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ORIGINAL RESEARCH

Retrospective Study on the Association Between Climate Factors and Infant Colic in Beijing (2021-2022)

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Purpose: To assess seasonal variations in infant colic (IC) prevalence and explore the association between climate factors, including temperature, air pollutants, and their interactions, with IC.

Methods: Medical records of 1955 infants aged 0–3 months from October 2021 to September 2022 were analyzed, with IC diagnosed according to Rome IV criteria. Seasonal differences in IC prevalence were compared using chi-square tests. Climate data, including weekly averages of temperature, PM2.5, PM10, NO2, CO, O3, and AQI, along with 1-, 2-, and 4-week lags, were collected via web scraping. Interaction terms between temperature and pollutants (including lagged variables) were created. Variance Inflation Factors (VIF) addressed multicollinearity. Pearson correlation assessed linear relationships, while Generalized Additive Models (GAM) evaluated non-linear associations.

Results: The overall IC prevalence was 38.62%. Demographic analysis showed no significant differences between infants with and without IC. Seasonal analysis revealed significant differences, with the highest IC prevalence in winter. After Bonferroni correction, spring (34.52%) and winter (43.60%) differed significantly ($p < 0.0083$). Linear correlation analysis indicated weak associations between temperature, pollutants, and their interactions with IC (correlation coefficients: −0.05 to 0.03). GAM confirmed these findings, with individual climate factors explaining only 0.002 of the deviance and their interactions explaining 0.007. No meaningful relationship between climate factors and IC prevalence was identified.

Conclusion: This study identified significant seasonal differences in IC prevalence, with the highest rates observed in winter. However, no significant linear or non-linear associations were found between IC and temperature, air pollutants, or their interactions. These findings underscore the need for future research to explore non-climatic factors.

Keywords: climate, infant colic, Rome IV, web scraping

Introduction

Infantile colic (IC) is a common early functional gastrointestinal disorder (FGID) and one of the first challenges many families face after welcoming a new baby.[1,2] IC is characterized by frequent, persistent crying, usually peaking in the evening.[3] It can affect cortisol secretion through the hypothalamic-pituitary-adrenal (HPA) axis. This disruption may interfere with melatonin production and hinder the development of circadian rhythms.[4] Studies have shown that infants with IC wake up more often at night, and they may sleep about two hours less per day compared to infants without IC.[5] This lack of sleep affects the infants and adds stress to parents. Mothers, in particular, may face an increased risk of postpartum depression and anxiety.[6–8] Further, managing IC can also put a strain on family relationships.[9] Therefore, parents want to identify risk factors that may be associated with IC in order to prevent or alleviate the problem.

Existing studies have demonstrated that climatic factors are often closely associated with gastrointestinal discomfort, particularly abdominal pain. A study analyzing internet search data found that "abdominal pain" is one of the most frequently searched types of pain in Asia, including China, with search volumes peaking during the cold winter months.[10] The study did not analyze specific populations in-depth, such as certain age groups or conditions. However, it still

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suggests that cold weather may be linked to a higher incidence of abdominal pain. Studies also indicate that short-term exposure to air pollutants, such as PM2.5, PM10, ozone, nitrogen dioxide, and carbon monoxide, can trigger non-specific abdominal pain, with these effects may vary by seasons.[11,12] Pollutants may act through several mechanisms, including the gut-lung axis and changes in gut microbiota, to increase the risk of abdominal pain.[13,14]

However, current studies have focused on nonspecific abdominal pain in adults or the general population, with limited data conducting on the relationship between climate change and IC, particularly those in Beijing, China. Beijing is characterized by a warm-temperate, semi-humid and semi-arid monsoon climate, and lies in the frequent path of cold, dry continental air masses moving southeastward from Siberia. As a result, the city experiences significant seasonal climate fluctuations, with cold winters lasting from October through May. Therefore, it is necessary to understand the impact of Beijing's unique climatic factors on IC. This study aims to investigate the potential association between climatic factors (temperature and air pollution) and the incidence of IC in Beijing, providing insights into whether environmental variables may play a role in this context.

Methods

Study Subjects and Data Collection

According to the Rome IV diagnostic criteria, IC is defined as repeated, prolonged episodes of unexplained crying or irritability in infants that are difficult for caregivers to soothe. These symptoms must begin and resolve before 5 months of age, and the infant must not show signs of growth restriction, fever, or any other illness that could explain the symptoms.[15]

This study utilized a retrospective analysis to examine cases of IC. We collected data on infants aged 0–3 months who underwent physical examinations at Beijing Jishuitan Hospital, Capital Medical University, between October 2021 and September 2022. At their initial physical examination, parents were interviewed to learn about the children. The interview included the presence of unexplained crying in the infant, the frequency, duration, and intensity of episodes, as well as any accompanying signs of irritability. Subsequently, a physical examination and, if necessary, additional tests were performed to detect other pathological causes. All symptoms and related information were recorded according to the standard.

To ensure the validity, we established inclusion and exclusion criteria. Inclusion criteria required that infants were aged 0–3 months at their initial visit and had complete medical records. These infants were also required to have follow-up records extending to at least 5 months of age. The follow-up records allowed us to assess whether their symptoms were self-limiting. Exclusion criteria included any acute disease, congenital disorders, or other chronic conditions, as well as any sequelae of acute or chronic illnesses.

Ethical approval for this retrospective study was obtained from the Beijing Jishuitan Hospital, Capital Medical University, Beijing, China (approval number: K2024-195-00). Patient parental consent was waived by the ethics committee because the study used anonymized data and posed minimal risk to participants. All data were handled in compliance with applicable data protection regulations, and confidentiality was strictly maintained throughout the study. This study complies with the ethical principles outlined in the Declaration of Helsinki.

Sample Size Calculation

The required sample size was estimated based on an expected IC prevalence of 43.8%, derived from previous studies on the prevalence of IC among early infants aged 0–3 months in China.[16] The calculation assumed a statistical power of 80%, an alpha value of 0.05, and a margin of error (E) of 5%. Using the formula for sample size calculation:

$$n = \frac{Z^2 p \ (1 - p)}{E^2}$$

where Z is the critical value for a 95% confidence level (1.96), p is the expected prevalence (43.8%), and E is the margin of error (0.05), the estimated sample size was 378 infants.

