Supplemental Materials

Details and formulas in 2.3. Study Methods

The single-pollutant model:

$$Log(\mu_t)=\alpha+\beta X_{t,l}+ns(Temp_t,df)+ns(RH_t,df)+ns(Time_t,df)+Dow+Holiday$$

where α is the intercept, μ_t denotes outpatient visits to the URTI on day t, $X_{t,l}$ indicates the cross-basis matrix of each pollutant adopted by applying the DLNM, β is the regression coefficient for $X_{t,l}$, *ns* is the natural cubic spline function, *df* represents the degree of freedom. $Temp_t$ is daily temperature on day t, RH_t is daily RH on day t, $Time_t$ is a time variable that controls long-term trends and seasonality. *Dow* and *Holiday* are categorical variables reflect days of the week and holiday effects, respectively. Based on previous literature studies, we used Quasi-Poisson Akaike Information Criterion (Q-AIC) minimization principle to determine the *df* for related confounding factors.[38] In this study, we specified 3 *df* for both temperature and RH, and set a *df* of 7/year for the time variable $Time_t$.[11,39-40]

The DLNM model of ambient temperature is shown below:

$$Log(\mu_t)=\alpha+\beta Temp_{t,l}+ns(Pollutant_t,df)+ns(RH_t,df)+ns(Time_t,df)+Dow+Holiday$$

Where $Temp_{t,l}$ refers to the DLNM cross basis matrix of ambient temperature, we selected a natural cubic spline for the space of temperature with two internal knots at equally spaced temperature percentiles and another natural cubic spline with two internal knots at equally spaced log_{10}-values of lags (plus intercept). $Pollutant_t$ is the daily concentration of PM_{10}, SO_2, NO_2 on day t, other variables are defined with the previous formula. The Q-AIC was used to assess the model fit and ensure the optimal *df* for different variables, we specified 3 *df* for both $Pollutant_t$ and RH_t, and set a *df* of 7/year for the time variable $Time_t$.[20]

The model fitting the impact of RH on outpatient visits for URTI is as follows:

$$\text{Log}(\mu_t)=\alpha+\beta RH_{t,l}+ns(Pollutant_t,df)+ns(Temp_t,df)+ns(Time_t,df)+Dow+Holiday$$

Where $RH_{t,l}$ is cross basis matrix produced by DLNM to model the RH, we selected a natural cubic spline for the space of RH with two internal knots at equally spaced RH percentiles and another natural cubic spline with two internal knots at equally spaced $\log_{10}$-values of lags (plus intercept). $Pollutant_t$ is the concentration value of each air pollutant on t, other variables are defined with the previous formula. Similarly, the df for related variables were chosen based on the Q-AIC, we specified 3 *df* for both $Pollutant_t$ and $Temp_t$, and set a *df* of 7/year for the time variable $Time_t$.[42]

The formula for the interaction effect model between air pollutants and temperature is shown below:

$$\text{Log}(\mu_t)=\alpha+Te(AP_{t,l},Temp_t)+ns(RH_t,df)+ns(Time_t,df)+Dow+Holiday$$

The formula for the interaction effect model between air pollutants and RH is provided below:

$$\text{Log}(\mu_t)=\alpha+Te(AP_{t,l},RH_t)+ns(Temp_t,df)+ns(Time_t,df)+Dow+Holiday$$

In the above two formulas, *Te*() is the tensor product smooth function, $AP_{t,l}$ is the l-day moving average of air pollutants on day t, and other variables are defined with the previous formula. Based on the Q-AIC minimization principle, the *df* of $Temp_t$ and RH_t is set to 3, and the *df* of $Time_t$ is set to 7/year.

The following shows the formula for the temperature stratification model:

$$\text{Log}(\mu_t)=\alpha+\beta_1 Pollutant+\beta_2 Temp_k+\beta_3(Pollutant_t:Temp_k)+ns(RH_t,df)+ns(Time_t,df)+Dow+Holiday$$

The following shows the formula for the RH stratification model:

$$\text{Log}(\mu_t)=\alpha+\beta_1 Pollutant+\beta_2 RH_k+\beta_3(Pollutant_t:RH_k)+ns(Temp_t,df)+ns(Time_t,df)+Dow+Holiday$$

$Temp_t$ is the daily mean temperature level on t, RH_t is the RH level on t, which are categorical variables. β_1, β_2, and β_3 reflect the main effect of air pollutants, the main effect of temperature or RH, and the effect of the interaction term between air pollutants and the daily mean temperature or RH, respectively. And other variables are defined with the previous formula. Based on the Q-AIC minimization principle, the *df* of $Temp_t$ and RH_t is set to 3, and the *df* of *Time* is set to 7/year.

