag06	-0.72(-1.82,0.39)	-5.98(-8.86,-3.00)
	lag012	-1.44(-3.00,0.15)	-4.94(-7.18,-2.65)
	lag024	-2.49(-4.38,-0.57)	-4.37(-6.14,-2.57)
	lag036	-2.49(-4.52,-0.41)	-4.78(-6.84,-2.67)
	lag048	-2.58(-4.82,-0.30)	-4.43(-6.61,-2.21)
	lag072	-2.24(-4.76,0.35)	-3.77(-6.12,-1.37)
MIP-3 α	lag06	0.31(-0.36,0.98)	1.40(-1.83,4.74)
	lag012	0.26(-0.70,1.23)	1.18(-1.29,3.71)
	lag024	0.57(-0.64,1.79)	1.37(-0.60,3.37)
	lag036	0.35(-0.94,1.65)	1.53(-0.75,3.85)
	lag048	0.26(-1.17,1.70)	1.60(-0.77,4.01)
	lag072	0.24(-1.36,1.87)	2.03(-0.41,4.54)
TNF- α	lag06	-0.76(-1.22,-0.30)	-2.07(-3.64,-0.48)
	lag012	-1.27(-1.92,-0.61)	-1.91(-3.12,-0.70)
	lag024	-1.77(-2.56,-0.97)	-1.75(-2.72,-0.78)
	lag036	-1.95(-2.79,-1.10)	-1.92(-3.03,-0.80)
	lag048	-2.15(-3.08,-1.22)	-1.87(-3.02,-0.70)
	lag072	-1.96(-3.03,-0.87)	-1.88(-3.10,-0.64)
Other biomarkers			
MCP.1	lag06	0.31(-0.16,0.77)	-0.30(-1.44,0.84)
	lag012	0.39(-0.27,1.07)	-0.19(-1.07,0.69)
	lag024	0.11(-0.72,0.95)	0.03(-0.67,0.74)
	lag036	0.15(-0.75,1.05)	0.15(-0.65,0.96)
	lag048	0.12(-0.86,1.12)	0.26(-0.57,1.10)
	lag072	-0.18(-1.27,0.92)	0.41(-0.47,1.29)
PYY	lag06	-0.42(-1.17,0.35)	1.09(-1.27,3.52)
	lag012	-0.60(-1.68,0.49)	0.02(-1.76,1.83)
	lag024	-0.20(-1.54,1.16)	-0.26(-1.70,1.21)
	lag036	-0.14(-1.58,1.33)	-0.77(-2.39,0.88)
	lag048	-0.06(-1.66,1.57)	-0.95(-2.62,0.74)
	lag072	-0.27(-2.04,1.53)	-1.18(-2.91,0.57)
CRP	lag06	-0.23(-1.93,1.50)	7.46(0.15,15.31)
	lag012	-0.75(-3.17,1.73)	4.62(-0.76,10.29)
	lag024	-0.94(-3.95,2.17)	2.71(-1.59,7.19)
	lag036	-1.23(-4.45,2.11)	2.73(-2.14,7.84)
	lag048	-1.41(-4.99,2.30)	1.88(-3.10,7.13)
	lag072	-1.07(-5.15,3.19)	1.11(-4.00,6.49)
Fetuin A	lag06	0.65(0.24,1.07)	-0.37(-1.86,1.14)

	lag012	0.90(0.30,1.51)	-0.13(-1.21,0.97)
	lag024	0.74(-0.02,1.51)	-0.07(-0.98,0.85)
	lag036	0.89(0.05,1.74)	0.01(-1.00,1.04)
	lag048	0.82(-0.17,1.82)	0.03(-1.01,1.08)
	lag072	0.36(-0.75,1.48)	-0.06(-1.13,1.03)
SAP	lag06	0.81(0.26,1.36)	-0.37(-2.33,1.63)
	lag012	0.77(-0.04,1.59)	-0.41(-1.88,1.09)
	lag024	0.23(-0.78,1.25)	-0.33(-1.54,0.90)
	lag036	0.29(-0.82,1.41)	-0.13(-1.51,1.26)
	lag048	0.11(-1.18,1.42)	-0.13(-1.55,1.31)
	lag072	-0.17(-1.63,1.31)	-0.24(-1.71,1.25)
Functional factors			
Glucose	lag06	0.10(-0.23,0.43)	0.86(-0.36,2.10)
	lag012	0.47(-0.02,0.96)	0.79(-0.06,1.64)
	lag024	1.05(0.43,1.68)	0.71(0.04,1.38)
	lag036	1.05(0.39,1.72)	0.78(0.04,1.52)
	lag048	1.36(0.63,2.10)	0.78(0.03,1.53)
	lag072	1.54(0.72,2.37)	0.87(0.09,1.65)
TC	lag06	0.14(-0.19,0.47)	1.47(-0.11,3.07)
	lag012	0.59(0.11,1.07)	1.67(0.57,2.79)
	lag024	1.41(0.81,2.00)	1.70(0.84,2.57)
	lag036	1.31(0.67,1.95)	2.07(1.11,3.03)
	lag048	1.73(1.03,2.44)	2.14(1.18,3.11)
	lag072	1.98(1.19,2.77)	2.10(1.11,3.11)
TG	lag06	0.05(-0.38,0.49)	1.77(-0.02,3.59)
	lag012	0.20(-0.44,0.84)	1.69(0.38,3.00)
	lag024	0.44(-0.39,1.28)	1.64(0.60,2.70)
	lag036	0.21(-0.67,1.10)	1.96(0.79,3.14)
	lag048	0.25(-0.75,1.25)	2.02(0.83,3.23)
	lag072	0.19(-0.93,1.32)	1.86(0.64,3.10)

Table S5: Kruskal-Wallis H test of featured genera amongst all study participants.