Collection of Climate Information

We collected climate data for Beijing (September 2021 to September 2022) using Python 3.8.0 and the following libraries: Requests (for processing HTTP requests), Selenium (for automating web interactions), and BeautifulSoup (for parsing and extracting data from HTML pages).

Temperature data were from the 2345 Weather website, and air pollutant data were from the China Air Quality Online Monitoring and Analysis Platform.

Temperature Data Collection

Temperature data was obtained from the 2345 Weather website and processed using the Selenium database. Starting with the current month's page, we used Selenium to interact with the "Last Month" button to iteratively retrieve historical data by loading each month's HTML content. BeautifulSoup was then used to parse the HTML and extract the temperature information, storing this information in an array.

Air Pollutant Data Collection

For air pollutant data collection, we use Requests to send HTTPS POST requests to retrieve BASE64 encoded encrypted weather data. After decoding and decrypting using a specified encryption key, we obtained monthly air pollutant data.

Correlation Analysis Between IC and Climate

After collecting the data, we first conducted a descriptive analysis of the study population to establish a baseline of IC prevalence. We then conducted a conjoint analysis between IC and climatic factors, looking for possible associations between the two. In this process, we analyzed from a number of different perspectives.The analysis process can be seen in the flow chart (Figure 1). Data analysis was performed using Python 3.8.0 in combination with the following packages: NumPy (for numerical operations), pandas (for data manipulation), and statsmodels (for statistical analysis).

Differences in the Prevalence of IC in Different Seasons

At the beginning of the analysis, we first compare whether there are differences in the prevalence of IC in different seasons, which can build a framework for our subsequent analysis. Differences between seasons may better explain the results of subsequent multifactorial effects. In this study, we used the chi-square test. And Bonferroni correction was used to control for Type I errors to ensure the robustness of seasonal comparisons.

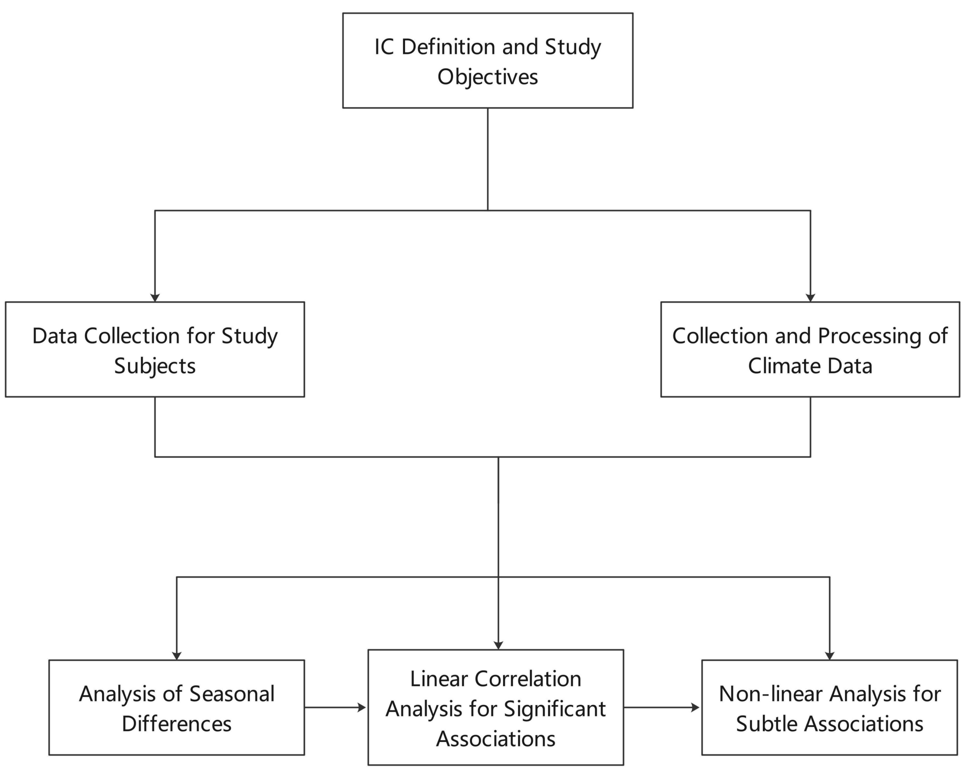

Figure 1 Flowchart for Investigating IC Prevalence and Climate Associations.
Abbreviations: IC, infant colic.

Treatment of Climate Factors

Based on previous studies, we chose to include temperature (maximum and minimum temperature, temperature difference) and pollutant levels (PM2.5, PM10, nitrogen dioxide, carbon monoxide, ozone, and air quality index) as climatic factors for the current study.[11,12,17] In addition, it is worth noting that the body's expression of an immune or inflammatory response to climatic factors may take time to accumulate. We should not only analyze what the climatic situation was like at the moment of the patient's illness, but also analyze the role of climatic factors in the period prior to the patient's illness. Therefore, we created lagged variables of climatic factors (one week, two weeks and four weeks) to explore possible delayed effects.

Analysis of the Linear Relationship Between Climatic Factors and IC

Considering the large number of climatic factors to be studied after processing, and in order to avoid multicollinearity among these factors that would distort the model results, we calculated the VIF for each climatic variable.Variables with a VIF value exceeding 10 were excluded to ensure the stability of the model. Subsequently Pearson correlation analysis was performed to analyze the direct associations between climate factors and IC, to initially explore the climate factors that may form a significant effect on IC and to understand the general trend of the relationship between climate and IC.

