Seasonality in the incidence of acute sinusitis, air pollutant levels, and climate

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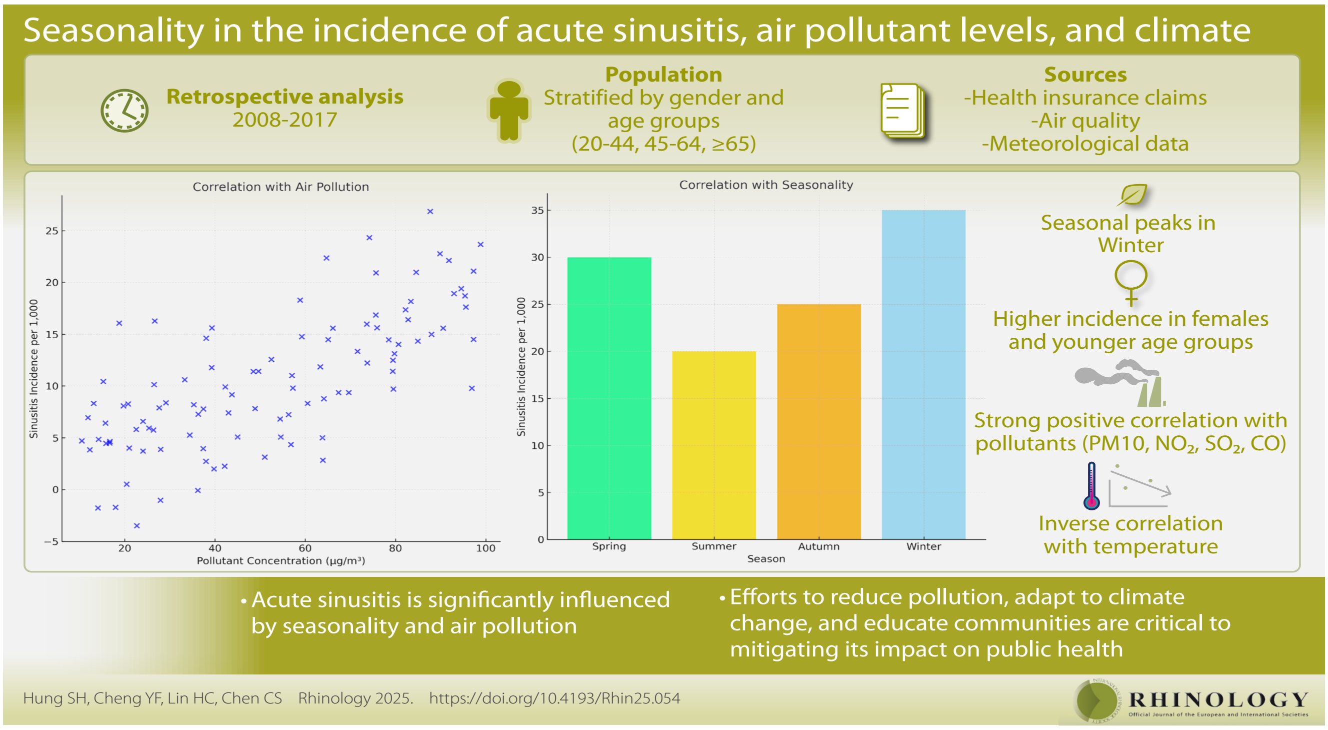

Abstract

Introduction: Emerging evidence from epidemiological studies highlights the interaction between air quality metrics and sinusitis occurrence. This study investigates the relationship between acute sinusitis incidence, air pollutant levels, and climatic conditions in Taiwan from 2008 to 2017.

Methods: This study extracted outpatient claims data from the Longitudinal Health Insurance Database 2010. We computed seasonal incidence rates of acute sinusitis episodes per 1000 population over 120 months, stratifying the data by gender and three age groups: 20-44, 45-64, and 65 years and older. Addressing the seasonal variability inherent in our dataset, we utilized Auto-Regressive Moving Average (ARMA) models to analyze each variable as a univariate time series influenced by its historical values.