Genera name	<i>P</i>
g__Ruminococcus_1	1.1×10 ⁻¹¹
g__Lachnospiraceae_ND3007_group	1.3×10 ⁻⁰⁷
g__Streptococcus	3.5×10 ⁻⁰⁷
g__norank_f__Muribaculaceae	2.1×10 ⁻¹¹
g__Lactobacillus	0.019
g__Peptococcus	0.0017
g__Cellulosilyticum	9.3×10 ⁻⁰⁵
g__Anaerotruncus	0.029
g__Shuttleworthia	1.2×10 ⁻²⁰
g__norank_o__DTU014	9.8×10 ⁻⁰⁹
g__Oribacterium	0.35
g__Ruminiclostridium	0.78
g__DNF00809	4.9×10 ⁻⁰⁵
g__A2	0.78
g__Enorma	0.25
g__Mucispirillum	0.76

Table S6: Mediated effects of gut microbiota in the associations linking PM_{2.5} with sphingolipid metabolism among older Chinese adults in the Jinan panel study.

Outcome	Mediator	Lag (h)	Mediation Effect (95%CI)	<i>P</i>	Proportion Mediated (%) (95%CI)	<i>P</i>
Sphingosine	Oribacterium	lag06	-0.12 (-0.3 , -0.0003)	0.049	8.59 (0.01, 29.34)	0.05
	Shuttleworthia	lag06	-0.66 (-1.07, -0.26)	0.0004	37.83 (16.42, 72.9)	0.0008
	Shuttleworthia	lag072	-0.19 (-0.46 , -0.004)	0.044	8.62 (0.16, 30.71)	0.046

Table S7: Sensitivity analysis models in the Jinan panel study.

Model	Covariables
1 (Main model)	Age, Sex, BMI, Education, Income, Drinking, Cook, Cotinine, DOW, ns(temp,3), ns(rh,3)
2	Age, Sex, BMI, Education, -Income , Drinking, Cook, Cotinine, DOW, ns(temp,3), ns(rh,3)
3	Age, Sex, BMI, -Education , Income, Drinking, Cook, Cotinine, DOW, ns(temp,3), ns(rh,3)
4	Age, Sex, BMI, Education, Income, Drinking, Cook, Cotinine, ns(time,3), -DOW , ns(temp,3), ns(rh,3)
5	Age, Sex, BMI, Education, Income, Drinking, Cook, Cotinine, ns(time,4), -DOW , ns(temp,3), ns(rh,3)
6	Age, Sex, BMI, Education, Income, Drinking, Cook, Cotinine, Month, -DOW , ns(temp,3), ns(rh,3)
7	Age, Sex, BMI, Education, Income, Drinking, Cook, Cotinine, DOW, ns(temp,3), ns(rh,3), PM ₁₀ , SO ₂ , NO ₂ , O ₃ , CO

BMI=body-mass index; DOW=day of week; ns=natural spline function; temp=temperature; rh=relative humidity; time=the accumulated days; Month= month of the health examinations.

Table S8: Sensitivity analysis results in the Jinan panel study.

Variables	Lag (h)	ER(95% CI)					
		Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Inflammations							
IL-4	lag06	-0.69(-1.41,0.04)	-0.68(-1.41,0.04)	0.54(-0.22,1.29)	0.31(-0.33,0.95)	0.09(-0.55,0.73)	-0.24(-0.97,0.5)
	lag012	-1.17(-2.11,-0.23)	-1.17(-2.09,-0.23)	0.55(-0.40,1.50)	0.37(-0.44,1.17)	-0.04(-0.83,0.76)	-0.47(-1.48,0.55)
	lag024	-1.63(-2.59,-0.65)	-1.61(-2.57,-0.64)	-0.18(-1.16,0.81)	0.32(-0.52,1.17)	-0.03(-0.85,0.80)	-0.97(-2.23,0.31)
	lag036	-1.89(-2.94,-0.82)	-1.87(-2.93,-0.81)	-0.05(-1.11,1.03)	0.17(-0.74,1.08)	-0.11(-0.99,0.79)	-0.97(-2.3,0.38)
	lag048	-1.89(-3.02,-0.74)	-1.87(-3.00,-0.73)	0.33(-0.76,1.42)	0.25(-0.68,1.18)	0.02(-0.89,0.93)	-0.86(-2.33,0.64)
	lag072	-1.64(-2.88,-0.38)	-1.62(-2.86,-0.36)	0.56(-0.64,1.77)	0.38(-0.64,1.41)	0.14(-0.86,1.15)	-0.49(-2.02,1.07)
IL-6	lag06	-0.49(-1.13,0.15)	-0.50(-1.14,0.14)	0.02(-0.62,0.67)	-0.10(-0.71,0.51)	-0.20(-0.81,0.42)	-0.32(-2,1.4)
	lag012	-0.67(-1.49,0.16)	-0.69(-1.51,0.14)	0.02(-0.78,0.83)	-0.08(-0.84,0.69)	-0.24(-1.01,0.53)	-0.37(-2.69,2.02)
	lag024	-0.66(-1.53,0.22)	-0.68(-1.55,0.19)	-0.28(-1.11,0.55)	-0.05(-0.85,0.75)	-0.21(-1.00,0.59)	-0.67(-3.59,2.34)
	lag036	-0.70(-1.67,0.28)	-0.72(-1.69,0.25)	-0.14(-1.04,0.77)	-0.05(-0.91,0.82)	-0.17(-1.03,0.70)	-0.17(-3.31,3.08)
	lag048	-0.59(-1.63,0.46)	-0.61(-1.65,0.44)	0.10(-0.81,1.03)	0.05(-0.82,0.93)	-0.03(-0.91,0.85)	0.38(-3.09,3.98)
	lag072	-0.33(-1.47,0.83)	-0.36(-1.49,0.79)	0.16(-0.85,1.19)	0.07(-0.90,1.05)	-0.02(-0.99,0.97)	1.54(-2.14,5.35)
IL-10	lag06	-0.98(-1.78,-0.16)	-0.97(-1.78,-0.16)	-0.41(-1.15,0.33)	-0.46(-1.20,0.28)	-0.54(-1.28,0.21)	-0.36(-1.17,0.45)
	lag012	-1.84(-2.86,-0.81)	-1.82(-2.84,-0.79)	-0.95(-1.87,-0.03)	-1.00(-1.90,-0.08)	-1.11(-2.02,-0.19)	-0.72(-1.83,0.41)
	lag024	-2.34(-3.4,-1.27)	-2.32(-3.38,-1.25)	-1.45(-2.39,-0.51)	-1.36(-2.30,-0.41)	-1.44(-2.38,-0.50)	-1.21(-2.62,0.22)
	lag036	-2.43(-3.61,-1.22)	-2.40(-3.59,-1.20)	-1.33(-2.35,-0.29)	-1.28(-2.30,-0.25)	-1.35(-2.36,-0.32)	-0.83(-2.34,0.7)
	lag048	-2.49(-3.77,-1.19)	-2.46(-3.74,-1.16)	-1.25(-2.29,-0.19)	-1.27(-2.31,-0.22)	-1.33(-2.36,-0.28)	-0.66(-2.33,1.04)
	lag072	-2.19(-3.6,-0.75)	-2.15(-3.57,-0.72)	-1.16(-2.32,0.02)	-1.2(-2.35,-0.04)	-1.28(-2.43,-0.12)	-0.13(-1.87,1.64)
IL-13	lag06	-1.28(-2.59,0.05)	-1.24(-2.55,0.09)	0.66(-0.60,1.94)	0.34(-0.80,1.48)	0.08(-1.08,1.24)	-0.51(-1.84,0.83)
	lag012	-1.88(-3.60,-0.14)	-1.80(-3.51,-0.06)	0.64(-0.97,2.27)	0.36(-1.07,1.81)	-0.13(-1.58,1.34)	-0.91(-2.75,0.97)