In addition, to further explore the interaction effects between climate variables and capture potential combined effects of climate factors and pollutants, we created interaction terms. For this purpose, we combined lowest temperature, highest temperature, and key pollutants (PM2.5, PM10). This selection was based on the typical characteristics of Beijing's winter climate and air pollution: low temperatures and large temperature differences may exacerbate pollutant retention, and PM2.5 and PM10 are major contributors to air pollution in the region.[18] To ensure robust analysis, we also calculated the VIF for these interaction terms, including only those with a VIF less than 10 in further analyses.

Nonlinear Analysis Using Generalized Additive Model

In addition to this significant effect of linear relationship, we also want to explore the weak effect between climate factors and IC, which may also form a large effect on infants after accumulating over time. We used a generalized additive model (GAM) to construct a nonlinear correlation analysis to explore possible weak effects, threshold effects, or asymmetric effects. In this stage of the analysis, we also incorporated interaction terms. Unlike in the linear model, the interaction terms in the GAM were constructed using tensor product smooths.

$$\mathrm{logit}(E(Y)) = \beta_0 + \sum_{I=1}^{N} s(X_I, df_i)$$

For the above model, E(Y) represents expected value of IC prevalence. logit(E(Y)) is the logit link function, chosen due to the binomial distribution of the dependent variable. β_0 represents the intercept term, and $s(X_i,df_i)$ stood for smoothing function for the independent variable X_i, where the degree of freedom df_i is chosen automatically by the Akaike Information Criterion (AIC).

Results

Demographic Characteristics

During the study, a total of 2340 infants were enrolled, ensuring adequate sample size to account for potential sample loss. After data collection, 1955 infants were included in the final analysis, accounting for a sample loss of 16.5% due to reasons such as loss to follow-up and incomplete medical records. These losses were analyzed to confirm that no significant selection bias was introduced, ensuring the robustness of the study results.

In all children, the results showed an overall prevalence of 38.62% for IC. The comparison between infants with and without IC for general characteristics is shown in Table 1. In summary, there were no significant differences in general demographic characteristics between infants with and without IC.

Seasonal Variation in IC Prevalence

Upon comparison, there was a significant difference in prevalence among the four seasons (p=0.01). We then conducted six comparisons of prevalence rates between seasons. According to the Bonferroni correction, a p-value of less than

Table 1 Comparison of General Characteristics Between IC and Non-IC

	IC (N=755)	Non-IC (N=1,200)	t/χ^2	p[c]
Male, n, (%)	408, 54.04%	618, 51.5%	1.199[a]	0.274
Day of Labor (day, mean ± SD)	47.55±5.28	47.61±5.50	−0.216[b]	0.829
Natural birth, n, (%)	529, 70.06%	820, 68.33%	0.651[a]	0.420
Gestational age (week, mean ± SD)	39.00±1.31	39.01±1.25	−0.211[b]	0.833
Birth weight (kg, mean ± SD)	3.31±0.43	3.35±1.00	−1.079[b]	0.281
Breastfeeding, n, (%)	377,49.93%	631,52.58%	1.303[a]	0.254
Average monthly weight gain (kg, mean ± SD)	1.36±1.88	1.25±1.32	1.514[b]	0.130

Notes: [a]represents χ^2 test, [b]represents independent samples *t*-test. [c]p values <0.05 were considered significant.
Abbreviations: IC, infant colic; Non-IC, non-infant colic.

0.0083 indicates significant differences between seasons. Using this criterion, we observed that the prevalence of IC was highest in winter (34.52%) and lowest in spring (43.60%), and the difference between the two was statistically significant (p=0.003). Detailed results are shown in Table 2.

The combined bar-line charts (Figure 2) reveal distinct seasonal variations in temperature and pollutant levels. This seasonal analysis appears to support the hypothesis that seasonal or climate-specific factors may influence IC prevalence. These findings provide a scientific basis for our subsequent analyses, guiding us to investigate specific climate factors that may contribute to IC, particularly climate characteristics unique to winter.

Linear Relationship Between IC and Climate

After exploring data from two websites, we obtained complete climate information and created the corresponding lagged variables (with lags of 1 week, 2 weeks, and 4 weeks). By excluding variables with a VIF greater than 10, we reduced the number of variables to 12 (Table s1).

Upon linear correlation analysis, we found that the correlation coefficients between these variables and in ranged from −0.05 to 0.03, indicating that none of these variables had a significant linear relationship with IC. The detailed results are presented in Figure 3A.

Furthermore, we applied interaction term analysis to examine the combined effects of climate factors, particularly how multiple variables may synergistically influence the risk of IC. For example, we investigated whether the coexistence of low temperatures and high PM2.5 levels could exacerbate the occurrence of IC.

To prevent an excessive number of interaction terms from affecting model stability, we selected representative variables—lowest temperature, highest temperature, and major pollutants (PM2.5, PM10)—based on the results of linear correlation analysis and the climatic characteristics of Beijing. Corresponding lagged variables were also created. Additionally, VIF values were calculated to mitigate the impact of multicollinearity on the model (Table s2). The analysis results for the interaction terms, as shown in Figure 3B, revealed no significant association with IC. This suggests that even when accounting for the combined effects of climate variables, the direct relationship between climate factors and IC remains relatively weak.

Table 2 Comparison of IC Prevalence Across Different Seasons

	IC Prevalence in Season 1[a] (n, %)	IC Prevalence in Season 2[b] (n, %)	χ^2	p[c]
Spring vs Summer	223 (34.52%)	147 (36.57%)	0.455	0.5
Spring vs Autumn	223 (34.52%)	201 (41.44%)	5.666	0.017
Spring vs Winter	223 (34.52%)	184 (43.60%)	8.926	0.003
Summer vs Autumn	147 (36.57%)	201 (41.44%)	2.192	0.139
Summer vs Winter	147 (36.57%)	184 (43.60%)	4.239	0.04
Autumn vs Winter	201 (41.44%)	184 (43.60%)	0.430	0.512

Notes: [a]Season 1 refers to the season listed first, [b]Season 2 refers to the season listed second. [c]p values <0.05 were considered significant. For example, in "Spring vs Summer", Season 1 is Spring and Season 2 is Summer.
Abbreviations: IC, infant colic; Non-IC, non-infant colic.