Results: The analysis reveals that, except relative humidity, all other climatic factors including CO, NO_2, SO_2, PM10, O_3, ambient temperature and rainfall demonstrated significant crude correlations with the rates of acute sinusitis. The ARIMA test suggested that seasonality plays a significant role in influencing sinusitis episodes across all age groups. Specifically, individuals experience significantly higher incidence rates during winter compared to spring. These findings underscore winter as a period with notably higher incidence rates of acute sinusitis, even after adjusting for meteorological and air pollution variables.

Conclusions: This study provides comprehensive evidence of the significant associations between acute sinusitis incidence, air quality, and climatic factors in Taiwan.

Key words: acute sinusitis, climate, air pollutants, epidemiology

Introduction

Acute sinusitis, a prevalent inflammatory condition of the paranasal sinuses, represents a significant public health concern due to its high incidence and association with environmental factors [1]. Globally, acute sinusitis contributes to substantial morbidity, influencing individuals across diverse age groups, with varying incidence patterns linked to seasonality and environmental exposures. Taiwan, characterized by distinct seasonal climates and notable urban pollution levels, provides a valuable context to examine the interplay between ecological determinants and acute sinusitis trends [2].

Research indicates a robust association between air pollution and respiratory conditions, including sinusitis. Elevated levels of pollutants such as particulate matter (PM10), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) have been implicated in exacerbating sinus inflammation, potentially by promoting mucosal irritation and impairing ciliary function [3-5]. Seasonal climatic variations, such as temperature and humidity changes, further modulate the incidence of sinusitis, as seen in both temperate and tropical regions [6-9].

Emerging evidence from epidemiological studies highlights the interaction between air quality metrics and sinusitis occurrence. Such findings underscore the necessity to understand how environmental and climatic factors jointly influence sinusitis trends across different demographics.

This study investigates the relationship between acute sinusitis incidence, air pollutant levels, and climatic conditions in Taiwan from 2008 to 2017. By integrating epidemiological data with air quality and meteorological records, this research seeks to comprehensively assess the multifactorial influences on sinusitis, with potential implications for public health interventions and policy formulation.

Materials and methods

Acute sinusitis data

To analyze the epidemiological trends of acute sinusitis in Taiwan, we extracted outpatient claims data from the Longitudinal Health Insurance Database 2010 (LHID2010), a National Health Insurance Research Database component. This data pertained to patients diagnosed with acute sinusitis under ICD-9-CM code 461.9 and ICD-10-CM code J01.90 from January 2008 to December 2017. In our methodology, we treated all outpatient visits within 30 days as a single episode to avoid counting multiple visits as separate incidents. Patients were segmented into three age groups: 20-44, 45-64, and 65 years and older. Using this classification, we calculated the national, age-specific, and gender-specific seasonal incidence rates of acute sinusitis per 1,000 people, drawing on annual demographic data from the LHID2010 Registry for Beneficiaries over the same decade. This approach facilitated a detailed understanding of the demographic distribution and burden of acute sinusitis across different segments of Taiwan's population.

This study was conducted with the ethical approval of the Research Ethics Committee of National Taiwan University, under the approval number 202312EM054, in compliance with the ethical guidelines stipulated in the Declaration of Helsinki. We utilized deidentified administrative data for our analysis, which obviated the need for informed consent while ensuring the privacy and confidentiality of the participants. This approach effectively addressed potential ethical concerns related to using personal data, allowing the study to proceed without compromising participant integrity.

Air pollution data

Data on the seasonal average concentrations of air pollutants were sourced from the air quality monitoring databases managed by Taiwan's Environmental Protection Administration (EPA). The EPA conducts daily air quality assessments using 66 stations scattered throughout the island. We chose to work with seasonal mean data as it provides a more spatially consistent representation of air quality, reflective of community-wide exposure levels. The primary pollutants monitored include PM10, SO_2, CO, O_3, and NO_2. We excluded stations that did not report on all five pollutants or were situated in mountainous or remote areas. The analysis was thus carried out using data from the remaining 55 stations, from which we calculated the seasonal mean levels of these key air pollutants.

