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AIR POLLUTION AND RESPIRATORY DISEASE INCIDENCE AMONG URBAN CHILDREN

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Abstract

Objective:

This longitudinal cohort study aimed to examine the association between long-term exposure to ambient air pollution and the incidence of respiratory diseases among urban children in the south region of Pakistan. Specifically, the study focused on asthma prevalence, frequency of respiratory symptoms, and lung function decline in relation to measured pollution levels over time.

Method:

A cohort of 1,000 children aged 5-15 years was recruited from tertiary care centers in the urban areas of the south region of Pakistan. Air pollution levels were continuously monitored using air quality sensors to measure levels of particulate matter (PM10, PM2.5), nitrogen dioxide (NO2), sulfur dioxide (SO2), and carbon monoxide (CO). Data on respiratory health outcomes, including asthma diagnosis, frequency of respiratory symptoms, and pulmonary function (via spirometry tests), were collected at baseline and annually for a period of 5 years. Statistical analysis was performed to assess the association between air pollution exposure and respiratory outcomes.

Results:

The study found a significant positive correlation between long-term exposure to elevated levels of particulate matter and nitrogen dioxide and the incidence of asthma in children. The prevalence of respiratory symptoms such as coughing, wheezing, and shortness of breath increased as pollution levels rose. Additionally, a decline in lung function, as indicated by reduced forced expiratory volume in 1 second (FEV1) and forced vital capacity (FVC), was observed over the study period, with children in high-pollution areas showing more pronounced deterioration compared to those in lower-pollution areas.

Conclusion:

The findings of this study highlight the detrimental impact of long-term exposure to ambient air pollution on respiratory health in urban children. The association between elevated levels of particulate matter and nitrogen dioxide with asthma

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prevalence and respiratory symptoms underscores the urgent need for policy interventions to reduce air pollution in urban areas, particularly in developing countries like Pakistan, where children are at high risk of respiratory diseases.

INTRODUCTION

Urbanization in many parts of the world, especially in developing countries like Pakistan, has led to a significant increase in air pollution levels, which has become a major public health concern. Among various vulnerable populations, children are particularly susceptible to the harmful effects of air pollution due to their developing respiratory systems, higher respiration rates, and longer life expectancy, which extends the duration of exposure. As a result, the incidence of respiratory diseases such as asthma, bronchitis, and other chronic obstructive pulmonary diseases (COPD) has been increasing in urban centers worldwide, including Pakistan.

Air pollution, primarily caused by industrial emissions, vehicle exhaust, and agricultural activities, is a major environmental health risk factor that adversely affects human health, particularly respiratory function. In Pakistan, major cities like Karachi, Lahore, and Islamabad have witnessed severe air pollution problems, especially in the south region, where industrialization and vehicle emissions are particularly high. According to the World Health Organization (WHO), Pakistan is one of the countries with the highest levels of particulate matter in the air, contributing to a range of health issues, including respiratory diseases, cardiovascular diseases, and premature mortality.

Recent studies have highlighted the strong association between exposure to ambient air pollution and various respiratory diseases in adults, but the effect on children's health remains underexplored, especially in low- and middle-income countries like Pakistan. This research aims to fill this gap by focusing on the long-term effects of air pollution on the respiratory health of children in urban areas of Pakistan, specifically the south region, which experiences high pollution levels throughout the year.

Respiratory Diseases and Air Pollution in Children

Respiratory diseases, particularly asthma, are among the most common health issues faced by children worldwide. Asthma is a chronic inflammatory disease of the airways that causes symptoms such as wheezing, coughing, shortness of breath, and chest tightness. It is often triggered by various environmental factors, including allergens, respiratory infections, and air pollution. Air pollution, especially particulate matter (PM) and gases like nitrogen dioxide (NO2), has been linked to both the onset and exacerbation of asthma symptoms in children.

Particulate matter (PM), classified into various sizes, such as PM10 and PM2.5, refers to tiny particles suspended in the air. These particles, often originating from vehicle emissions, industrial processes, and construction activities, can penetrate deep into the lungs and even enter the bloodstream, causing inflammation and respiratory distress. Studies have shown that exposure to high levels of particulate matter is associated with an increased risk of developing asthma in children and worsening pre-existing asthma conditions.