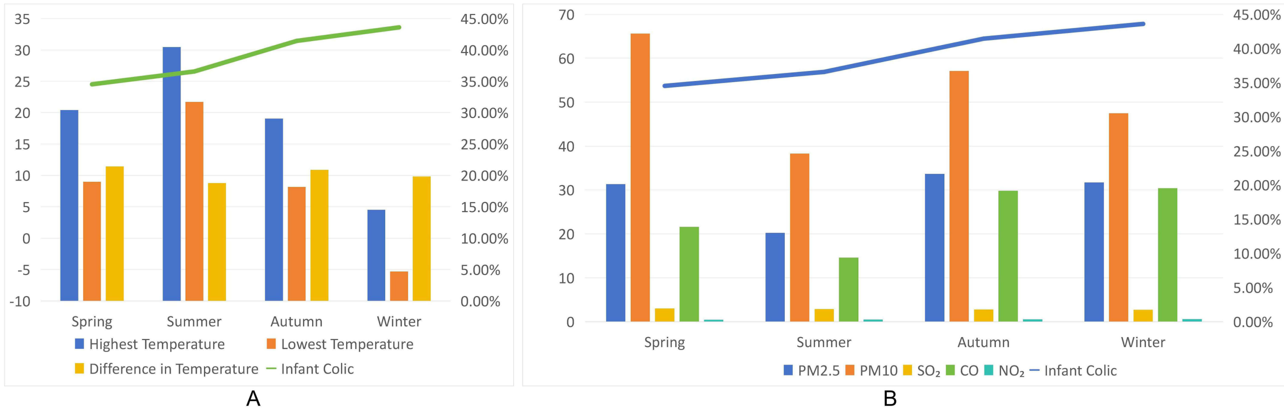

Figure 2 Seasonal variation in temperature, pollutants, and prevalence of IC. (**A**) Temperature and IC Prevalence, (**B**) Pollutants and IC Prevalence.
Abbreviations: IC, infant colic.

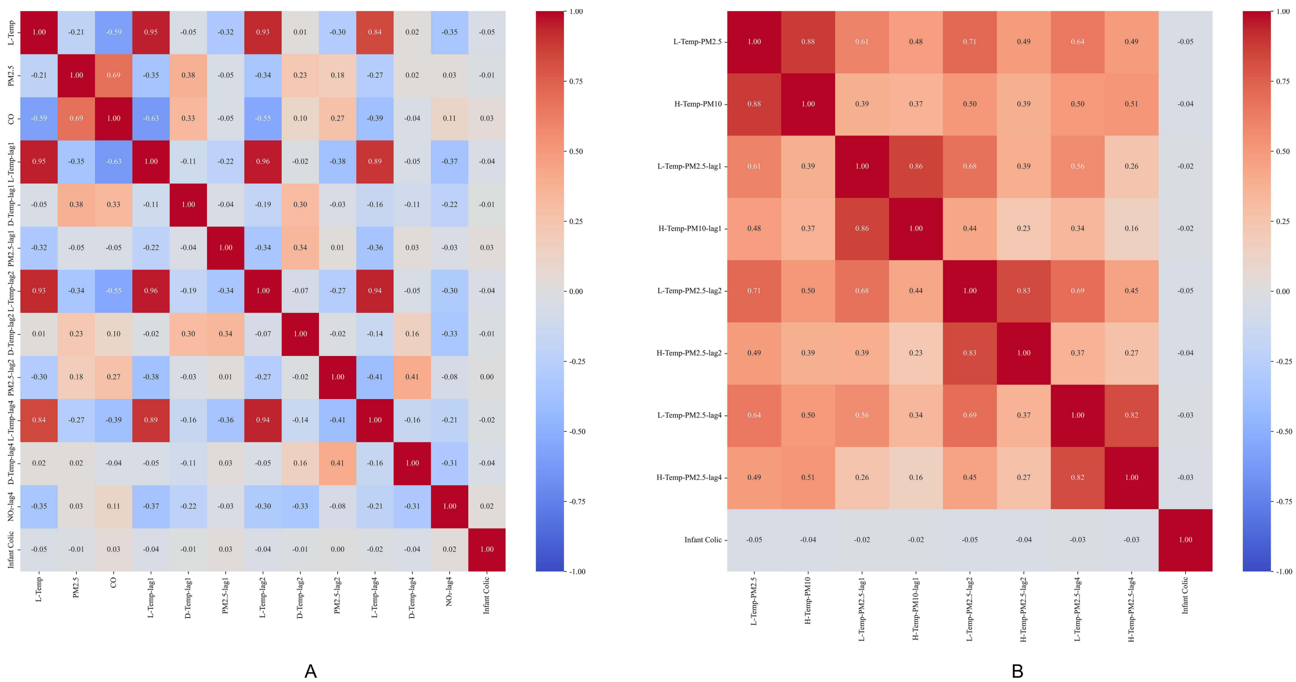

Figure 3 Heatmap of Linear Correlation Between Climate Factors and IC. (**A**) Individual Climate Factors and IC, (**B**) Climate Factors interactions and IC.
Abbreviations: IC, infant colic; L-Temp, lowest temperature; L-Temp-lag1, lowest temperature with a 1-week Lag; D-Temp-lag1, difference in temperature with a 1-week Lag; PM2.5-lag1, PM2.5 with a 1-week Lag; L-Temp-lag2, lowest temperature with a 2-week Lag; D-Temp-lag2, difference in temperature with a 2-week Lag; PM2.5-lag2, PM2.5 with a 2-week Lag; L-Temp-lag4, lowest temperature with a 4-week Lag; D-Temp-lag4, difference in temperature with a 4-week Lag; NO2-lag4, NO2 with a 4-week Lag; L-Temp-PM2.5, lowest temperature and PM2.5 interaction; H-Temp-PM10, highest temperature and PM10 interaction; L-Temp-PM2.5-lag1, lowest temperature and PM2.5 interaction with a 1-week lag; H-Temp-PM10-lag1, highest temperature and PM10 interaction with a 1-week lag; L-Temp-PM2.5-lag2, lowest temperature and PM2.5 interaction with a 2-week lag; H-Temp-PM2.5-lag2, highest temperature and PM2.5 interaction with a 2-week lag; L-Temp-PM2.5-lag4, lowest temperature and PM2.5 interaction with a 4-week lag; H-Temp-PM2.5-lag4, highest temperature and PM2.5 interaction with a 4-week lag.