IL.23	lag024	-2.06(-3.85,-0.22)	-1.95(-3.74,-0.12)	-0.26(-1.92,1.44)	0.45(-1.05,1.98)	-0.03(-1.54,1.50)	-1.58(-3.9,0.8)
	lag036	-2.10(-4.08,-0.08)	-1.99(-3.96,0.03)	0.21(-1.60,2.05)	0.50(-1.13,2.15)	0.14(-1.49,1.80)	-0.9(-3.38,1.64)
	lag048	-1.64(-3.78,0.55)	-1.53(-3.66,0.65)	0.79(-1.05,2.67)	0.66(-0.98,2.34)	0.40(-1.27,2.08)	0.05(-2.7,2.88)
	lag072	-0.73(-3.10,1.69)	-0.58(-2.95,1.84)	1.07(-0.96,3.14)	0.82(-1.01,2.67)	0.52(-1.33,2.39)	1.07(-1.83,4.06)
	lag06	-1.36(-2.33,-0.37)	-1.37(-2.35,-0.38)	0(-0.88,0.89)	-0.13(-0.98,0.74)	-0.25(-1.11,0.61)	-0.41(-1.36,0.56)
	lag012	-2.49(-3.72,-1.24)	-2.51(-3.75,-1.27)	-0.37(-1.47,0.74)	-0.46(-1.52,0.61)	-0.68(-1.74,0.39)	-0.8(-2.12,0.54)
	lag024	-3.33(-4.60,-2.05)	-3.36(-4.62,-2.08)	-0.85(-1.98,0.29)	-0.55(-1.66,0.56)	-0.74(-1.83,0.36)	-1.46(-3.11,0.22)
	lag036	-3.51(-4.93,-2.08)	-3.54(-4.95,-2.11)	-0.62(-1.86,0.64)	-0.47(-1.66,0.74)	-0.61(-1.79,0.59)	-1.11(-2.87,0.69)
MIP-3 α	lag048	-3.48(-5.01,-1.92)	-3.51(-5.04,-1.96)	-0.24(-1.50,1.04)	-0.26(-1.47,0.96)	-0.38(-1.59,0.83)	-0.7(-2.66,1.29)
	lag072	-2.98(-4.68,-1.25)	-3.01(-4.71,-1.29)	-0.22(-1.61,1.20)	-0.30(-1.64,1.06)	-0.45(-1.78,0.91)	-0.17(-2.22,1.92)
	lag06	0.34(-0.46,1.13)	0.32(-0.47,1.12)	0.04(-0.72,0.81)	0(-0.76,0.77)	-0.07(-0.83,0.70)	0.16(-0.65,0.98)
	lag012	0.37(-0.65,1.39)	0.35(-0.66,1.37)	-0.24(-1.19,0.72)	-0.27(-1.22,0.68)	-0.38(-1.32,0.58)	-0.03(-1.14,1.1)
	lag024	0.68(-0.40,1.76)	0.66(-0.41,1.74)	-0.39(-1.38,0.60)	-0.33(-1.32,0.67)	-0.41(-1.39,0.58)	-0.04(-1.45,1.38)
	lag036	0.63(-0.57,1.83)	0.61(-0.58,1.81)	-0.34(-1.41,0.74)	-0.30(-1.37,0.78)	-0.39(-1.45,0.69)	-0.12(-1.61,1.41)
	lag048	0.68(-0.61,1.98)	0.65(-0.63,1.95)	-0.28(-1.37,0.82)	-0.30(-1.38,0.80)	-0.36(-1.44,0.74)	-0.12(-1.77,1.57)
	lag072	0.87(-0.53,2.29)	0.83(-0.56,2.25)	-0.23(-1.44,0.99)	-0.26(-1.47,0.96)	-0.30(-1.50,0.91)	0.06(-1.68,1.82)
TNF- α	lag06	-0.93(-1.37,-0.49)	-0.92(-1.36,-0.48)	-0.33(-0.73,0.07)	-0.35(-0.75,0.05)	-0.40(-0.8,0)	-0.54(-0.96,-0.12)
	lag012	-1.50(-2.06,-0.94)	-1.47(-2.02,-0.91)	-0.59(-1.09,-0.09)	-0.61(-1.11,-0.11)	-0.68(-1.18,-0.17)	-0.83(-1.41,-0.25)
	lag024	-1.77(-2.35,-1.19)	-1.74(-2.32,-1.15)	-0.72(-1.24,-0.20)	-0.69(-1.21,-0.16)	-0.72(-1.24,-0.20)	-1.11(-1.84,-0.37)
	lag036	-1.95(-2.59,-1.30)	-1.91(-2.55,-1.26)	-0.82(-1.38,-0.26)	-0.80(-1.36,-0.24)	-0.84(-1.39,-0.27)	-1.11(-1.89,-0.33)
	lag048	-2.03(-2.73,-1.33)	-1.99(-2.69,-1.29)	-0.80(-1.37,-0.22)	-0.81(-1.38,-0.24)	-0.84(-1.41,-0.27)	-1.12(-1.98,-0.25)
	lag072	-1.94(-2.72,-1.15)	-1.89(-2.66,-1.10)	-0.87(-1.50,-0.23)	-0.89(-1.52,-0.25)	-0.94(-1.58,-0.31)	-0.92(-1.84,-0.01)
Other biomarkers							
MCP.1	lag06	0.24(-0.15,0.63)	0.23(-0.16,0.62)	0.38(0.01,0.75)	0.34(-0.02,0.71)	0.29(-0.08,0.66)	0.27(-0.13,0.68)
	lag012	0.12(-0.38,0.63)	0.11(-0.39,0.62)	0.47(0,0.94)	0.44(-0.02,0.90)	0.36(-0.10,0.83)	0.26(-0.3,0.82)