We tested for differences in effect estimates between categories of potential effect modifiers by calculating the 95% confidence interval. as shown below,

$$Z = \frac{\hat{Q}_1 - \hat{Q}_2}{\sqrt{\hat{SE}_1 + \hat{SE}_2}}$$

where Z is the z score, Q_1 and Q_2 are the effect estimates in the two subgroups; and SE_1 and SE_2 are their respective standard errors.[26]

BKMR is a machine learning approach that can be used to best simulate the mixed effects of exposure mixtures by using kernel functions. In this study, we performed a hierarchical variable selection method with 10,000 iterations via the Markov chain Monte Carlo algorithm. Comprehensive descriptions of the model are available in prior literature.[47,48]

Table S1 Basic profile of URTI outpatient visits in the three municipalities during the study period.

City	Variable	Mean±SD	Min	P_{25}	P_{50}	P_{75}	Max
Jiuquan	Outpatient Visits of URTI	105±60	0	61	105	146	315
	Male	56±37	0	38	58	135	206
	Female	49±22	0	23	46	101	114
	0-14 years	43±27	0	23	47	73	124
	15-64 years	27±16	0	15	25	42	99
	≥65 years	35±13	0	21	32	53	136
Dingxi	Outpatient Visits of URTI	99±53	0	58	96	136	298
	Male	59±33	0	36	57	71	187
	Female	40±22	0	20	38	66	117
	0-14 years	49±29	0	29	47	67	161
	15-64 years	26±14	0	12	24	34	78
	≥65 years	24±16	0	15	25	35	60
Tianshui	Outpatient Visits of URTI	70±59	0	32	68	115	441
	Male	44±24	0	25	42	76	296
	Female	26±18	0	8	21	50	145
	0-14 years	37±32	0	19	38	64	180
	15-64 years	14±8	0	6	11	23	106
	≥65 years	19±11	0	7	18	31	126

Table S2 Basic daily air pollutants and meteorological factors in three cities during the study period.

Variable	City	Mean±SD	Min	P_{25}	P_{50}	P_{75}	Max	F	P
$PM_{2.5}$ (μg/m^3)	Jiuquan	31.00±26.00	7.00	17.00	24.00	36.00	325.00	1.051	0.350
	Dingxi	33.97±22.61	6.00	18.00	27.00	45.00	243.00		
	Tianshui	33.51±22.91	4.00	18.00	26.00	46.00	224.00		
PM_{10} (μg/m^3)	Jiuquan	113.00±43.00	11.00	54.00	78.00	116.00	1727.00	27.427	< 0.05
	Dingxi	77.82±59.83	8.00	40.00	60.00	94.00	1059.00		
	Tianshui	69.22±51.08	8.00	36.00	58.00	90.00	761.00		
SO_2 (μg/m^3)	Jiuquan	12.00±6.00	2.00	8.00	10.00	14.00	36.00	3.235	< 0.05
	Dingxi	16.36±11.81	2.00	5.00	8.00	23.00	86.00		
	Tianshui	15.20±13.07	5.00	8.00	10.00	16.00	95.00		
NO_2 (μg/m^3)	Jiuquan	24.00±9.00	4.00	17.00	23.00	30.00	64.00	15.679	< 0.05
	Dingxi	26.43±10.17	4.00	18.00	26.00	34.00	59.00		
	Tianshui	31.53±13.75	2.00	21.00	28.00	40.00	83.00		
$O_3$8h (μg/m^3)	Jiuquan	93.00±26.00	32.00	73.00	95.00	112.00	168.00	1.567	0.213
	Dingxi	93.33±27.95	7.00	72.00	91.00	114.00	173.00		
	Tianshui	86.72±33.60	6.00	63.00	87.00	110.00	261.00		
CO (mg/m^3)	Jiuquan	0.57±0.23	0.18	0.40	0.50	0.70	1.80	5.678	< 0.05
	Dingxi	0.63±0.40	0.10	0.40	0.50	0.80	2.40		
	Tianshui	0.70±0.44	0.20	0.40	0.60	0.90	3.30		
Mean temperature (℃)	Jiuquan	8.80±5.70	-21.00	-1.10	10.00	19.30	29.50	10.235	< 0.05
	Dingxi	7.82±4.36	-13.60	-0.50	9.05	16.20	26.10		
	Tianshui	11.93±8.90	-8.90	3.90	12.80	19.61	29.10		
Relative humidity (%)	Jiuquan	44.88±15.80	13.00	33.00	43.00	55.00	99.00	35.679	< 0.05
	Dingxi	63.14±16.55	18.33	50.54	64.00	76.00	100.00		
	Tianshui	65.63±13.30	17.42	57.00	67.00	75.00	95.00		