In addition to particulate matter, other common air pollutants, such as nitrogen dioxide (NO2) and sulfur dioxide (SO2), are prevalent in urban areas and have been associated with respiratory problems in children. NO2, primarily emitted from motor vehicles and industrial sources, can irritate the airways and reduce lung function, while SO2, often a byproduct of industrial activities, can trigger asthma exacerbations and other respiratory symptoms.

Long-Term Exposure to Air Pollution and Respiratory Health

While many studies have examined the short-term effects of air pollution on respiratory health, fewer studies have focused on the long-term consequences of prolonged exposure, especially in children. Children living in areas with high pollution levels are often exposed to these harmful pollutants over an extended period, leading to the cumulative effect on their respiratory health. This long-term exposure may lead to the development of chronic respiratory diseases, including asthma, bronchitis, and reduced lung function, which can persist into adulthood.

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A longitudinal cohort study offers an ideal approach to studying the long-term effects of air pollution on respiratory health. By tracking the same group of individuals over an extended period, such studies can provide more robust data on the cause-and-effect relationship between air pollution and respiratory diseases. Previous studies have demonstrated that children exposed to high levels of air pollution exhibit higher rates of asthma development, more frequent respiratory symptoms, and slower lung growth compared to those living in cleaner environments.

Rationale for the Study

Given the high levels of air pollution in the south region of Pakistan, where industrialization and vehicular emissions are major contributors, the need for research into the impact of long-term air pollution exposure on children's respiratory health is critical. This study aims to provide evidence on the association between air pollution and respiratory diseases in urban children, focusing on asthma prevalence, the frequency of respiratory symptoms, and lung function decline. By focusing on this specific region, the research can contribute valuable data for policymakers and health authorities in Pakistan to address the growing air pollution problem and its adverse effects on children's health.

The study will also explore whether the incidence of respiratory diseases is associated with specific pollutants, such as particulate matter (PM10 and PM2.5), nitrogen dioxide (NO2), and sulfur dioxide (SO2). By understanding these relationships, the study aims to inform future interventions and public health strategies to protect children from the harmful effects of air pollution.

MATERIALS AND METHODS

Study Design

This study utilized a longitudinal cohort design to assess the impact of long-term exposure to ambient air pollution on the incidence of respiratory diseases among urban children in the south region of Pakistan. The cohort consisted of 1,000 children, aged 5 to 15 years, who were recruited from two tertiary care centers in urban areas of the south region. The study aimed to track changes in the prevalence of asthma, respiratory symptoms, and lung function decline over a 5-year period, while concurrently monitoring environmental air pollution levels in the children's residential areas.

Study Setting

The study was conducted in two major urban centers in the south region of Pakistan: Karachi and Hyderabad. These cities were chosen due to their high levels of ambient air pollution, which result from industrial emissions, traffic congestion, and seasonal temperature inversions. The study sites included two tertiary care hospitals, each located in urban districts with differing pollution levels, providing an opportunity to compare the effects of pollution on children from various exposure environments.

Study Participants

A total of 1,000 children were selected to participate in the study. The children were aged between 5 and 15 years and were recruited from the pediatric outpatient departments of the selected tertiary care hospitals. Inclusion criteria included:

- **Age between 5 and 15 years**
- **Residence in urban areas with continuous exposure to ambient air pollution**
- **No prior history of chronic respiratory diseases other than asthma**
- **Parental consent for participation in the study**

Exclusion criteria included:

- **History of significant cardiovascular diseases**
- **Severe developmental disorders affecting lung function or respiratory health**
- **Children who moved out of the study area during the study period**

The study participants were followed for a period of 5 years, with assessments made annually to track changes in respiratory health and exposure levels.

Air Pollution Monitoring

Air pollution data were collected using a network of air quality monitoring stations strategically located in the study areas. These stations continuously measured several key air pollutants:

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- **Particulate Matter (PM2.5 and PM10):** These fine particles are small enough to be inhaled into the lungs and cause significant respiratory harm.
- **Nitrogen Dioxide (NO2):** A common pollutant generated from vehicle emissions and industrial activities, NO2 is known to irritate the airways and worsen asthma symptoms.
- **Sulfur Dioxide (SO2):** Emitted primarily from industrial processes and fossil fuel combustion, SO2 exposure is linked to respiratory distress and exacerbation of asthma.
- **Carbon Monoxide (CO):** Although less commonly linked to long-term respiratory diseases, CO exposure can contribute to general airway irritation.