Non-Linear Relationship Between IC and Climate

The GAM constructed in this study yielded a deviance explained of only 0.002. This indicates that there is no significant nonlinear relationship between IC and climate factors. While some smoothing curves displayed weak nonlinear trends for specific climate variables, such as a slight upward trend for lowest temperature, these effects were not statistically significant (Table 3). The wide confidence intervals further suggest a lack of substantial correlation between these factors and the prevalence of IC, as shown in Figure 4.

Table 3 GAM for Individual Climate Factors

	Climate Factor	EDoF	p		Climate Factor	EDoF	p
1	L-Temp	10.8	0.204	7	L-Temp-lag2	0.0	0.268
2	PM2.5	7.7	0.618	8	D-Temp-lag2	0.0	0.367
3	CO	5.1	0.790	9	PM2.5-lag2	0.0	0.187
4	L-Temp-lag1	0.0	0.680	10	L-Temp-lag4	0.0	0.110
5	D-Temp-lag1	0.0	0.655	11	D-Temp-lag4	0.0	0.379
6	PM2.5-lag1	0.0	0.373	12	NO_2-lag4	0.0	0.814

Abbreviations: GAM, Generalized Additive Model; EDoF, Estimated Degrees of Freedom; L-Temp, lowest temperature; L-Temp-lag1, lowest temperature with a 1-week Lag; D-Temp-lag1, difference in temperature with a 1-week Lag; PM2.5-lag1, PM2.5 with a 1-week Lag; L-Temp-lag2, lowest temperature with a 2-week Lag; D-Temp-lag2, difference in temperature with a 2-week Lag; PM2.5-lag2, PM2.5 with a 2-week Lag; L-Temp-lag4, lowest temperature with a 4-week Lag; D-Temp-lag4, difference in temperature with a 4-week Lag; NO_2-lag4, NO_2 with a 4-week Lag.

To assess the temporal independence of residuals, we conducted autocorrelation function (ACF) and partial autocorrelation function (PACF) analyses (Figure s1A and s1B). The ACF results indicated no significant correlation among residuals across multiple lags, suggesting that the residuals are independent and do not exhibit temporal clustering. Similarly, the PACF analysis confirmed the absence of strong correlations at specific lags after accounting for the influence of preceding lags. These findings reinforce the robustness of the model and rule out temporal dependence or unaccounted-for time-related effects.

In exploring non-linear relationships, we utilized tensor product smoothing to create interaction terms, selecting variables consistent with the linear correlation analysis. Lagged variables were also generated, and VIF calculations were performed (Table s3). Interaction terms with VIF values below 10 were included in the GAM model for analysis. The results indicated that these interaction terms also showed no significant effects in the non-linear model (Table 4). The deviance explained of only 0.007. The wide confidence intervals of the smoothing curves further highlighted the lack of statistical significance in the relationship between the interaction terms and IC (Figure 5). Additionally, the ACF and PACF confirmed the absence of notable temporal dependence or periodic patterns in the model residuals (Figure s1C and s1D). These findings provide further evidence, from a non-linear perspective, that the influence of climate factors and their interactions on IC is likely minimal.

Discussion

Prevalence and Harm of IC

Since its introduction in 2016, the Rome IV diagnostic criteria have been widely adopted globally, significantly influencing the diagnosis of IC. Compared to the Rome III criteria, Rome IV removed quantitative thresholds such as "crying for 3 days a week, 3 hours a day" and instead emphasized individualized assessments.[19,20] While this change increased diagnostic flexibility and raised prevalence rates from 10.4% to 14.9%, it also potentially heightened parental anxiety due to the higher reported rates.[21]

The prevalence of IC reported in this study is notably higher than these studies, a difference mainly attributed to the age range of the study population. While previous studies often focused on infants aged 0–6 months, our study specifically examined the 0–3 months. This early period is when IC episodes are most frequent and severe.[22] In fact, a Chinese study found that the prevalence of IC in early infancy was 43.8%, consistent with our findings.[16]

The impacts of IC are multifaceted. Beyond the short-term effects highlighted earlier, IC may have long-term consequences for infants. Children with IC may have more challenging temperaments as they grow older and are more likely to experience sleep deprivation.[23,24] At the family level, IC can negatively affect caregivers' mental health and contribute to physical issues such as poor sleep quality and fatigue.[25,26] On a broader societal level, IC significantly increases the likelihood of repeated medical visits, leading to wasted healthcare resources.[27] Additionally, parents may seek treatments such as massage therapy or probiotics, further raising childcare costs.[28,29] Therefore, parents often wish to understand when IC is more prevalent so they can better prepare accordingly.