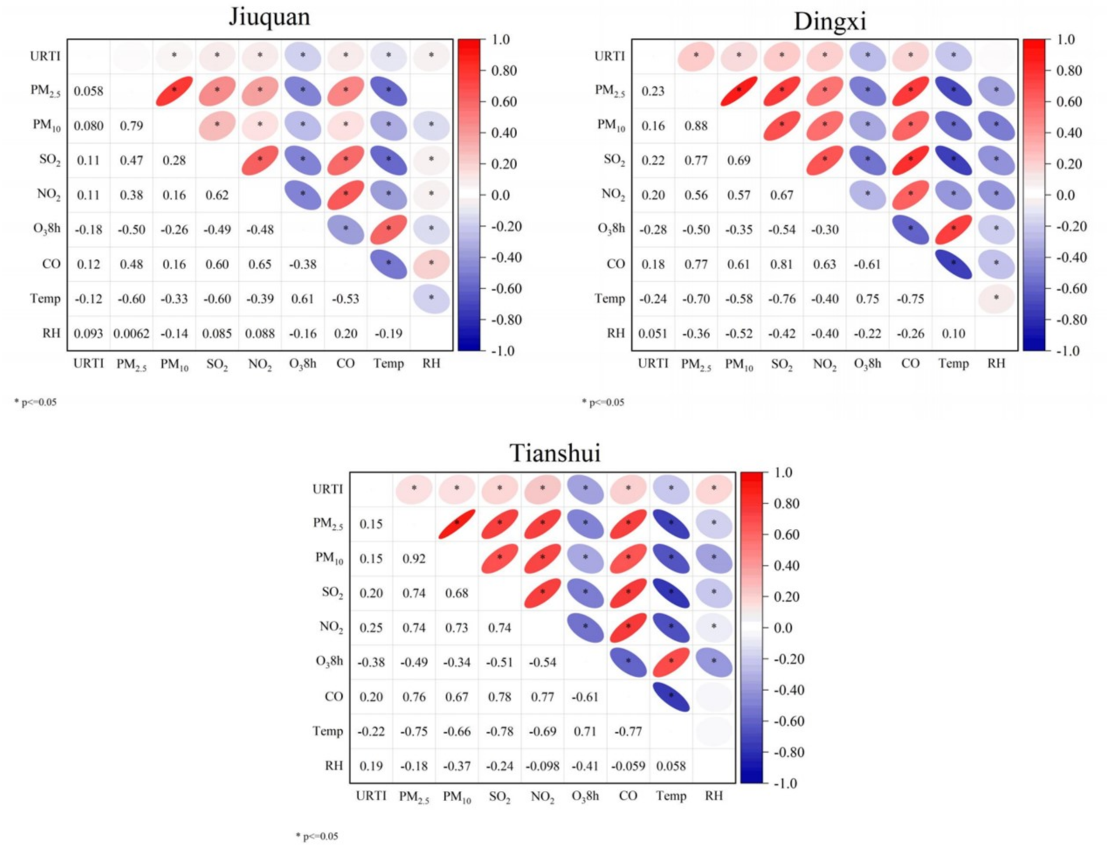

Figure S1 Spearman's correlation analysis of URTI outpatient visits, air pollutants and meteorological factors in three cities of Gansu Province.

Table S3 Relative risk and 95% CI of outpatient visits for URTI associated with a 10 μg/m[3] increase in pollutants concentrations (each 1mg/m[3] increase in CO concentration) [a] by gender, age and season in three cities analyzed.

	$PM_{2.5}$	PM_{10}	NO_2	CO
Jiuquan				
Gender				
Male	1.134(1.055,1.219)	1.056(1.025,1.076)	1.129(1.030,1.238)	2.502(1.876,2.911)
Female	1.122(1.020,1.233)	1.044(1.025,1.063)	0.941(0.839,1.056)	1.844(0.712,4.775)
Age(years)				
0-14	1.142(1.094,1.191)	1.035(1.024,1.046)	1.171(1.005,1.366)	3.336(2.190,5.081)
15-64	0.851(0.760,0.953)	0.972(0.936,1.010)	0.745(0.667,0.833)	0.829(0.681,1.213)
≥65	1.008(0.903,1.127)	1.013(0.986,1.041)	1.093(1.036,1.152)	1.501(0.844,2.143)
Season				
Cold	1.126(1.001,1.267)	1.093(1.056,1.130)	1.694(1.331,2.155)	2.307(1.521,3.126)
Warm	0.936(0.821,1.066)	0.993(0.963,1.024)	1.052(0.945,1.170)	1.455(0.743,2.850)
Dingxi				
Gender				
Male	1.132(1.076,1.191)	1.014(0.999,1.030)	1.072(1.006,1.142)	2.650(1.852,3.792)
Female	1.113(1.064,1.164)	1.010(0.992,1.028)	1.046(0.988,1.107)	2.214(1.597,3.070)
Age(years)				
0-14	1.156(1.021,1.308)	1.042(1.001,1.085)	1.153(1.063,1.288)	3.039(1.306,5.067)
15-64	1.109(1.056,1.164)	1.012(0.996,1.028)	1.021(0.965,1.081)	2.102(1.474,2.997)
≥65	1.131(1.080,1.184)	1.013(0.996,1.030)	1.053(0.989,1.120)	2.546(1.834,3.533)
Season				
Cold	1.193(1.117,1.273)	1.029(0.991,1.068)	1.245(1.154,1.344)	2.396(1.664,3.451)
Warm	0.994(0.922,1.072)	1.017(0.994,1.042)	1.030(0.918,1.155)	1.543(0.689,3.453)
Tianshui				
Gender				
Male	1.028(0.988,1.069)	1.017(0.999,1.034)	1.163(1.109,1.221)	1.912(1.522,2.402)
Female	0.948(0.897,1.003)	1.011(0.984,1.038)	1.144(1.075,1.218)	1.470(1.079,2.004)
Age(years)				
0-14	1.092(0.991,1.203)	1.065(1.019,1.113)	1.197(1.137,1.260)	2.574(2.012,3.292)
15-64	0.991(0.936,1.049)	1.002(0.983,1.022)	0.945(0.846,1.056)	0.861(0.758,0.933)
≥65	1.012(0.969,1.056)	1.027(1.000,1.054)	1.110(1.039,1.185)	1.644(1.202,2.250)
Season				
Cold	1.042(0.986,1.101)	1.032(1.001,1.064)	1.276(1.193,1.364)	2.115(1.318,2.805)
Warm	0.917(0.859,0.980)	0.993(0.964,1.022)	1.146(0.990,1.326)	1.455(1.028,2.060)