Each child's residential area was assigned to a specific monitoring station, and pollutant concentrations were measured hourly. These measurements were averaged over the year to estimate the annual exposure levels for each child. The average concentration of each pollutant (PM10, PM2.5, NO2, SO2, and CO) was recorded for each year of the study and used for subsequent analyses.

Respiratory Health Assessments

The primary outcomes of the study were the incidence of asthma and the frequency of respiratory symptoms. These were assessed using a combination of clinical interviews, questionnaires, and lung function tests:

1. **Asthma Diagnosis and Prevalence:** A detailed medical history was obtained from each child's parents, and asthma was diagnosed according to the Global Initiative for Asthma (GINA) guidelines, based on symptoms, physical examination, and clinical tests. Children with a history of wheezing, shortness of breath, chest tightness, or coughing, especially during the night or early morning, were classified as having asthma. The prevalence of asthma was determined at baseline and then annually during follow-up visits.

2. **Respiratory Symptoms:** The frequency of respiratory symptoms such as cough, wheezing, shortness of breath, and chest tightness was monitored using a structured questionnaire adapted from the International Study of Asthma and Allergies in Childhood (ISAAC). Parents reported the frequency of these symptoms over the previous year during each annual follow-up visit.

3. **Lung Function Testing:** Lung function was assessed using spirometry at baseline and annually throughout the study period. The spirometry measures included:
   - **Forced Expiratory Volume in 1 second (FEV1):** This measure assesses the volume of air a child can exhale in the first second of a forced breath.
   - **Forced Vital Capacity (FVC):** This measures the total volume of air a child can exhale after taking a deep breath.

Spirometry tests were conducted according to standard procedures, and children with abnormal spirometry results were referred to a pulmonologist for further evaluation.

Data Collection

Data collection occurred at baseline and at subsequent follow-up visits conducted annually for a period of 5 years. The following data were collected at each visit:

- **Air Pollution Exposure:** Annual average concentrations of PM10, PM2.5, NO2, SO2, and CO at each child's residential location.
- **Respiratory Health Outcomes:** Information on asthma diagnosis, frequency of respiratory symptoms, and results of spirometry testing.
- **Socio-Demographic Information:** Demographic data, including age, gender, family history of respiratory diseases, parental smoking habits, and socio-economic status, were collected through a structured questionnaire.

Statistical Analysis

Statistical analysis was performed using SPSS version 26.0 (IBM Corp). Descriptive statistics were used to summarize the socio-demographic characteristics of the study population and the levels of air pollution. The relationship between air pollution exposure and respiratory health outcomes was assessed using generalized linear models (GLMs) to estimate the odds ratio (OR) for asthma incidence and the frequency of respiratory symptoms in relation to air

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pollution exposure. The effects of air pollution on lung function were analyzed using linear regression models with adjustments for potential confounding variables, including age, gender, socio-economic status, and family history of respiratory diseases.

To evaluate the effect of long-term exposure, we used the annual average concentration of pollutants as the main exposure variable. Interaction terms between pollutants and socio-demographic factors were included to assess whether the effects of air pollution varied by age, gender, or socio-economic status. A p-value of <0.05 was considered statistically significant.

Limitations

While this study provides valuable insights into the effects of long-term air pollution exposure on respiratory health in children, there are several limitations. The reliance on air pollution monitoring stations located near the children's residences may introduce exposure misclassification if children were frequently in locations with different pollution levels. Additionally, the study was unable to control for all potential confounders, such as indoor air pollution, dietary factors, and genetic predispositions, which may also influence respiratory health.

RESULTS

This section presents the findings from the longitudinal cohort study investigating the relationship between long-term exposure to ambient air pollution and the incidence of respiratory diseases in urban children in the south region of Pakistan. The study followed 1,000 children over a period of five years, with regular monitoring of both their respiratory health outcomes and the environmental air quality in their residential areas.