We utilized seasonal averages from 55 monitoring stations to assess air quality across Taiwan, a relatively compact island of approximately 36,188 square kilometers. This choice was informed by the island's geography, which features a large, sparsely populated central mountainous region contrasted with a densely populated coastal rim where population density and pollution from vehicles and industries are more uniformly distributed. Given this setup, further disaggregating seasonal admission rates by region and age classifications would likely reduce statistical power without significantly enhancing accuracy due to regional homogeneity. Analysis of the standard deviations across these stations confirmed this homogeneity in pollutant levels. Thus, we used seasonal mean values across the island to maintain methodological consistency and relevance.

Meteorological data

Meteorological data, including ambient temperature, relative humidity, atmospheric pressure, rainfall, and sunshine hours, were collected from 23 observation stations operated by the Central Weather Bureau. We calculated seasonal mean values to analyze this data by averaging the daily records from all 23 stations. This approach provided a comprehensive overview of the climatic conditions across different regions, facilitating a uniform understanding of the environmental factors during the study period.

Table 1. Seasonal incidence rates of acute sinusitis episodes per 1000 population alongside meteorological and air pollution variables in Taiwan, 2008-2017.

Variable	Mean	Standard deviation	Minimum	25th percentile	Median	75th percentile	Maximum
Seasonal incidence rates of acute sinusitis episodes per 1000 population							
Total	57.04	13.77	33.60	47.35	55.36	67.53	88.24
Sex							
Male	50.48	12.14	29.20	41.86	50.23	59.97	78.33
Female	63.29	15.44	37.85	52.35	61.10	73.89	97.64
Age							
20~44	69.90	16.98	39.51	57.03	69.18	81.93	108.63
45~64	49.93	12.24	29.74	41.64	47.43	59.92	77.60
≥ 65	33.86	7.57	20.45	27.61	32.95	40.17	51.15
Air pollution factor							
CO (ppm)	0.46	0.08	0.30	0.38	0.46	0.53	0.64
NO_2 (ppb)	15.31	2.92	10.27	12.85	15.32	17.62	20.95
SO_2 (ppb)	3.61	0.56	2.62	3.14	3.51	4.02	4.83
PM10 (μg/m^3)	51.87	12.40	29.86	41.43	53.15	60.99	70.54
O_3 (ppb)	29.68	4.76	22.18	24.87	29.99	32.61	39.50
Meteorological factor							
Temperature (ºC)	23.79	4.19	16.66	20.38	24.13	27.35	29.38
Rainfall (mm)	515.32	315.07	98.82	273.81	390.70	755.92	1302.73
Humidity (%)	75.68	1.86	71.66	74.25	75.95	77.01	79.92
Asthma admissions/100,000 populations	2389.39	286.71	1883.15	2165.72	2370.47	2671.43	2837.22

Table 2. Correlation coefficient (ρ) between seasonal incidence rates of acute sinusitis episodes per 1000 population and seasonal mean of air pollution and meteorology data between 2008 and 2017 by Spearman rank correlations.

	Total		Sex				Age					
			Male		Female		20~44		45~64		≥ 65	
CO (ppm)	0.814	***	0.784	***	0.821	***	0.784	***	0.802	***	0.771	***
NO_2 (ppb)	0.788	***	0.753	***	0.796	***	0.754	***	0.775	***	0.743	***
SO_2 (ppb)	0.249		0.169		0.293		0.175		0.241		0.179	
PM10 (μg/m^3)	0.683	***	0.638	***	0.701	***	0.645	***	0.663	***	0.631	***
O_3 (ppb)	0.317	*	0.314	*	0.325	*	0.328	*	0.305		0.329	*
Temperature (ºC)	-0.866	***	-0.859	***	-0.849	***	-0.862	***	-0.852	***	-0.842	***
Rainfall (mm)	-0.722	***	-0.719	***	-0.704	***	-0.724	***	-0.695	***	-0.699	***
Humidity (%)	-0.091		-0.077		-0.094		-0.079		-0.077		-0.104	

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Statistical analysis

We computed seasonal incidence rates of acute sinusitis episodes per 1000 population over 120 months, stratifying the data by gender and three age groups: 20-44, 45-64, and 65 years and older. To explore the relationship between these incidence rates and environmental factors, we employed two-tailed Spearman rank correlations to assess associations with air pollutants and climatic conditions. Addressing the seasonal variability inherent in our dataset, we utilized Auto-Regressive Moving Average (ARMA) models to analyze each variable as a univariate time series influenced by its historical values. ARMA models integrate autoregressive (AR) and moving average (MA) components to describe stationary stochastic processes, where the AR component uses lagged values of the variable and the MA component

Table 3. ARMA regression analysis showing seasonal and meteorological effects on seasonal acute sinusitis episodes per 1000 population according to age group in Taiwan.