[a] Concentration of $PM_{2.5}$ at lag014, PM_{10} at lag014, NO_2 at lag011, and CO at lag014 were analyzed.

Table S4 Associations of each 10 μg/m^3 increase in pollutants (each 1mg/m^3 increase in CO concentration) [a] with relative risk of outpatient visits for URTI using single and two pollutant models in three cities.

Pollutants and Models	$PM_{2.5}$	PM_{10}	NO_2	CO
Jiuquan				
Single-pollutant model	1.134(1.057,1.218)	1.045(1.026,1.064)	1.118(1.022,1.224)	5.433(2.818,10.475)
+ $PM_{2.5}$	-	-	1.112(1.043,1.151)	5.399(2.859,10.460)
+ PM_{10}	-	-	1.124(1.081,1.237)	5.408(2.818,10.160)
+ SO_2	1.115(1.037,1.200)	1.045(1.023,1.064)	1.096(1.008,1.189)	5.417(2.881,10.969)
+ NO_2	1.122(1.037,1.214)	1.042(1.023,1.061)	-	5.411(2.818,10.448)
+ $O_3$8h	1.144(1.065,1.229)	1.051(1.032,1.071)	1.117(1.016,1.228)	5.448(2.848,11.609)
+ CO	1.159(1.071,1.254)	1.035(1.016,1.054)	0.914(0.794,1.052)	-
Dingxi				
Single-pollutant model	1.118(1.069,1.168)	1.014(0.999,1.029)	1.050(0.993,1.111)	2.289(1.659,3.156)
+ $PM_{2.5}$	-	-	1.040(0.982,1.102)	2.088(1.499,2.909)
+ PM_{10}	-	-	1.059(0.993,1.131)	2.483(1.730,3.563)
+ SO_2	1.099(1.056,1.151)	1.016(0.993,1.032)	1.060(0.993,1.031)	1.921(1.366,2.842)
+ NO_2	1.110(1.056,1.167)	1.010(0.993,1.027)	-	2.262(1.730,3.074)
+ $O_3$8h	1.142(1.092,1.194)	1.013(0.997,1.028)	1.043(0.966,1.093)	1.980(1.348,2.923)
+ CO	1.107(1.058,1.159)	1.019(0.994,1.034)	1.060(0.995,1.120)	-
Tianshui				
Single-pollutant model	1.012(0.972,1.053)	1.016(0.998,1.035)	1.158(1.104,1.215)	1.836(1.453,2.295)
+ $PM_{2.5}$	-	-	1.179(1.115,1.246)	1.831(1.434,2.338)
+ PM_{10}	-	-	1.170(1.103,1.242)	1.809(1.393,2.349)
+ SO_2	1.015(0.914,1.059)	1.012(0.973,1.031)	1.129(1.103,1.192)	2.061(1.599,2.658)
+ NO_2	1.059(0.914,1.007)	1.093(0.973,1.015)	-	1.894(1.393,2.218)
+ $O_3$8h	1.009(0.969,1.050)	1.016(0.998,1.035)	1.163(1.102,1.226)	1.778(1.407,2.246)
+ CO	1.000(0.959,1.043)	1.013(0.996,1.032)	1.110(1.053,1.171)	-

[a] Concentration of $PM_{2.5}$ at lag014, PM_{10} at lag014, NO_2 at lag011, and CO at lag014 were analyzed.