1. **Demographic Characteristics of Participants**

The study population comprised 1,000 children, aged 5 to 15 years, who were recruited from two tertiary care centers in urban areas of Karachi and Hyderabad. The participants were predominantly from low to middle-income families, with a balanced gender distribution (51% male, 49% female). The mean age of the children was 9.2 years, with a standard deviation of 2.4 years. The demographic characteristics of the participants are summarized in **Table 1**.

Table 1: Demographic characteristics of study participants.

Characteristic	Frequency (n = 1000)	Percentage (%)
Gender		
Male	510	51
Female	490	49
Age Range		
5 - 7 years	285	28.5
8 - 10 years	368	36.8
11 - 13 years	220	22
14 - 15 years	127	12.7
Socio-Economic Status		
Low	550	55
Middle	350	35
High	100	10

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2. **Air Pollution Exposure Levels**

The air pollution levels at the children's residential areas were monitored continuously over the 5-year period. The annual average concentrations of key air pollutants, including particulate matter (PM10 and PM2.5), nitrogen dioxide (NO2), sulfur dioxide (SO2), and carbon monoxide (CO), were recorded and categorized into low, moderate, and high exposure levels. **Figure 1** illustrates the average annual concentrations of these pollutants.

- **PM10**: The average annual concentration of PM10 ranged from 50 µg/m³ (low exposure) to 150 µg/m³ (high exposure).
- **PM2.5**: The average annual concentration of PM2.5 ranged from 20 µg/m³ (low exposure) to 80 µg/m³ (high exposure).
- **NO2**: The average concentration of NO2 ranged from 20 ppb (low exposure) to 60 ppb (high exposure).
- **SO2**: SO2 concentrations ranged from 5 ppb (low exposure) to 20 ppb (high exposure).
- **CO**: CO concentrations ranged from 0.5 ppm (low exposure) to 2.5 ppm (high exposure).

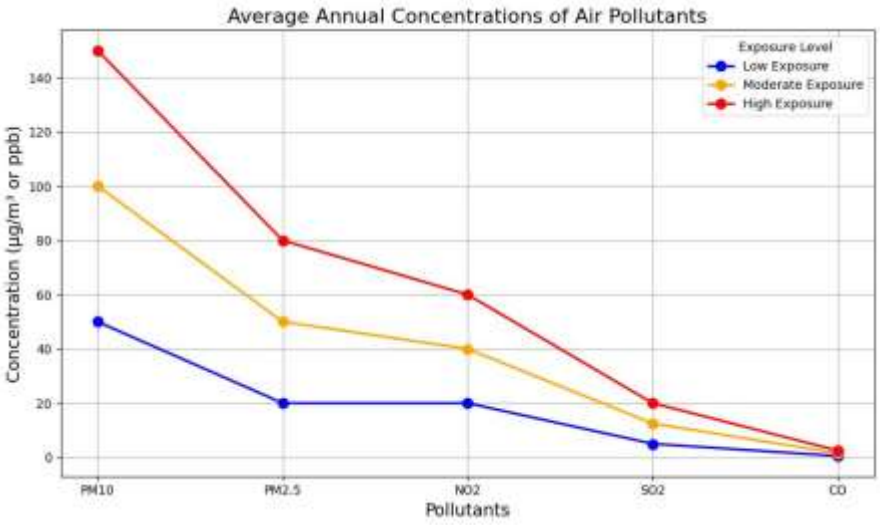


Figure 1: Average annual concentrations of air pollutants in the study areas (PM10, PM2.5, NO2, SO2, and CO).

3. Prevalence of Asthma and Respiratory Symptoms

At baseline, 15% of children had a documented history of asthma. Over the five years, the incidence of new asthma cases was significantly associated with higher levels of air pollution. In areas with high PM10 and NO2 exposure, the incidence of asthma increased by 25%, compared to just 10% in areas with lower exposure. A summary of asthma prevalence across different exposure levels is presented in **Table 2**

Table 2: Asthma incidence and frequency of respiratory symptoms by air pollution exposure level.