	ALL				20 ~ 44				45 ~ 64				≥ 65			
Independent variable	β	SE	t-value		β	SE	t-value		β	SE	t-value		β	SE	t-value	
Intercept	7.958	112.532	0.070		-77.991	108.504	-0.720		-42.087	100.703	-0.420		-43.642	39.908	-1.090	
Trend	-0.017	0.272	-0.060		0.232	0.297	0.780		0.012	0.218	0.060		0.020	0.181	0.110	
Asthma admission rate	0.048	0.005	8.780	***	0.050	0.007	6.780	***	0.045	0.004	10.000	***	0.029	0.003	10.540	***
Rainfall (mm)	0.006	0.004	1.270		0.001	0.005	0.220		0.004	0.003	1.540		0.006	0.002	3.310	***
Temperature (ºC)	0.213	1.130	0.190		-0.261	1.285	-0.200		0.480	0.987	0.490		0.368	0.460	0.800	
Humidity (%)	-1.037	0.939	-1.100		-0.504	0.833	-0.610		-0.596	0.578	-1.030		-0.219	0.252	-0.870	
PM10 (μg/m^3)	-0.043	0.138	-0.310		-0.189	0.181	-1.050		-0.114	0.138	-0.830		0.005	0.059	0.080	
NO2 (ppb)	-5.166	3.006	-1.720		-3.152	4.678	-0.670		-3.763	1.980	-1.900		-1.618	1.024	-1.580	
SO2 (ppb)	12.190	5.220	2.340	*	16.588	6.763	2.450	*	12.496	3.116	4.010	***	7.085	2.741	2.580	**
O3 (ppb)	0.394	0.249	1.580		0.512	0.300	1.700		0.383	0.218	1.760		0.409	0.132	3.110	**
CO (ppm)	67.005	86.880	0.770		-3.017	79.036	-0.040		38.050	44.810	0.850		-14.105	14.281	-0.990	
Summer	-6.104	9.823	-0.620		-4.009	13.510	-0.300		-4.961	6.582	-0.750		-4.134	4.660	-0.890	
Autumn	3.985	3.917	1.020		7.048	4.974	1.420		2.661	2.811	0.950		0.781	2.273	0.340	
Winter	17.710	6.041	2.930	**	19.895	6.641	3.000	**	16.225	5.707	2.840	**	11.733	2.674	4.390	***
AR1	0.723	0.274	2.640	**	0.861	0.137	6.270	***	0.633	0.281	2.260	*	0.872	0.145	6.000	***
AR2	0.496	0.299	1.660		-	-	-		0.756	0.339	2.230	*	-	-	-	
AR3	-0.361	0.230	-1.570		-	-	-		-0.310	0.262	-1.180		-	-	-	
AR4	-	-	-		-	-	-		-0.247	0.323	-0.760		-	-	-	
MA1	-	-	-		-0.662	0.437	-1.520		-	-	-		0.771	5474.158	0.000	
MA2	-	-	-		1.000	0.453	2.210	*	-	-	-		-0.229	1255.953	0.000	
AIC		208.955				224.142				194.291				148.818		
Schwarz criterion (SC)		239.355				252.853				226.380				179.217		

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; AR1, autoregressive, lag 1; MA1, moving average, lag 1; Selection of the final parameters was based upon the lowest AIC and SC.