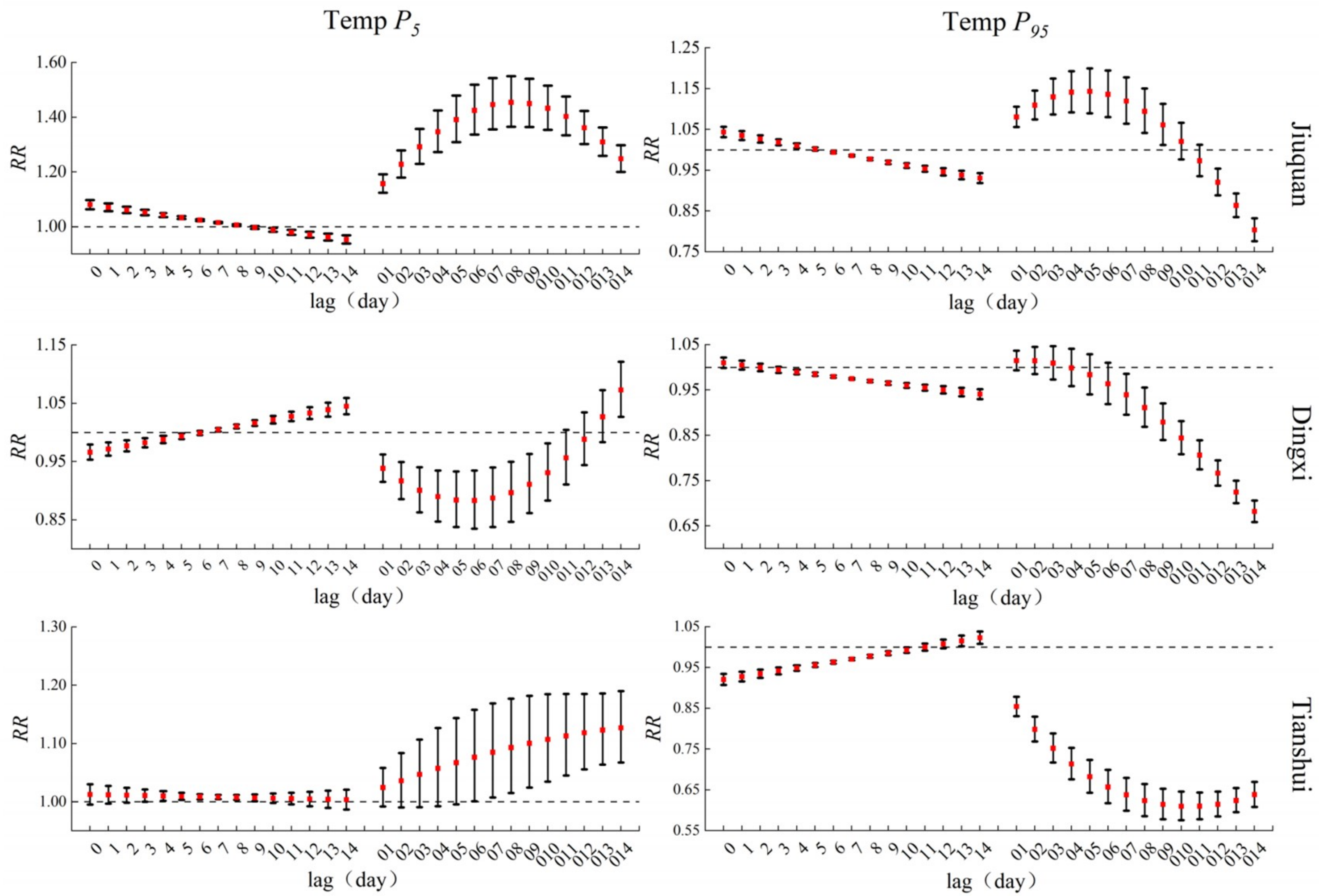

Figure S2 Impact of extreme low temperature (P_5) and extreme high temperature (P_{95}) on URTI outpatient volumes in three cities.