	lag024	-0.11(-0.64,0.42)	-0.13(-0.66,0.41)	0.34(-0.14,0.83)	0.42(-0.06,0.91)	0.37(-0.11,0.85)	0.21(-0.5,0.93)
	lag036	-0.04(-0.63,0.56)	-0.06(-0.65,0.54)	0.44(-0.08,0.97)	0.48(-0.04,1.00)	0.43(-0.09,0.95)	0.29(-0.46,1.06)
	lag048	-0.04(-0.67,0.60)	-0.06(-0.69,0.58)	0.47(-0.06,1.01)	0.46(-0.06,0.99)	0.41(-0.11,0.94)	0.27(-0.56,1.11)
	lag072	-0.17(-0.86,0.53)	-0.19(-0.88,0.50)	0.44(-0.16,1.03)	0.41(-0.18,1.01)	0.36(-0.23,0.95)	0.01(-0.86,0.89)
PYY	lag06	-0.13(-0.78,0.52)	-0.13(-0.78,0.53)	-0.39(-0.99,0.22)	-0.40(-1.00,0.21)	-0.41(-1.02,0.20)	-0.45(-1.17,0.27)
	lag012	-0.23(-1.07,0.61)	-0.23(-1.06,0.61)	-0.74(-1.49,0.02)	-0.75(-1.50,0.02)	-0.82(-1.57,-0.06)	-0.96(-1.94,0.03)
	lag024	-0.03(-0.92,0.87)	-0.02(-0.91,0.87)	-0.87(-1.65,-0.08)	-0.82(-1.62,-0.03)	-0.87(-1.65,-0.08)	-1.37(-2.6,-0.13)
	lag036	-0.21(-1.19,0.79)	-0.21(-1.18,0.78)	-1.09(-1.93,-0.23)	-1.07(-1.92,-0.22)	-1.11(-1.95,-0.27)	-1.82(-3.11,-0.5)
	lag048	-0.27(-1.33,0.8)	-0.27(-1.32,0.79)	-1.08(-1.94,-0.21)	-1.08(-1.94,-0.21)	-1.11(-1.97,-0.25)	-2.24(-3.66,-0.8)
	lag072	-0.60(-1.74,0.56)	-0.60(-1.73,0.55)	-1.26(-2.20,-0.31)	-1.26(-2.21,-0.31)	-1.27(-2.21,-0.32)	-2.64(-4.11,-1.15)
CRP	lag06	1.16(-0.70,3.06)	1.16(-0.69,3.05)	0.06(-1.73,1.88)	0.21(-1.57,2.02)	0.38(-1.40,2.20)	0.77(-1.15,2.72)
	lag012	1.71(-0.67,4.14)	1.69(-0.67,4.10)	-0.27(-2.50,2.02)	-0.15(-2.37,2.12)	0.04(-2.19,2.32)	0.96(-1.66,3.65)
	lag024	1.82(-0.70,4.39)	1.77(-0.73,4.32)	-0.66(-3.00,1.74)	-0.98(-3.31,1.41)	-0.85(-3.16,1.53)	0.07(-3.19,3.44)
	lag036	1.88(-0.89,4.74)	1.86(-0.90,4.69)	-0.52(-3.04,2.08)	-0.65(-3.16,1.92)	-0.54(-3.04,2.02)	0.24(-3.23,3.84)
	lag048	1.59(-1.38,4.66)	1.57(-1.37,4.61)	-0.91(-3.47,1.73)	-0.84(-3.39,1.77)	-0.72(-3.27,1.89)	-0.35(-4.16,3.61)
	lag072	1.34(-1.89,4.67)	1.28(-1.92,4.58)	-1.41(-4.23,1.50)	-1.29(-4.10,1.60)	-1.10(-3.91,1.79)	-0.73(-4.75,3.46)
Fetuin A	lag06	0.58(0.16,0.99)	0.56(0.15,0.98)	0.77(0.37,1.17)	0.77(0.37,1.18)	0.78(0.37,1.19)	0.66(0.24,1.07)
	lag012	0.58(0.05,1.11)	0.54(0.02,1.07)	0.74(0.22,1.26)	0.74(0.22,1.26)	0.75(0.23,1.27)	0.8(0.23,1.37)
	lag024	0.42(-0.15,0.99)	0.37(-0.19,0.94)	0.52(-0.04,1.08)	0.51(-0.05,1.08)	0.53(-0.03,1.09)	0.86(0.14,1.58)
	lag036	0.53(-0.10,1.16)	0.48(-0.14,1.10)	0.64(0.04,1.25)	0.64(0.03,1.26)	0.66(0.06,1.27)	1.12(0.35,1.89)
	lag048	0.46(-0.23,1.14)	0.41(-0.27,1.08)	0.53(-0.11,1.17)	0.53(-0.11,1.17)	0.55(-0.09,1.18)	1.27(0.41,2.13)
	lag072	0.25(-0.49,1.00)	0.19(-0.53,0.92)	0.35(-0.34,1.06)	0.36(-0.34,1.06)	0.37(-0.33,1.07)	0.9(-0.02,1.83)
SAP	lag06	0.70(0.15,1.25)	0.68(0.13,1.23)	0.88(0.35,1.41)	0.90(0.37,1.44)	0.90(0.37,1.44)	0.86(0.31,1.42)
	lag012	0.53(-0.17,1.24)	0.51(-0.19,1.22)	0.67(-0.01,1.36)	0.69(0.01,1.37)	0.69(0.01,1.38)	0.98(0.22,1.74)
	lag024	0.18(-0.57,0.94)	0.18(-0.57,0.93)	0.22(-0.50,0.94)	0.19(-0.53,0.92)	0.21(-0.51,0.93)	0.95(-0.02,1.92)