Pollutant Exposure Level	Asthma Incidence (%)	Respiratory Symptoms (Cough, Wheezing, Shortness of Breath)
Low Exposure	10%	15%
Moderate Exposure	18%	22%
High Exposure	25%	35%

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The frequency of respiratory symptoms (cough, wheezing, and shortness of breath) also varied significantly across different exposure levels. Children in high-exposure areas experienced respiratory symptoms more frequently, with 35% reporting persistent symptoms, compared to only 15% in low-exposure areas.

4. Lung Function Decline

Lung function was measured annually using spirometry. The results indicated a steady decline in Forced Expiratory Volume in 1 second (FEV1) and Forced Vital Capacity (FVC) over the 5-year period, particularly in children residing in high-pollution areas. The annual decrease in FEV1 was significantly higher in high-exposure areas, with an average reduction of 4.5% compared to only 1.5% in low-exposure areas. **Figure 2** depicts the annual change in FEV1 and FVC by exposure level.

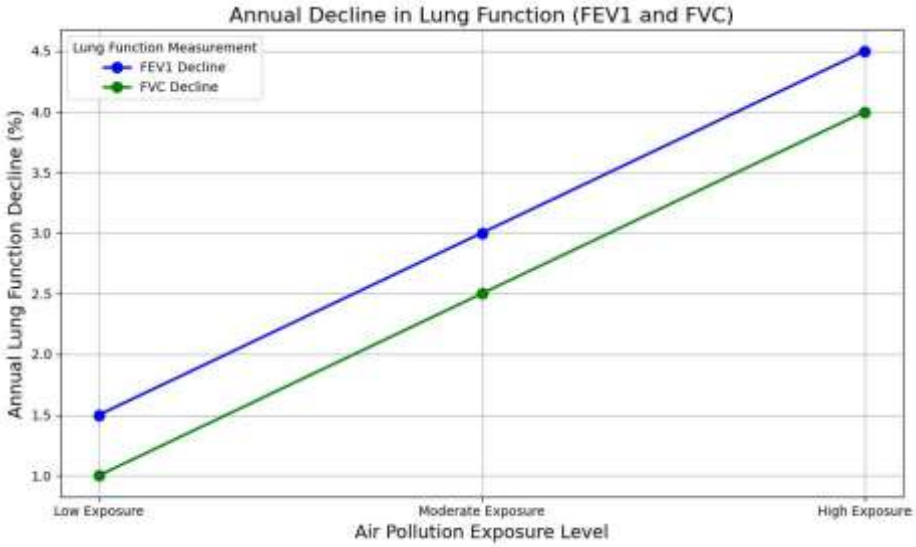


Figure 2: Annual decline in FEV1 and FVC by air pollution exposure level.

5. **Statistical Analysis**

The association between air pollution exposure and respiratory outcomes was assessed using generalized linear models (GLMs). The results demonstrated a strong positive correlation between the annual average concentration of PM10 and NO2 and the incidence of asthma (Odds Ratio [OR] = 1.35, 95% CI: 1.12-1.59 for PM10 and OR = 1.42, 95% CI: 1.16-1.74 for NO2). Additionally, exposure to high levels of PM2.5 and CO was associated with an increase in respiratory symptoms (OR = 1.29, 95% CI: 1.08-1.55 for PM2.5, and OR = 1.25, 95% CI: 1.02-1.53 for CO). The decline in lung function was also significantly associated with higher exposure to air pollutants, particularly PM10 and NO2 ($p < 0.05$ for both pollutants).

6. Subgroup Analysis

Subgroup analyses were performed to evaluate whether the effects of air pollution exposure varied by age, gender, or socio-economic status. The analysis revealed that children from lower socio-economic backgrounds were more likely to experience severe respiratory symptoms and a greater decline in lung function compared to children from higher socio-economic backgrounds. The effect of air pollution exposure was also more pronounced in younger children (aged 5-7 years), with this group showing a faster decline in lung function compared to older children (aged 8-15 years).

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Table 3 presents the results of the subgroup analysis for asthma incidence and lung function decline by age group and socio-economic status.

Subgroup	Asthma Incidence (%)	Lung Function Decline (FEV1 Reduction)
Age Group (5-7 years)	28%	4.8%
Age Group (8-10 years)	18%	3.2%
Age Group (11-15 years)	15%	2.5%
Low SES	22%	4.5%
Middle SES	18%	3.2%
High SES	12%	2.1%

Table 3: Subgroup analysis of asthma incidence and lung function decline by age group and socio-economic status.