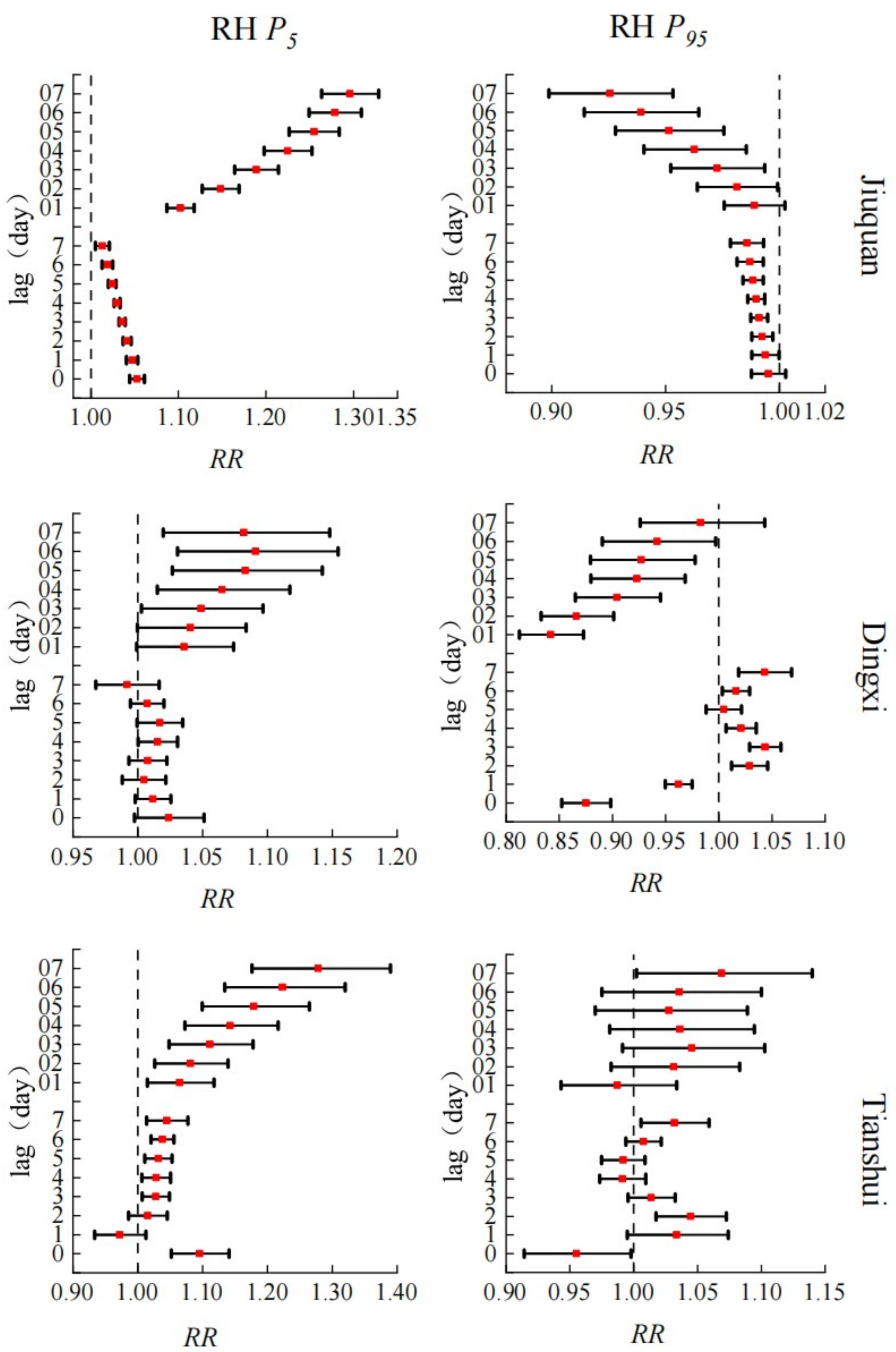

Figure S3 Impact of extreme low RH (P_5) and extreme high RH (P_{95}) on URTI outpatient volumes in three cities

Table S5 Relative risk and 95% CI of outpatient visits for URTI associated with meteorological factors [a] by gender, age and season in three cities analyzed.

	Low temperature	High temperature	Low RH	High RH
Jiuquan				
Gender				
Male	1.276(1.225,1.330)	1.161(1.030,1.293)	1.113(1.059,1.170)	0.974(0.751,1.261)
Female	1.114(0.970,1.279)	0.867(0.723,1.018)	1.049(1.019,1.079)	0.904(0.859,1.052)
Age(years)				
0-14	2.042(1.138,3.676)	1.012(0.957,1.071)	1.929(1.871,1.988)	0.810(0.753,0.872)
15-64	0.816(0.780,0.955)	0.612(0.451,0.831)	1.345(1.226,1.527)	0.530(0.478,0.587)
≥65	1.490(1.417,1.567)	0.693(0.662,0.726)	1.928(1.855,2.008)	0.854(0.655,0.981)
Season				
Cold	1.333(1.251,1.420)	-	1.350(1.278,1.427)	0.560(0.528,0.593)
Warm	-	0.579(0.539,0.621)	0.585(0.547,0.625)	0.797(0.748,0.849)
Dingxi				
Gender				
Male	1.268(1.150,1.399)	0.641(0.591,0.695)	1.088(1.020,1.162)	0.966(0.835,1.117)
Female	1.028(0.978,1.081)	0.691(0.665,0.719)	1.044(0.905,1.204)	0.987(0.924,1.054)
Age(years)				
0-14	1.821(1.453,2.283)	0.664(0.637,0.693)	1.181(1.099,1.268)	1.084(1.010,1.164)
15-64	1.234(1.086,1.386)	0.687(0.640,0.737)	0.941(0.838,1.058)	0.728(0.646,0.819)
≥65	1.402(1.286,1.528)	1.144(0.963,1.358)	1.067(1.007,1.179)	1.303(0.975,1.741)
Season				
Cold	1.263(1.181,1.351)	-	1.245(1.157,1.339)	0.842(0.784,0.904)
Warm	-	0.762(0.718,0.809)	0.537(0.504,0.573)	1.952(1.745,2.183)
Tianshui				
Gender				
Male	1.162(1.048,1.290)	0.731(0.658,0.811)	1.710(1.387,2.109)	1.155(1.094,1.213)
Female	1.134(1.065,1.207)	0.616(0.584,0.651)	1.205(1.100,1.320)	1.047(0.975,1.124)
Age(years)				
0-14	1.319(1.237,1.406)	0.592(0.558,0.629)	1.888(1.231,2.545)	1.693(1.479,1.907)
15-64	1.156(1.064,1.215)	0.675(0.615,0.740)	1.072(0.969,1.186)	0.852(0.784,0.925)
≥65	1.214(1.079,1.366)	0.413(0.314,0.543)	1.226(1.038,1.449)	1.066(1.006,1.121)
Season				
Cold	1.184(1.092,1.284)	-	1.323(1.191,1.471)	1.275(1.181,1.377)
Warm	-	0.627(0.571,0.689)	0.929(0.853,0.010)	1.334(1.234,1.442)

[a] Concentration of Low temperature at lag08, High temperature at lag05, Low RH at lag07, and High RH at lag04 were analyzed.