	lag036	0.33(-0.51,1.16)	0.30(-0.53,1.14)	0.32(-0.47,1.11)	0.31(-0.48,1.10)	0.32(-0.46,1.12)	1.17(0.14,2.21)
	lag048	0.19(-0.72,1.10)	0.17(-0.73,1.09)	0.13(-0.69,0.95)	0.13(-0.68,0.96)	0.14(-0.68,0.96)	1.25(0.09,2.42)
	lag072	0.02(-0.96,1.02)	0.01(-0.97,1.00)	-0.05(-0.95,0.86)	-0.04(-0.94,0.88)	-0.04(-0.95,0.87)	0.89(-0.34,2.14)
Functional factors							
Glucose	lag06	0.14(-0.14,0.41)	0.14(-0.13,0.42)	0(-0.24,0.25)	-0.04(-0.27,0.2)	0.03(-0.22,0.28)	-0.07(-0.33,0.19)
	lag012	0.48(0.13,0.84)	0.50(0.15,0.86)	0.09(-0.22,0.41)	0.04(-0.26,0.35)	0.17(-0.15,0.50)	-0.03(-0.38,0.32)
	lag024	0.78(0.40,1.16)	0.81(0.44,1.18)	0.23(-0.12,0.58)	0.26(-0.07,0.60)	0.38(0.02,0.73)	-0.1(-0.54,0.34)
	lag036	0.83(0.42,1.24)	0.85(0.44,1.25)	0.30(-0.07,0.67)	0.30(-0.06,0.66)	0.42(0.05,0.80)	0(-0.47,0.48)
	lag048	0.96(0.52,1.39)	0.98(0.55,1.41)	0.42(0.06,0.80)	0.39(0.03,0.75)	0.54(0.16,0.92)	0.13(-0.4,0.67)
	lag072	1.07(0.59,1.55)	1.10(0.63,1.57)	0.47(0.07,0.88)	0.42(0.03,0.83)	0.58(0.16,1.01)	0.22(-0.36,0.81)
TC	lag06	0.25(-0.09,0.59)	0.27(-0.08,0.61)	0.08(-0.21,0.38)	0.05(-0.24,0.34)	0.12(-0.18,0.43)	0(-0.28,0.29)
	lag012	0.86(0.42,1.31)	0.90(0.45,1.35)	0.35(-0.03,0.74)	0.31(-0.07,0.69)	0.46(0.07,0.86)	0.23(-0.17,0.62)
	lag024	1.51(1.03,1.99)	1.54(1.07,2.02)	0.76(0.34,1.19)	0.79(0.37,1.21)	0.91(0.48,1.35)	0.46(-0.05,0.97)
	lag036	1.62(1.10,2.14)	1.66(1.15,2.18)	0.89(0.43,1.34)	0.88(0.43,1.32)	1.01(0.55,1.47)	0.57(0.03,1.12)
	lag048	1.90(1.35,2.46)	1.95(1.41,2.50)	1.07(0.62,1.53)	1.04(0.59,1.49)	1.20(0.73,1.67)	0.86(0.25,1.47)
	lag072	2.08(1.48,2.69)	2.14(1.54,2.74)	1.20(0.71,1.70)	1.17(0.67,1.67)	1.34(0.83,1.85)	1.05(0.39,1.72)
TG	lag06	0.07(-0.33,0.47)	0.07(-0.34,0.47)	0.10(-0.32,0.52)	0.01(-0.39,0.41)	0.01(-0.4,0.41)	-0.03(-0.44,0.38)
	lag012	0.36(-0.18,0.91)	0.36(-0.18,0.9)	0.22(-0.33,0.78)	0.09(-0.43,0.61)	0.10(-0.43,0.64)	0.15(-0.43,0.74)
	lag024	0.74(0.13,1.36)	0.75(0.14,1.37)	0.57(-0.05,1.19)	0.64(0.06,1.23)	0.65(0.06,1.24)	0.5(-0.27,1.27)
	lag036	0.74(0.07,1.41)	0.75(0.09,1.41)	0.79(0.13,1.46)	0.74(0.12,1.36)	0.77(0.14,1.40)	0.56(-0.25,1.38)
	lag048	0.88(0.15,1.60)	0.89(0.17,1.61)	1.13(0.45,1.80)	0.97(0.34,1.61)	1.03(0.39,1.68)	0.86(-0.07,1.79)
	lag072	0.93(0.14,1.72)	0.94(0.16,1.73)	1.13(0.38,1.88)	0.96(0.26,1.68)	1.03(0.31,1.75)	0.97(-0.02,1.98)