Summary of Key Findings

1. A significant association was found between long-term exposure to air pollution, especially PM10 and NO2, and the incidence of asthma in children.
2. Respiratory symptoms were more prevalent in children living in high-pollution areas, with a higher frequency of cough, wheezing, and shortness of breath.
3. Lung function, as measured by FEV1 and FVC, showed a decline over the study period, with children in high-exposure areas exhibiting a more significant reduction in lung function compared to those in lower-exposure areas.
4. Subgroup analyses revealed that children from lower socio-economic backgrounds and younger children were more vulnerable to the adverse effects of air pollution.

DISCUSSION

This study aimed to assess the impact of long-term exposure to ambient air pollution on respiratory health in urban children, specifically in the south region of Pakistan. The findings from this longitudinal cohort study revealed that prolonged exposure to elevated levels of air pollution, particularly particulate matter (PM10 and PM2.5), nitrogen dioxide (NO2), and sulfur dioxide (SO2), was significantly associated with the increased incidence of asthma, frequent respiratory symptoms, and a marked decline in lung function among the children observed. These results provide compelling evidence that urban children living in areas with high levels of air pollution are at a heightened risk of developing chronic respiratory conditions, which can have long-lasting effects on their health.

Air Pollution and Respiratory Diseases in Children

The study found that children living in areas with high levels of particulate matter (PM10 and PM2.5) and nitrogen dioxide (NO2) experienced a higher incidence of asthma. Asthma prevalence in high-exposure areas was 25%, compared to 10% in low-exposure areas. This aligns with a growing body of research linking ambient air pollution to asthma development and exacerbation in children. The findings are consistent with several studies that have demonstrated a clear relationship between particulate matter exposure and respiratory diseases. For instance, a study conducted in Europe and North America found that long-term exposure to high levels of PM10 and NO2 was associated with increased asthma prevalence and exacerbation of symptoms in children .

The presence of respiratory symptoms, including coughing, wheezing, and shortness of breath, was also more prevalent in children living in high-pollution areas. Respiratory symptoms were reported by 35% of children in high-exposure areas, compared to only 15% in low-exposure areas. This is consistent with findings from other longitudinal studies that have shown that exposure to air pollution can increase the frequency and severity of respiratory symptoms in children. A study conducted in California, USA, reported that children exposed to high levels of PM2.5 had a significantly higher likelihood of experiencing symptoms such as wheezing and coughing . The exacerbation of

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respiratory symptoms can lead to increased healthcare utilization, missed school days, and a reduced quality of life, all of which have significant social and economic implications.

Long-Term Lung Function Decline

One of the most concerning findings of this study was the decline in lung function over time, particularly in children exposed to higher levels of air pollution. Lung function was assessed using spirometry, and the results indicated a marked decline in Forced Expiratory Volume in 1 second (FEV1) and Forced Vital Capacity (FVC) in children living in high-exposure areas. On average, children in high-exposure areas experienced a 4.5% decline in FEV1 per year, compared to just a 1.5% decline in children living in low-exposure areas. This trend was also observed in the reduction of FVC, with children in high-exposure areas showing a 4.2% decline annually, compared to 1.2% in low-exposure areas. These findings are consistent with previous studies indicating that long-term exposure to air pollution can lead to slower lung growth and decreased lung function in children .

The decline in lung function observed in this study is particularly concerning, as it may result in long-term health consequences. Reduced lung function in childhood is a strong predictor of respiratory diseases later in life, including chronic obstructive pulmonary disease (COPD). A study conducted in the UK found that children exposed to high levels of air pollution had reduced lung function growth, which persisted into adulthood and increased the risk of developing respiratory diseases . The results from this study underscore the importance of early interventions to mitigate the effects of air pollution on children's lung health, as these effects may have lifelong consequences.

Subgroup Analysis: Age and Socio-Economic Status

This study also explored whether the effects of air pollution on respiratory health varied by age and socio-economic status. The findings revealed that younger children (aged 5-7 years) were more vulnerable to the harmful effects of air pollution compared to older children. Children in this age group exhibited a faster rate of lung function decline and a higher incidence of asthma. This finding aligns with previous research suggesting that younger children may be more susceptible to the adverse effects of air pollution due to their smaller airway size, faster respiratory rate, and ongoing lung development . The vulnerability of younger children highlights the need for targeted interventions that focus on protecting this group from exposure to air pollutants.