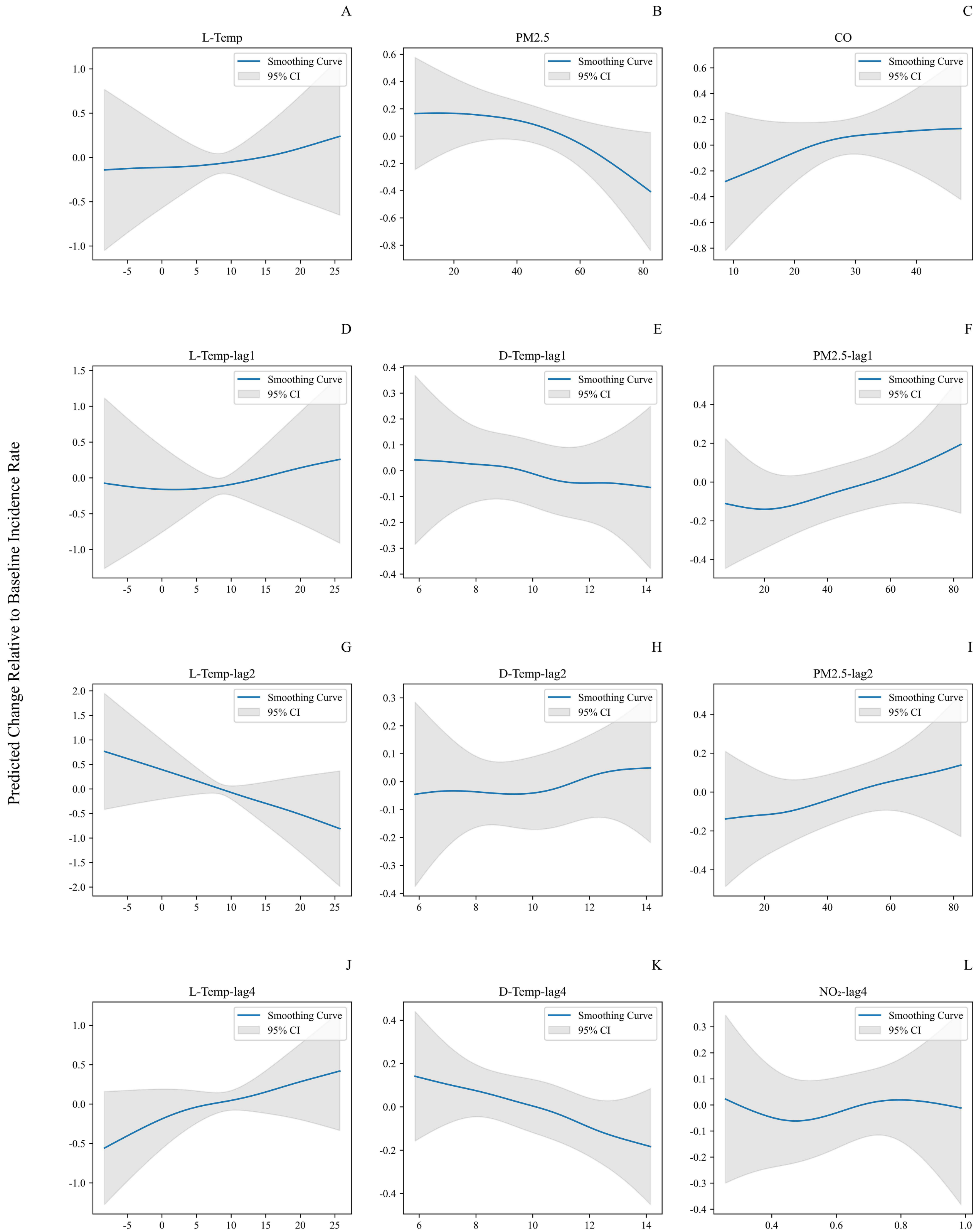

Figure 4 Smoothing Curves of the Non-Linear Relationship Between Individual Climate Factors and IC. (**A**) L-Temp, (**B**) PM2.5, (**C**) CO, (**D**) L-Temp-lag1, (**E**) D-Temp-lag1, (**F**) PM2.5-lag1, (**G**) L-Temp-lag2, (**H**) D-Temp-lag2, (**I**) PM2.5-lag2, (**J**) L-Temp-lag4, (**K**) D- Temp-lag4, (**L**)NO2-lag4.

Abbreviations: IC, infant colic; L-Temp, lowest temperature; L-Temp-lag1, lowest temperature with a 1-week Lag; D-Temp-lag1, difference in temperature with a 1-week Lag; PM2.5-lag1, PM2.5 with a 1-week Lag; L-Temp-lag2, lowest temperature with a 2-week Lag; D-Temp-lag2, difference in temperature with a 2-week Lag; PM2.5-lag2, PM2.5 with a 2-week Lag; L-Temp-lag4, lowest temperature with a 4-week Lag; D-Temp-lag4, difference in temperature with a 4-week Lag; NO2-lag4, NO2 with a 4-week Lag.

Table 4 GAM for Interaction Terms Between Climate Factors

	Climate Factor	EDoF	p		Climate Factor	EDoF	p
1	L-Temp-PM2.5	11.1	0.258	7	L-Temp-PM2.5-lag2	0.0	0.542
2	H-Temp-PM2.5	4.4	0.558	8	H-Temp-PM2.5-lag2	0.0	0.358
3	H-Temp-PM10	1.9	0.497	9	H-Temp-PM10-lag2	0.0	0.548
4	L-Temp-PM2.5-lag1	1.6	0.566	10	L-Temp-PM2.5-lag4	0.0	0.681
5	H-Temp-PM2.5-lag1	0.3	0.455	11	H-Temp-PM2.5-lag4	0.0	0.449
6	H-Temp-PM10-lag1	0.0	0.525	12	H-Temp-PM10-lag4	0.0	0.744

Abbreviations: GAM, Generalized Additive Model; EDoF, Estimated Degrees of Freedom; L-Temp-PM2.5, lowest temperature and PM2.5 interaction; H-Temp-PM2.5, highest temperature and PM2.5 interaction; H-Temp-PM10, highest temperature and PM10 interaction; L-Temp-PM2.5-lag1, lowest temperature and PM2.5 interaction with a 1-week lag; H-Temp-PM2.5-lag1, highest temperature and PM2.5 interaction with a 1-week lag; H-Temp-PM10-lag1, highest temperature and PM10 interaction with a 1-week lag; L-Temp-PM2.5-lag2, lowest temperature and PM2.5 interaction with a 2-week lag; H-Temp-PM2.5-lag2, highest temperature and PM2.5 interaction with a 2-week lag; H-Temp-PM10-lag2, highest temperature and PM10 interaction with a 2-week lag; L-Temp-PM2.5-lag4, lowest temperature and PM2.5 interaction with a 4-week lag; H-Temp-PM2.5-lag4, highest temperature and PM2.5 interaction with a 4-week lag; H-Temp-PM10-lag4, highest temperature and PM10 interaction with a 4-week lag.