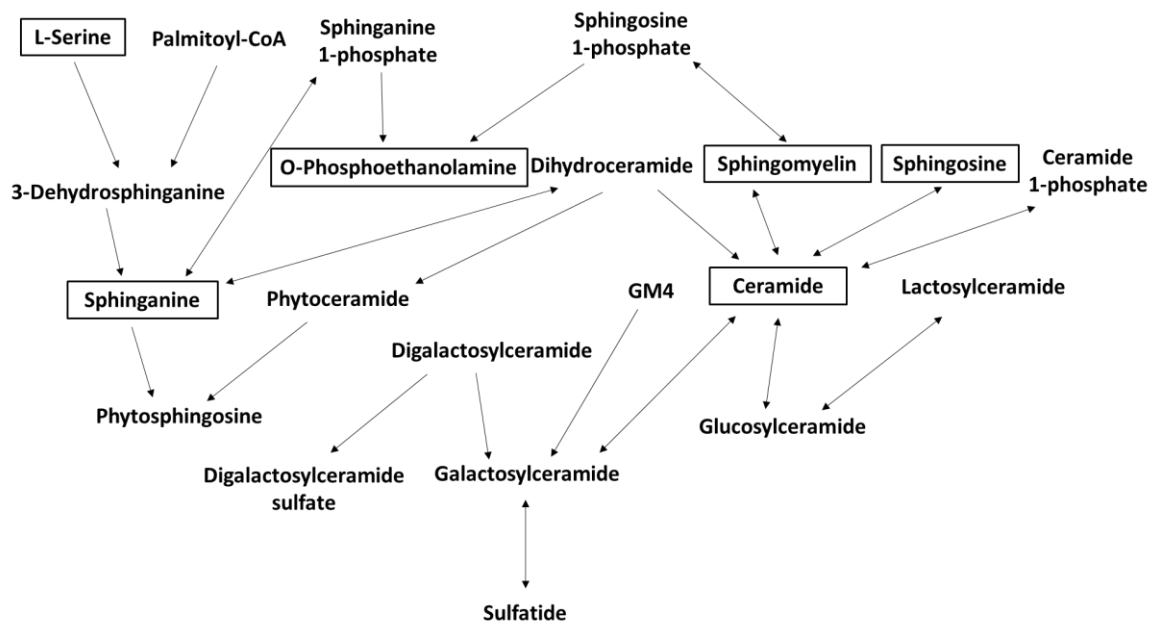


Figure S1: The pathway of sphingolipid metabolism.

Note: Solid boxes denote the featured metabolites of the sphingolipid metabolism pathway through this repeated-measures panel study.

The pathway of sphingolipid metabolism was analyzed through the MetaboAnalyst website.

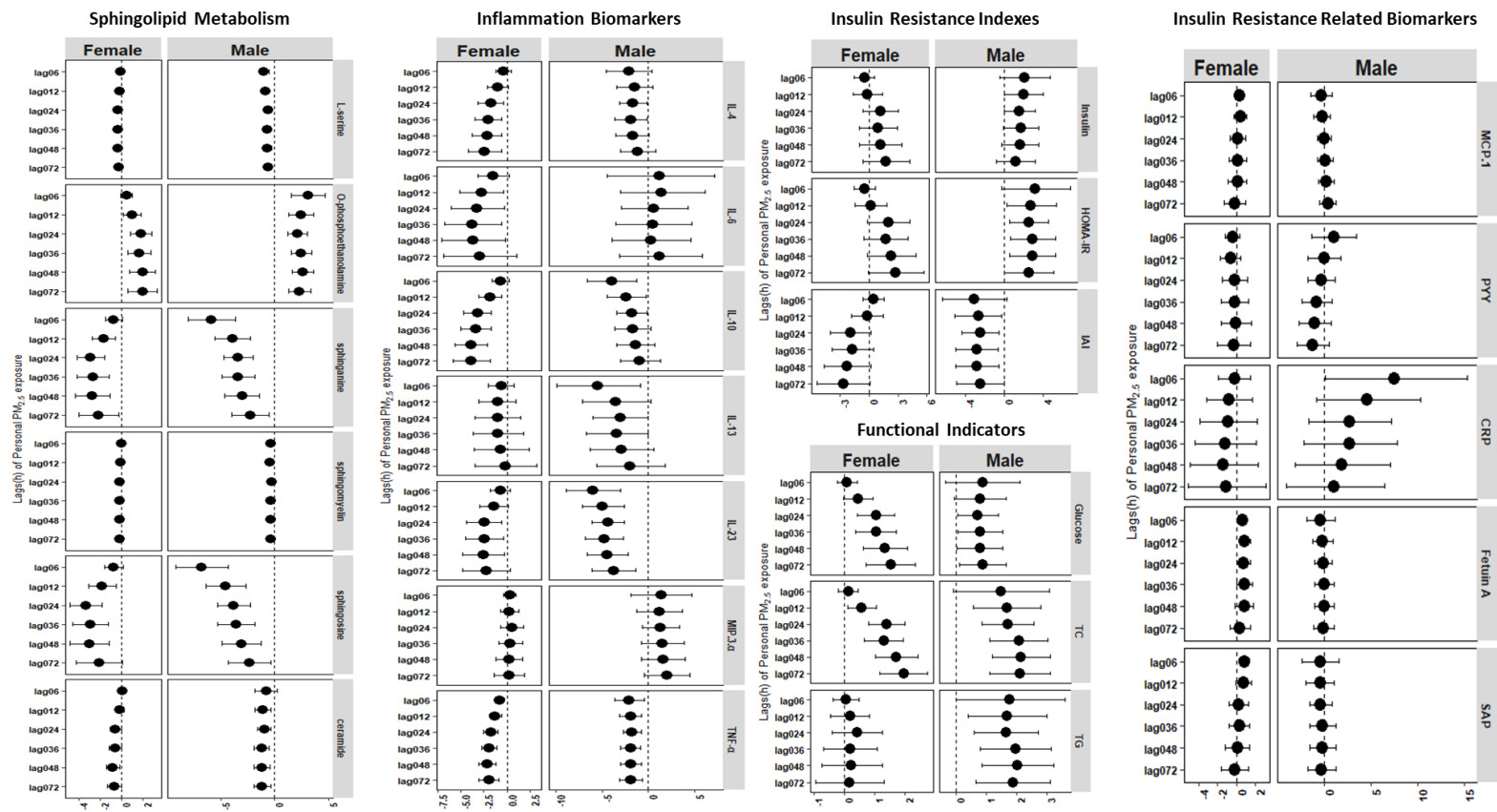


Figure S2: Percent change in insulin resistance-related biomarkers for a 10 $\mu\text{g}/\text{m}^3$ increase in $\text{PM}_{2.5}$ among older Chinese adults in the LME models with 95% confidence intervals (gender stratification).