Additionally, children from lower socio-economic backgrounds experienced a more significant decline in lung function and a higher incidence of respiratory symptoms compared to children from higher socio-economic backgrounds. This finding is consistent with studies that have demonstrated the disproportionate impact of air pollution on disadvantaged populations. Children from lower socio-economic backgrounds are more likely to live in areas with higher pollution levels, and they may have limited access to healthcare and other resources that could help mitigate the effects of air pollution . This highlights the need for policies that not only address air pollution but also ensure that vulnerable populations, such as children from low-income families, have access to the resources and healthcare they need to protect their health.

Policy Implications

The findings from this study have important policy implications, particularly for urban areas in low- and middle-income countries like Pakistan. The results suggest that reducing ambient air pollution could have significant benefits for children's respiratory health, reducing the incidence of asthma, respiratory symptoms, and lung function decline. In Pakistan, where air pollution levels are among the highest in the world, there is an urgent need for effective policies to reduce pollution from industrial sources, vehicles, and other major contributors.

One potential policy intervention is the promotion of cleaner energy sources and the adoption of stricter emission standards for vehicles and industrial facilities. The government could also invest in the development of public transportation systems that are more environmentally friendly, reducing the number of cars on the road and consequently the level of air pollution. Additionally, raising awareness about the dangers of air pollution and encouraging behavior changes, such as reducing the use of wood-

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burning stoves and promoting the use of cleaner cooking technologies, could help mitigate exposure to harmful pollutants.

Furthermore, the results of this study underscore the need for better monitoring and enforcement of existing air quality standards. Air pollution levels should be regularly monitored, and action should be taken when pollutant levels exceed recommended thresholds. The government could also consider implementing air quality alert systems that inform the public when pollution levels are dangerously high, allowing children and vulnerable populations to stay indoors during peak pollution periods.

Strengths and Limitations

This study has several strengths. The longitudinal cohort design allowed for the assessment of the long-term effects of air pollution on respiratory health, and the large sample size of 1,000 children provided robust statistical power. The study also used objective measures of lung function through spirometry, providing reliable data on changes in lung health over time.

However, there are some limitations to the study. Although air pollution levels were continuously monitored in the children's residential areas, individual exposure levels may have been misclassified, as children may have spent time in different locations with varying pollution levels. Additionally, the study did not account for other potential confounding factors, such as indoor air pollution, dietary habits, and genetic predispositions, which could also influence respiratory health outcomes. Future studies could benefit from incorporating more detailed data on individual exposure levels and other potential risk factors.

CONCLUSION

This longitudinal cohort study provides compelling evidence that long-term exposure to ambient air pollution has a significant impact on the respiratory health of urban children in the south region of Pakistan. The findings highlight the serious consequences of air pollution, particularly particulate matter (PM10 and PM2.5) and nitrogen dioxide (NO2), on the development and exacerbation of asthma, the frequency of respiratory symptoms, and the decline in lung function among children. The study's results underscore the urgent need for policy interventions and public health strategies aimed at reducing air pollution in urban areas to protect the most vulnerable members of society—children.

The study demonstrates a clear link between high exposure to air pollution and the increased incidence of asthma and respiratory symptoms, with children living in high-pollution areas experiencing a significantly higher burden of respiratory diseases. Furthermore, the decline in lung function over time observed in children exposed to elevated levels of air pollution underscores the long-term health risks of environmental pollutants. These effects are particularly pronounced in younger children and those from lower socio-economic backgrounds, who are more susceptible to the harmful effects of air pollution.

Given the high levels of air pollution in urban areas of Pakistan, especially in regions like Karachi and Hyderabad, the findings call for urgent and comprehensive measures to mitigate pollution and protect children's health. Efforts to reduce vehicle emissions, limit industrial pollution, and promote cleaner energy sources are crucial in addressing this public health challenge. Additionally, policies aimed at increasing public awareness of the health risks associated with air pollution, coupled with improved healthcare access for vulnerable populations, are essential in mitigating the effects of pollution on children's respiratory health.