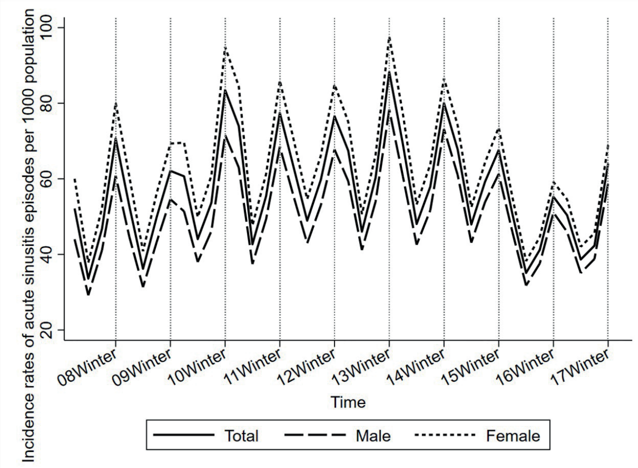

Figure 1. Seasonal incidence rates of acute sinusitis episodes per 1000 population according to gender groups.

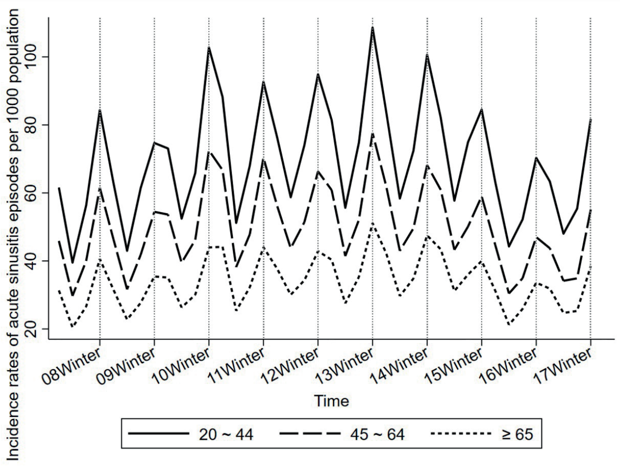

Figure 2. Seasonal incidence rates of acute sinusitis episodes per 1000 population according to age groups.

represents the error term as a linear combination of past and current errors. This model is expressed as ARMA (p, q), with 'p' indicating the number of AR terms and 'q' the number of MA terms. We selected model parameters that minimized the Akaike Information Criterion (AIC) and Schwarz Criterion (SC), utilizing the SAS software package for our analysis. We deemed the results significant at a p-value threshold of 0.05.

Results

Seasonal incidence rates of acute sinusitis

Table 1 presents the descriptive statistics for the seasonal incidence rates of acute sinusitis alongside meteorological and air pollution variables. The seasonal incidence rates per 1000 population varied from a low of 33.60 to a high of 88.24, with an average rate of 57.04 and a standard deviation of 13.77. Notably, females exhibited a higher mean seasonal incidence rate of 63.29 compared to 50.48 for males, and rates significantly declined with age, dropping from 69.90 in the 20-44 age group to 33.86 for those aged 65 and older. The average seasonal values for air pollution and meteorological factors included CO at 0.46 ppm, NO_2 at 15.31 ppb, SO_2 at 3.61 ppb, PM10 at 51.87, O_3 at 29.68 ppb, ambient temperature at 23.79°C, relative humidity at 75.68%, and rainfall at 515.32 mm. In addition, the seasonal asthma admission rate per 100,000 populations was 2389.39 with a standard deviation of 286.71.

Spearman rank correlations of acute sinusitis episodes per 1000 population with climate and air pollution factors

Table 2 details the correlations between meteorological and air pollution factors and the incidence of acute sinusitis episodes per 1000 population, segmented by gender and age group. The analysis reveals that, except relative humidity, all other climatic factors demonstrated significant crude correlations with the rates of acute sinusitis. This indicates a notable link between environmental conditions and sinusitis across different demographic segments.

Calendar seasonal variations

Figures 1 and 2 highlight the seasonal variations in the incidence of acute sinusitis in Taiwan, analyzed by gender and age group. The seasonal divisions are as follows: spring from February to April, summer from May to July, autumn from August to October, and winter from November to January. Both figures illustrate a consistent seasonal pattern across the pooled sample, genders, and age groups, with a notable peak occurring in winter. This peak is followed by a sharp decline in Spring, and a significant trough is observed in Summer.