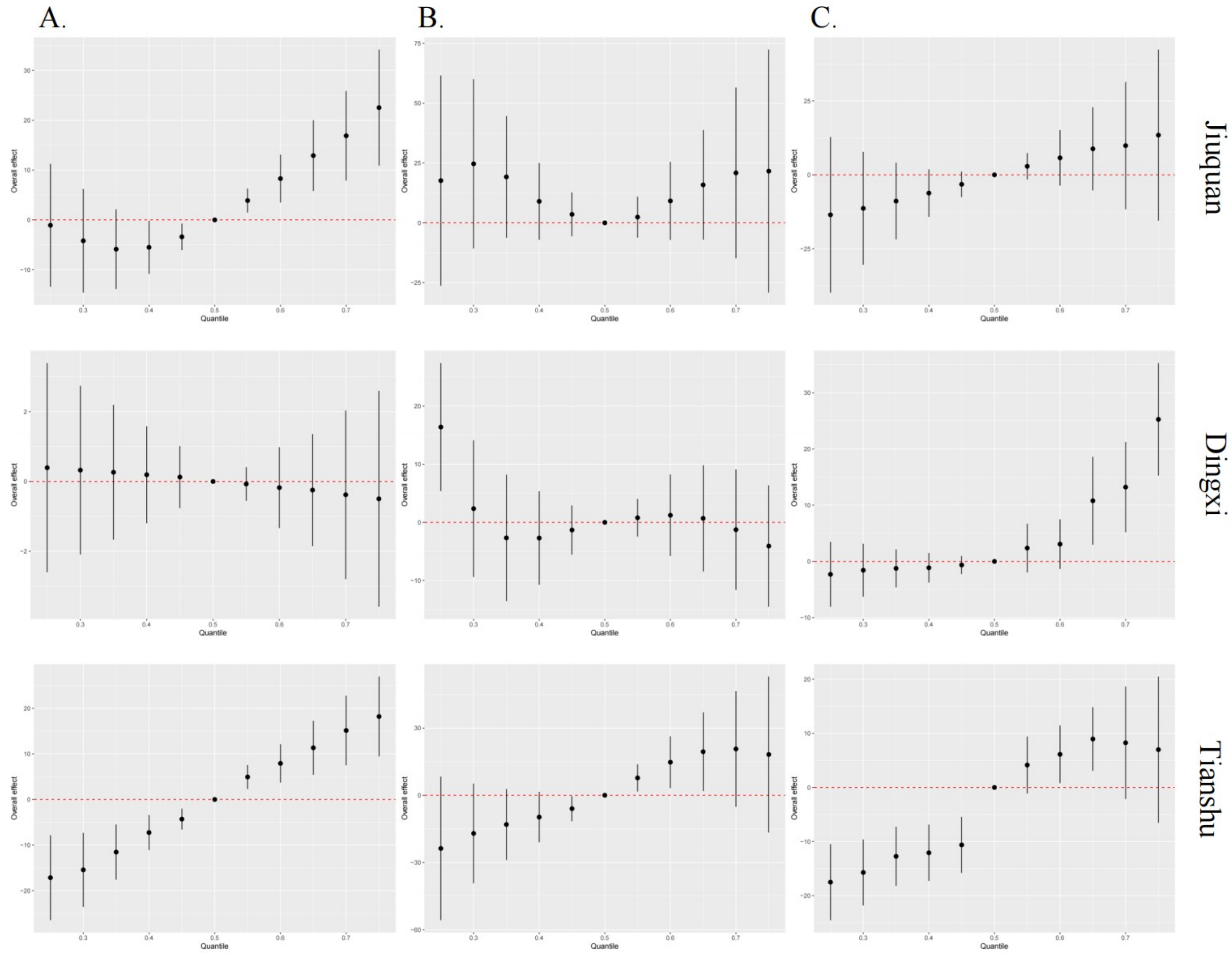

Figure S4 Mixed effect of air pollutants and meteorological factors (temperature and RH) on URTI outpatient visits according to the BKMR. **A** air pollutants and temperature. **B** air pollutants and RH. **C** air pollutants model