Adjusted covariates included age (continuous), sex (female or male), BMI (continuous), annual income (continuous), education status, smoking status, alcohol consumption status, cooking status, day of the week of the clinical visit, temperature and relative humidity.

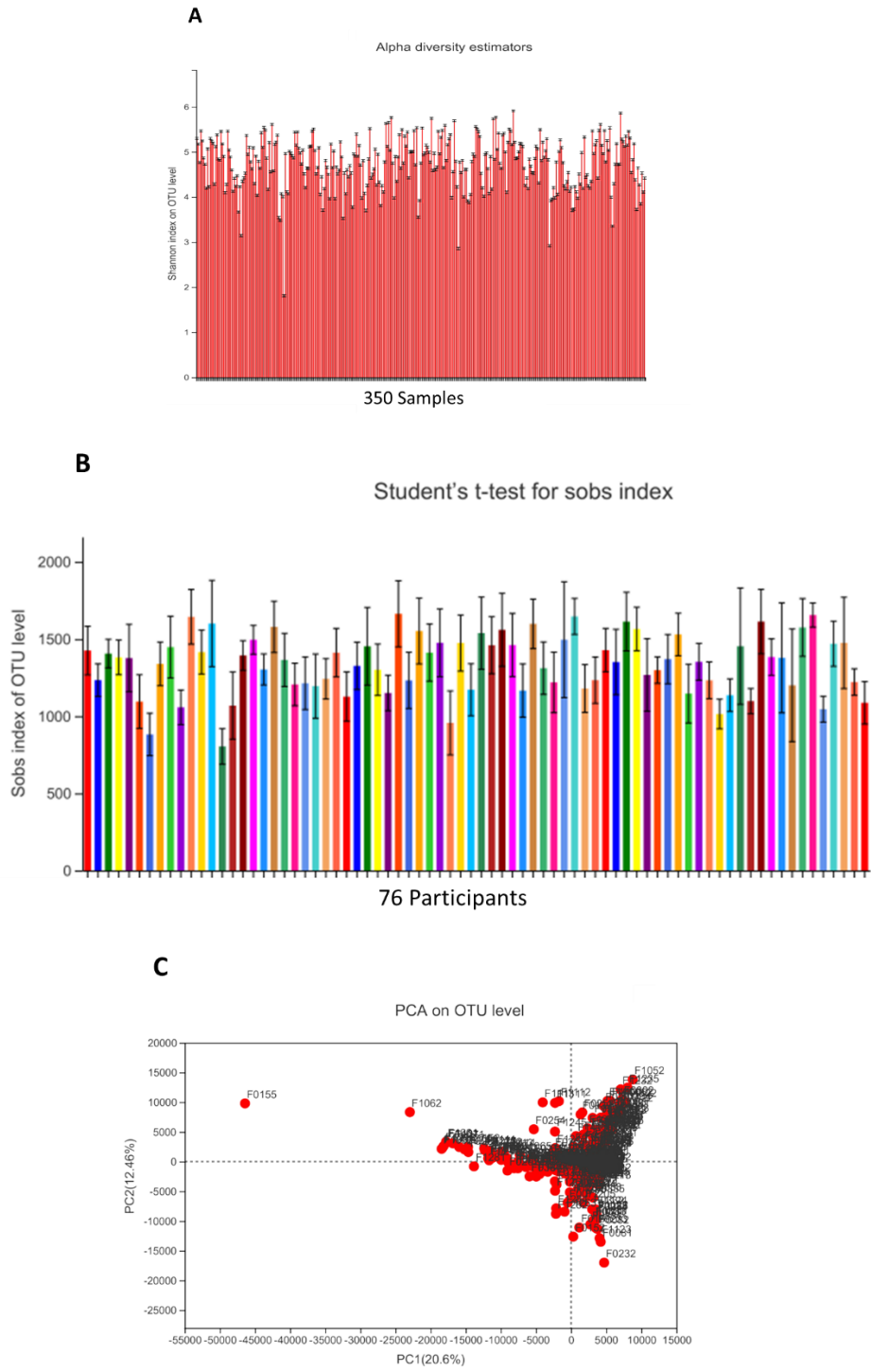


Figure S3: Changes in feces microbial diversities among older Chinese adults in the Jinan panel study.

A: Comparison of the microbial alpha diversity using the Shannon index, based on the OTU levels.

B: Comparison of the microbial alpha diversity using the Sobs index, based on the OTU levels.

C: PCA plot of the gut microbiota based on the unweighted UniFrac metric. The percentages shown on each axis explain the proportion of each dimension.

