Test file: The Impact of Air Pollution on Childhood Asthma Hospitalizations: A Time-Stratified Case-Crossover Study

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Abstract

This time-stratified case-crossover study examined the association between short-term air pollution exposure and childhood asthma hospitalizations in 12 major cities. Analyzing 45,832 hospitalization records from 2018-2022, we found significant exposure-response relationships for PM2.5, NO2, and O3. The strongest associations were observed for NO2, with a 2.8% increase in asthma hospitalizations per 10 μg/m³ increase. Children under 5 years and those from low-income neighborhoods showed heightened susceptibility. These findings underscore the need for stricter air quality standards and targeted protection for vulnerable pediatric populations.

Keywords: Air Pollution; Childhood Asthma; Hospitalizations; Case-Crossover Study; Environmental Epidemiology; Public Health

1. Introduction

Asthma represents the most common chronic disease in children worldwide, affecting approximately 339 million people globally. The prevalence of childhood asthma has increased substantially over recent decades, with environmental factors identified as major contributors to this trend. Air pollution, particularly fine particulate matter (PM2.5), nitrogen dioxide (NO2), and ozone (O3), has been implicated in asthma exacerbations through multiple biological mechanisms including airway inflammation, oxidative stress, and enhanced allergic sensitization. While numerous studies have investigated air pollution and asthma outcomes, most have focused on adult populations or have been limited by study design constraints. The case-crossover design, which uses cases as their own controls, offers methodological advantages for studying acute effects of transient exposures while controlling for time-invariant confounding factors. This study aims to quantify the association between short-term air pollution exposure and childhood asthma hospitalizations using a time-stratified case-crossover design across multiple cities with varying pollution profiles and climatic conditions.

2. Methods

2.1 Study Population and Data Sources

We identified 45,832 asthma hospitalization records for children aged 0-14 years from 12 major cities between January 2018 and December 2022. Data were obtained from hospital discharge databases, which included admission dates, primary diagnosis codes (ICD-10 J45-J46), and patient residential addresses. Air pollution data (PM2.5, NO2, O3) were collected from fixed-site monitoring stations, with 24-hour average concentrations for PM2.5 and NO2, and maximum 8-hour average for O3. Meteorological data including temperature and relative humidity were

obtained from national weather services.

2.2 Study Design and Statistical Analysis

We employed a time-stratified case-crossover design where each case's exposure on the hospitalization date (case period) was compared with exposures on control dates selected from the same month, year, and day of week. Conditional logistic regression models were used to estimate odds ratios (ORs) and 95% confidence intervals for asthma hospitalization associated with interquartile range increases in pollutant concentrations. Models were adjusted for daily mean temperature and relative humidity using natural splines. Stratified analyses were conducted by age group (0-4, 5-9, 10-14 years), sex, season, and neighborhood socioeconomic status. Sensitivity analyses included varying lag structures (single-day lags 0-3 and moving averages) and adjusting for co-pollutants in two-pollutant models.

3. Results

3.1 Air Pollution Exposure and Asthma Hospitalizations

Significant positive associations were observed between childhood asthma hospitalizations and exposure to all three pollutants. The strongest association was found for NO2, with a 2.8% (95% CI: 1.9-3.7%) increase in hospitalizations per 10 μg/m³ increase at lag 0-1 days. PM2.5 exposure was associated with a 1.6% (95% CI: 0.9-2.3%) increase per 10 μg/m³ increase, while O3 showed a 1.2% (95% CI: 0.5-1.9%) increase per 10 ppb increase. Exposure-response relationships were approximately linear for all pollutants, with no evidence of threshold effects below current air quality standards.

3.2 Effect Modification and Susceptible Subgroups

Children aged 0-4 years showed the strongest associations with air pollution exposure, particularly for PM2.5 (OR: 1.024, 95% CI: 1.014-1.034). Those residing in low-income neighborhoods had significantly higher risks compared to children from high-income areas, with the disparity most pronounced for NO2 exposure. Seasonal variations were observed, with stronger associations during spring and fall months. Two-pollutant models indicated independent effects for NO2 after adjusting for other pollutants, while PM2.5 associations were attenuated when controlling for NO2.

4. Discussion

This multi-city case-crossover study provides robust evidence that short-term exposure to air pollution triggers childhood asthma hospitalizations. The findings are consistent with biological plausibility, as air pollutants can induce bronchoconstriction, airway inflammation, and increased respiratory infections. The stronger effects observed in younger children may reflect their higher ventilation rates per body weight, developing immune systems, and smaller airway diameters. The socioeconomic disparities highlight the combined burden of environmental and social stressors in vulnerable communities. The study's strengths include the large sample size, case-crossover design controlling for time-invariant confounders, and detailed analysis of susceptible subgroups. Limitations include potential exposure misclassification from using fixed-site monitors and inability to assess effects of indoor air pollution sources. Future research should incorporate personal exposure monitoring and investigate synergistic effects with other environmental factors.

5. Conclusion

Short-term exposure to PM2.5, NO2, and O3 significantly increases the risk of childhood asthma hospitalizations, with particularly strong effects for NO2. Young children and those from low-income communities are most vulnerable to these effects. The findings support strengthening air quality standards and implementing targeted interventions to protect susceptible pediatric populations. Public health strategies should include air quality alert systems, reduced outdoor activities during high pollution days, and structural interventions to reduce traffic-related air pollution exposure in residential areas and schools.

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