Adjusted season and meteorological associations

Table 3 details the findings from ARMA multivariate regression models that were categorized by age group, analyzing the seasonal impact on acute sinusitis incidence rates. The models integrated climate and air pollution variables along with calendar seasons to evaluate their effect on the incidence rates of acute sinusitis. This analysis aimed to discern whether elements like temperature and humidity could fully or partially explain the variations in seasonal incidence rates and to identify if specific seasons demonstrated significant correlations after accounting for these environmental factors. Notably, seasonal asthma admission rate per 100,000 populations emerged as a consistently substantial predictor across all models. The degree of impact varied by age, with increases of 0.050 for individuals younger than 44 years, 0.045 for those aged 45-64, and 0.029 for those 65 and older.

The results of Table 3 also indicate that seasonality plays a significant role in influencing sinusitis episodes across all age groups ($p < 0.01$). Specifically, individuals experience significantly higher incidence rates during winter compared to spring.

These findings underscore winter as a period with notably higher incidence rates of acute sinusitis, even after adjusting for meteorological and air pollution variables.

Discussion

This study investigated the complex interplay between the incidence of acute sinusitis, air pollutant levels, and climatic conditions in Taiwan from 2008 to 2017. Utilizing data from the LHID2010, alongside air quality and meteorological records, we analyzed seasonal incidence rates of acute sinusitis across different age groups and genders, and correlated these with environmental variables. Our findings reveal significant associations between acute sinusitis incidence and both air quality and climatic factors, highlighting the multifactorial nature of this common respiratory condition.

Seasonal variations and climatic influences

Our results demonstrate a clear seasonal pattern in the incidence of acute sinusitis, with a prominent peak in winter and a significant trough in summer. This pattern is consistent across genders and age groups, suggesting a strong environmental influence on the occurrence of acute sinusitis. The observed spring peak aligns with findings from other studies that reported increased sinusitis incidence during significant temperature and humidity fluctuations [10]. Such climatic transitions may facilitate the proliferation of pathogens or allergens, contributing to the higher incidence rates observed [11].

Ambient temperature emerged as a particularly significant predictor of acute sinusitis incidence. Our analysis revealed that mean seasonal temperature was associated with decreased incidence rates, with the most pronounced effect observed in younger individuals. This inverse relationship between temperature and sinusitis incidence is corroborated by studies conducted in temperate and tropical regions, suggesting that colder temperatures may impair mucociliary clearance and increase susceptibility to respiratory infections [12]. Conversely, higher temperatures may be associated with reduced viral survival and improved immune function, potentially contributing to lower incidence rates during warmer months.

Relative humidity, however, did not show a significant correlation with acute sinusitis incidence in our study. This contrasts with previous research that has implicated high humidity in promoting fungal growth and exacerbating sinusitis symptoms [13,14]. The lack of a significant association in our analysis may be due to the complex and potentially non-linear relationship between humidity and respiratory health, which may vary depending on the specific climatic context and population characteristics [15].

Air pollution and acute sinusitis

Our study found significant correlations between acute sinusitis incidence and the levels of several air pollutants, including PM10, NO_2, SO_2, and CO. These findings are consistent with a growing body of evidence linking air pollution to respiratory morbidity, including sinusitis [2-4]. Particulate matter, in particular, has been shown to induce oxidative stress and inflammation in the respiratory tract, potentially impairing mucociliary function and increasing susceptibility to infections [16-18]. NO_2 and SO_2, common byproducts of fossil fuel combustion, have also been implicated in exacerbating respiratory inflammation and increasing the risk of sinusitis [19,20].

The association between air pollution and acute sinusitis may be particularly relevant in urban areas with high traffic and industrial emissions. Taiwan, with its densely populated coastal regions and significant industrial activity, presents a unique context for studying the impact of air pollution on respiratory health. Our findings underscore the need for effective air quality management strategies to mitigate the public health burden of acute sinusitis and other respiratory conditions.