Seasonal Variation of IC

In previous studies, there have been few comparative analyses specifically focusing on the differences in the prevalence of IC between seasons. In the present study, we found that the prevalence of IC was significantly higher in winter, a finding very similar to the seasonal characteristics of other types of acute abdominal pain.[17,30,31]

This finding provides a new perspective for clinical practice. First, as winter is a period of high IC prevalence, clinicians can enhance health education for parents and remind them to prepare for IC in advance. Such preventive guidance can help families better manage their infants' health. However, while emphasizing health education, we need to carefully assess its possible negative effects, such as over-emphasizing the risk of IC to parents, which may increase their anxiety and burden of parenting.

Second, the high prevalence of IC in winter inevitably brings to mind the potential effects of cold weather and poor air quality. This assumption is consistent with the concept of "harmony between heaven and humanity" in traditional Chinese medicine (TCM). In TCM theory, abdominal pain is often attributed to "cold attack".[32] IC is regarded as a "infantile-morbid-night-crying" and has been considered to be closely related to cold since the Sui Dynasty.[33] This traditional belief has had a profound effect on Chinese parents, many of whom are convinced that cold is the main cause of IC, and therefore severely limit their infants' outdoor activities in winter, avoiding cold air exposure as much as possible.[34]

Relationship Between Climate Factors and IC

We conducted an in-depth analysis of climatic factors, including temperature, air pollutants and their interactions, based on observed seasonal differences. However, the results showed no significant linear or nonlinear relationship between these factors and IC. This finding contradicts our initial hypothesis. Although these results may seem like "useless" negative findings, they offer valuable insights for correcting assumptions in empirical medicine.

Previous studies of seasonal variations in abdominal pain have often hypothesized that the observed differences may be due to climatic factors without further analysis. This is consistent with the TCM hypothesis of IC. Our study scientifically disproves this assumption. This study not only elucidates the relationship between IC and climate factors, but also encourages a broader view of other possible factors.

These findings have important clinical implications. First, physicians can provide parents with evidence-based explanations of IC triggers. This can help reduce unnecessary protective measures, such as overdressing infants or avoiding outdoor activities in cool weather. Such overprotective behaviors may limit an infant's normal activities and even lead to other health risks. Second, the findings open up new directions for research. By ruling out temperature and air pollution as major factors, we can focus on other potential factors. For example, seasonal changes may affect the level