Community barplot analysis

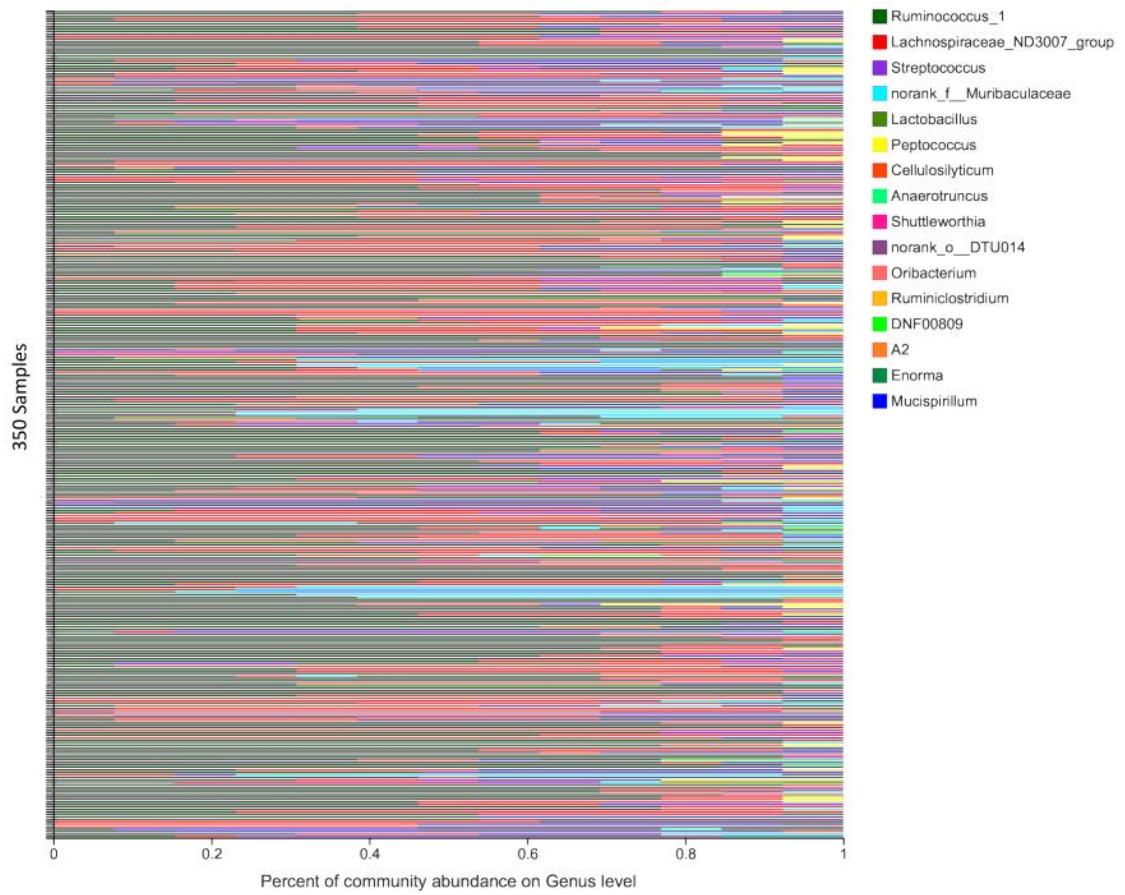


Figure S4: Abundance of gut microbiota (16 genera) among older Chinese adults in the Jinan panel study.

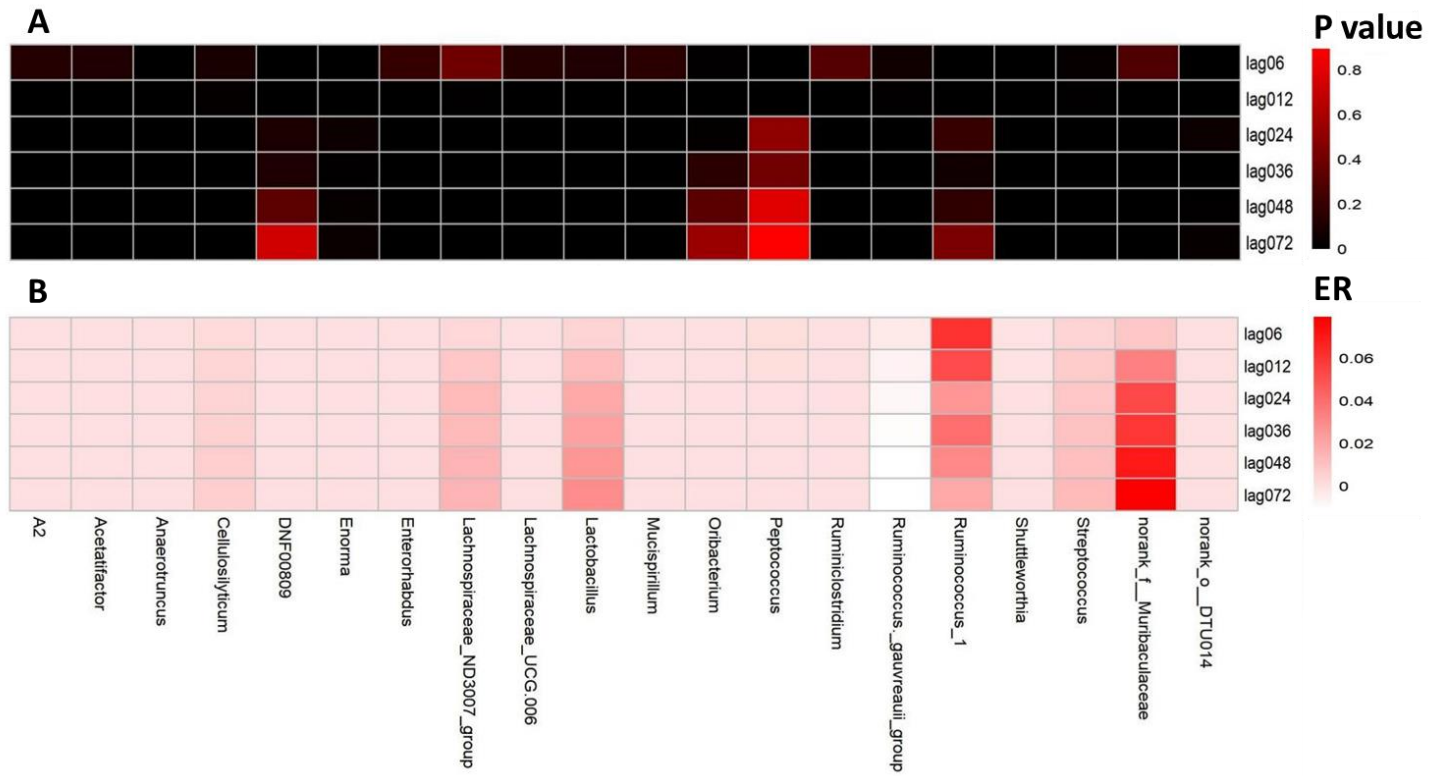


Figure S5: Significant results of 16S rRNA associated with PM_{2.5} among older Chinese adults in the Jinan panel study.