Demographic factors

Our analysis revealed significant differences in acute sinusitis incidence across age groups and genders. Females exhibited a higher mean seasonal incidence rate than males, which may be attributed to hormonal factors or differences in immune responses [21]. Incidence rates also declined with age, with the highest rates observed in the 20-44 age group. This pattern may reflect age-related changes in immune function, exposure patterns, or healthcare-seeking behavior [22]. The lower incidence rates observed in older adults could also be related to the development of acquired immunity over time. However, it is important to note that older adults may be more susceptible to severe complications from acute sinusitis, highlighting the need for targeted prevention and management strategies in this population [23].

Implications for public health and policy

The findings of this study have important implications for public health interventions and policy formulation. The strong association between acute sinusitis, climatic factors, and air pollution suggests that a multifaceted approach is needed to address this common respiratory condition.

Public health campaigns should emphasize minimizing individual exposure to air pollutants, particularly during periods of high pollution. Recommendations may include staying indoors, avoiding strenuous outdoor activities, using air purifiers in enclosed spaces, and wearing particulate-filtering masks (e.g., N95) when outdoor exposure is unavoidable [24]. Real-time air quality monitoring tools should also be promoted to help individuals make informed decisions. In parallel, long-term strategies to reduce the overall burden of air pollution should remain a public health priority. These include promoting cleaner transportation options, enhancing regulatory standards for emissions, and incentivizing industry compliance with environmental protection measures.

Climate change is expected to alter temperature and precipitation patterns, potentially exacerbating the seasonal variations in acute sinusitis incidence [25]. Therefore, climate change mitigation and adaptation strategies should be integrated into public health planning to address the potential impacts on respiratory health.

Healthcare providers should be aware of the seasonal patterns in acute sinusitis incidence and consider environmental factors when diagnosing and managing patients. Educating patients about the potential risks of air pollution and climatic fluctuations can empower them to take preventive measures and seek timely medical care.

Limitations

This study has several limitations. First, as the analysis was based on administrative claims data, we lacked information on the clinical details of how acute sinusitis diagnoses were established and by whom, which may lead to diagnostic heterogeneity and potential misclassification. Second, underreporting is possible, particularly for individuals with mild symptoms who may not seek medical attention, resulting in underestimated incidence rates. Additionally, certain unmeasured confounders, such as allergic diseases and smoking history, could influence the observed associations between environmental exposures and sinusitis incidence. Despite these limitations, the large-scale, population-based nature of the dataset and the use of standardized diagnostic codes strengthen the reliability and generalizability of our findings.

Future research should utilize more granular data on air pollution and climatic variables, potentially incorporating personal monitoring data to characterize individual exposures better. Longitudinal studies with individual-level data on risk factors and health outcomes are needed to elucidate further the causal relationships between environmental factors and acute sinusitis. Additionally, exploring the potential role of specific pathogens, allergens, and other environmental triggers in the pathogenesis of acute sinusitis may provide further insights into the mechanisms underlying the observed associations.

Conclusion

This study provides comprehensive evidence of the significant associations between acute sinusitis incidence, air quality, and climatic factors in Taiwan. Our findings highlight the importance of considering environmental influences when addressing the public health burden of acute sinusitis. By integrating epidemiological data with air quality and meteorological records, we have demonstrated the multifactorial nature of this common respiratory condition. The observed seasonal patterns, the inverse relationship with temperature, and the positive correlations with air pollutants underscore the need for a multifaceted approach to prevention and management. Public health interventions should focus on minimizing exposure to air pollutants, adapting to climate change impacts, and educating healthcare providers and patients about environmental risk factors. Further research is needed to refine our understanding of the complex interplay between environmental factors and acute sinusitis, with the ultimate goal of developing more effective strategies to reduce the incidence and impact of this prevalent condition.

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Authorship contribution

Conception or design: S-H, H-C; Methodology: H-C, C-S; Formal analysis: H-C, C-S; Validation, C-S, Y-F; Data curation, C-S; Writing-original draft preparation: S-H, Y-F, C-S, H-C; Review and editing: C-S; The final approval of the version to be published: S-H, Y-F, C-S, H-C All authors agree to be accountable for all aspects of the work.

Conflict of interest

The authors declare no conflict of interest

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