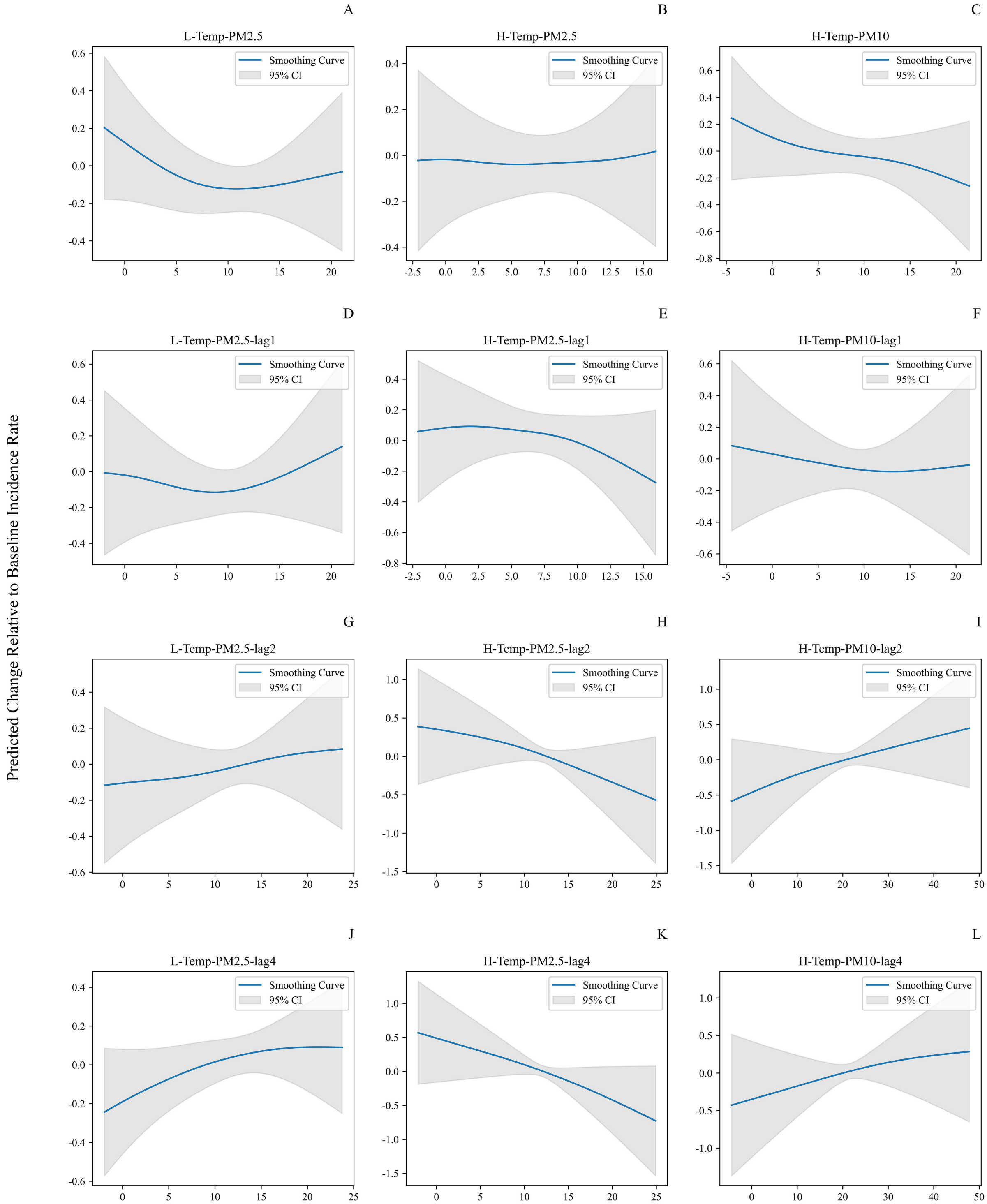

Figure 5 Smoothing Curves of the Non-Linear Relationship Between Climate Factors Int eractions and IC. (**A**) L-Temp-PM2.5, (**B**) H-Temp-PM2.5, (**C**) H-Temp-PM10, (**D**) L-Temp -PM2.5-lag1, (**E**) H-Temp-PM2.5-lag1, (**F**) H-Temp-PM10-lag1, (**G**) L-Temp-PM2.5-lag2, (**H**) H-Temp-PM2.5-lag2, (**I**) H-Temp-PM10-lag2, (**J**) L-Temp-PM2.5-lag4, (**K**) H-Temp-PM2. 5-lag4, (**L**) H-Temp-PM10-lag4.

Abbreviations: L-Temp-PM2.5, lowest temperature and PM2.5 interaction; H-Temp-PM2.5, highest temperature and PM2.5 interaction; H-Temp-PM10, highest temperature and PM10 interaction; L-Temp-PM2.5-lag1, lowest temperature and PM2.5 interaction with a 1-week lag; H-Temp-PM2.5-lag1, highest temperature and PM2.5 interaction with a 1-week lag; H-Temp-PM10-lag1, highest temperature and PM10 interaction with a 1-week lag; L-Temp-PM2.5-lag2, lowest temperature and PM2.5 interaction with a 2-week lag; H-Temp-PM2.5-lag2, highest temperature and PM2.5 interaction with a 2-week lag; H-Temp-PM10-lag2, highest temperature and PM10 interaction with a 2-week lag; L-Temp-PM2.5-lag4, lowest temperature and PM2.5 interaction with a 4-week lag; H-Temp-PM2.5-lag4, highest temperature and PM2.5 interaction with a 4-week lag; H-Temp-PM10-lag4, highest temperature and PM10 interaction with a 4-week lag.

of outdoor activity, feeding practices, or parenting styles, which may affect IC development. Future studies should explore these non-climatic factors to reveal the complex mechanisms behind seasonal variations in IC incidence.

Limitations of the Study

This study indeed has some limitations. Firstly, as a retrospective study based on existing records, many important pieces of information, such as behavioral data on the child's outdoor activity time, could not be obtained from the medical records. Secondly, this study only included data from one year, which limits our understanding of the temporal characteristics of IC prevalence. Extending the data collection period would help reveal long-term trends and seasonal variation characteristics of IC. Therefore, the collection of more data over a longer time is necessary for us to develop better health care strategies for IC.

Conclusion

This study revealed significant seasonal differences in IC prevalence, with the highest rates observed during winter. However, no significant associations were identified between IC and temperature, air pollutants, or their interactions. These findings provide new perspectives for understanding IC, suggesting that future research should focus on non-climatic factors to gain deeper insights into the mechanisms and seasonal variations of IC. This will enable more targeted strategies for the prevention and management of the condition.

Abbreviations

IC: infant colic, HPA: hypothalamic-pituitary-adrenal, GAM: Generalized Additive Model, VIF: Variance Inflation Factor, H-Temp: highest temperature, L-Temp: lowest temperature, D-Temp: difference in temperature, AQI: air quality index, H-Temp-lag1: highest temperature with a 1-week Lag, L-Temp-lag1: lowest temperature with a 1-week Lag, D-Temp-lag1: difference in temperature with a 1-week Lag, AQI-lag1: air quality index with a 1-week Lag, PM2.5-lag1: Particulate Matter with a diameter of 2.5 micrometers or less with a 1-week Lag, H-Temp-lag2: highest temperature with a 2-week Lag, L-Temp-lag2: lowest temperature with a 2-week Lag, D-Temp-lag2: difference in temperature with a 2-week Lag, AQI-lag2: air quality index with a 2-week Lag, PM2.5-lag2: Particulate Matter with a diameter of 2.5 micrometers or less with a 2-week Lag, H-Temp-lag4: highest temperature with a 4-week Lag, L-Temp-lag4: lowest temperature with a 4-week Lag, D-Temp-lag4: difference in temperature with a 4-week Lag, AQI-lag4: air quality index with a 4-week Lag, NO_2-lag4: NO_2 with a 4-week Lag, L-Temp-PM2.5: lowest temperature and PM2.5 interaction, H-Temp-PM2.5: highest temperature and PM2.5 interaction, H-Temp-PM10: highest temperature and PM10 interaction, L-Temp-PM2.5-lag1: lowest temperature and PM2.5 interaction with a 1-week lag, H-Temp-PM2.5-lag1: highest temperature and PM2.5 interaction with a 1-week lag, H-Temp-PM10-lag1: highest temperature and PM10 interaction with a 1-week lag, L-Temp-PM2.5-lag2: lowest temperature and PM2.5 interaction with a 2-week lag, H-Temp-PM2.5-lag2: highest temperature and PM2.5 interaction with a 2-week lag, H-Temp-PM10-lag2: highest temperature and PM10 interaction with a 2-week lag, L-Temp-PM2.5-lag4: lowest temperature and PM2.5 interaction with a 4-week lag, H-Temp-PM2.5-lag4: highest temperature and PM2.5 interaction with a 4-week lag, H-Temp-PM10-lag4: highest temperature and PM10 interaction with a 4-week lag, ACF: Autocorrelation Function, PACF: Partial Autocorrelation Function, 95% CI: 95% Confidence Interval.

Data Sharing Statement

The datasets analysed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

Ethical approval for this retrospective study was obtained from the Beijing Jishuitan Hospital, Capital Medical University, Beijing, China (approval number: K2024-195-00). Patient parental consent was waived by the ethics committee because the study used anonymized data and posed minimal risk to participants. All data were handled in compliance with applicable data protection regulations, and confidentiality was strictly maintained throughout the study. This study complies with the ethical principles outlined in the Declaration of Helsinki.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests.

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