Table S6 Previous studies on air pollutants and URTI

Authors (Year)	Model	Study Period	Location	Admission Type	N	Exposure	Lag (Days)	RR/OR
1. Wang et al.(2023)	GAM	2019-2021	Kunshan, China	Outpatient visits	93,4180	$PM_{2.5}$	lag05	1.065 (1.055, 1.076)
						PM_{10}	lag05	1.045 (1.037, 1.052)
						NO_2	lag05	1.098 (1.085, 1.111)
2. Nguyen et al.(2024)	Time-stratified Case-crossover	2007-2019	Hanoi, Vietnam	Hospital admissions among children	66,893	$PM_{2.5}$	lag02	1.008 (1.003, 1.013)
						PM_{10}	lag02	1.003 (1.000, 1.006)
						NO_2	lag02	1.011 (1.004, 1.019)
						CO	lag02	1.023 (1.004, 1.043)
3. Yang (2018)	Time-stratified Case-crossover	2013-2014	Shenyang, China	Outpatient visits	1,091	$PM_{2.5}$	lag4	1.002 (1.000, 1.004)
						PM_{10}	lag4	1.001 (1.000, 1.003)
						NO_2	lag4	1.009 (1.004, 1.013)
						CO	lag2	1.199 (1.088, 1.321)
4. Li et al.(2017)	Time-stratified Case-crossover	2013-2014	Beijing, China	Outpatient visits	36,615	$PM_{2.5}$	lag5	1.001 (1.001, 1.001)
						PM_{10}	lag5	1.001 (1.000, 1.001)
						NO_2	lag5	1.003 (1.002, 1.003)

						CO	lag5	1.095 (1.071, 1.118)
5. Tam et al.(2014)	GAM	2008-2010	Hongkong, China	Outpatient visits	817,240	PM_{10}	-	1.005 (1.002, 1.009)
						NO_2	-	1.010 (1.006, 1.013)

Note:

1. H. Wang, G. H. Qian, J. Shi, W. J. Lu, Y. C. Chen, K. Fang, Y. Shen, H. Rong, X. H. Huangfu, Y. Feng, W. Zhang and K. Zhang, Association between short-term exposure to ambient air pollution and upper respiratory tract infection in Kunshan, *Int. J. Biometeorol.*, 2024, **68**(2), 189-197. https://doi.org/10.1007/s00484-023-02582-5
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Authors (Year)	Study Period	Location	Admission Type	Conclusion
1. Hong et al.(2020)	2015-2016	Shenyang, China	Respiratory diseases outpatient visits	$PM_{2.5}$, PM_{10}, and NO_2 were most significantly affected by the presence of an interaction between low temperature and high concentration conditions
2. Ji (2021)	2016-2019	Fuzhou, China	Respiratory diseases deaths	At lower temperatures, the number of deaths from respiratory diseases among residents increases as the concentration of particulate matter rises.
3. Gao (2023)	2019-2021	Hohhot, China	Respiratory diseases outpatient visits	There were remarkable interaction effects between air pollutants and temperature on outpatient visits for respiratory diseases, while the extent of the effects varied among the pollutants. $PM_{2.5}$ and PM_{10} had more significant impacts on respiratory disease outpatient visits in high temperature-high concentration scenarios, while NO_2 and CO were more harmful in low temperature-high concentration conditions.
4. Li (2021)	2013-2018	5 cities in China	Respiratory diseases outpatient visits among children	The interaction effects between temperature and different pollutants on respiratory diseases in children were inconsistent across the cities.

Table S7 Previous studies on interaction effects between air pollutants and temperature on respiratory diseases

Note:

1. Y. Hong, Y. Zhang, Y. J. Ma, S. G. Wang, J. Zhang, L. Hou, K. Q. Chen and H. Li, Effects of air pollutants and meteorological factors on outpatient visitors for respiratory diseases in Shenyang, *China. Environ. Sci.*, 2020, **40**(9), 4077-4090.
2. S. M. Ji, *Assessment of the risk of death of residents by particulate matter, air temperature, and their interaction in Fuzhou*, Fujian Medical University, 2021.
3. C. H. Gao, *The influence of the interaction between air pollutants and temperature on outpatient volume of respiratory diseases in a hospital in Hohhot*, Inner Mongolia Medical University, 2023.
4. M. Li, *Short-term exposure to ambient air pollutants and respiratory outpatient visits among children: a multi-city time-series study*, Huazhong University of Science and Technology, 2021.

Authors (Year)	Study Period	Location	Admission Type	Conclusion
1. Li (2021)	2013-2018	5 cities in China	Respiratory diseases outpatient visits among children	The interactions of $PM_{2.5}$, PM_{10}, and NO_2 with humidity were stronger under high humidity conditions in Wuhan, while the interaction of $PM_{2.5}$ was stronger in Xining under low humidity conditions.
2. Zhong (2021)	2013-2015	Guangzhou, China	Emergency visits for respiratory diseases	The effect of $PM_{2.5}$, PM_{10}, and NO_2 on the number of residential respiratory emergencies was more pronounced under low humidity conditions

Table S8 Previous studies on interaction effects between air pollutants and RH on respiratory diseases

Note:

1. M. Li, *Short-term exposure to ambient air pollutants and respiratory outpatient visits among children: a multi-city time-series study*, Huazhong University of Science and Technology, 2021.
2. Y. P. Zhong, *Study on correlation of air pollution and meteorological factors and emergency room visits for respiratory diseases in Guangzhou*, China Medical University, 2021.