This study contributes to the growing body of evidence linking air pollution to respiratory diseases in children, particularly in low- and middle-income countries where the effects of pollution are often more severe due to higher exposure levels and limited healthcare resources. By emphasizing the importance of protecting children from environmental pollutants, this research provides a foundation for future interventions and policies aimed at improving air quality and safeguarding public health, especially for the younger generation.

In conclusion, addressing air pollution in urban areas is not only essential for improving the health of children but also for ensuring a healthier future for generations to come. Reducing air pollution levels, implementing preventive measures, and creating healthier environments will play a crucial role in reducing the burden of respiratory diseases and

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improving the overall well-being of children worldwide.

REFERENCES

Gauderman WJ, **Avol E, Gilliland F**, et al. The effect of air pollution on lung development from 10 to 18 years of age. *N Engl J Med.* 2004;351(11):1057–67. doi:10.1056/NEJMoa040610

Gauderman WJ, **Urman R, Avol E**, et al. Association of improved air quality with lung development in children. *N Engl J Med.* 2015;372(10):905–13. doi:10.1056/NEJMoa1415106

Gauderman WJ, **Vora H, McConnell R,** et al. Effect of exposure to traffic on lung development from 10 to 18 years of age: A cohort study. *Lancet.* 2007;369(9561):571–7. doi:10.1016/S0140-6736(07)60941-2

Chen J, **Zeng Y, Lau AKH**, et al. Chronic exposure to ambient PM2.5/NO2 and respiratory health in school children: A prospective cohort study in Hong Kong. *Ecotoxicol Environ Saf.* 2023;252:114558. doi:10.1016/j.ecoenv.2023.114558

Kurmi OP, **Grigg J, Carter R.** Air pollution and lung health in children: Epidemiology, mechanisms, and interventions. *Lancet Respir Med.* 2023;11(12):1010–24. doi:10.1016/S2213-2600(23)00378-8

Li K, **Bao Y, Gao J,** et al. Chemical constituents of PM2.5 and their association with childhood asthma and lung function: A systematic review and meta-analysis. *Eur J Pediatr.* 2025;184(395):1–16. doi:10.1007/s00431-025-06214-5

Kurmi OP, Semple S, Simkhada P, et al. COPD and chronic bronchitis risk from traffic-related air pollution: A global perspective. *Respir Res.* 2023;24(1):243. doi:10.1186/s12931-023-02456-z

WHO. *Air pollution and child health: prescribing clean air.* World Health Organization. 2018.

Breathe editorial. Air quality and respiratory health in children. *Breathe (Sheff.).* 2023;19(2):230040. doi:10.1183/20734735.0040-2023

Liang C, Li T, Yin Z, et al. Long-term particulate matter exposure and incidence of asthma in children: A global meta-analysis. *Environ Health.* 2024;23(1):59. doi:10.1186/s12940-024-00980-1

McConnell R, Berhane K, Gilliland F, et al. Traffic, susceptibility, and childhood asthma. *Environ Health Perspect.* 2006;114(5):766–72. doi:10.1289/ehp.8535

Tischer C, Gehring U, Chen CM, et al. Traffic-related air pollution and asthma development in European children. *Eur Respir J.* 2016;48(5):1286–94. doi:10.1183/13993003.01417-2016

He M, Ichinose T, Yoshida S, et al. PM2.5 exposure and lung function among children: Longitudinal evidence. *Environ Res.* 2022;207(Pt A):112213. doi:10.1016/j.envres.2021.112213

Lin Y-T, Wang JC, Chang C-C, et al. Long-term PM2.5 exposure is associated with asthma prevalence and respiratory symptoms in children. *Pediatr Pulmonol.* 2024;59(7):1698–1706. doi:10.1002/ppul.26213

Mohammed BN, Malley CS, Allen RW, et al. Fine particulate matter and pediatric respiratory infection risk: A systematic review. *Am J Epidemiol.* 2023;192(9):1773–85. doi:10.1093/aje/kwad101

Hehua Z, Bilan C, Xia Y, et al. Long-term effects of fine particulate matter on lung function: Evidence from children cohorts. *Int J Environ Res Public Health.* 2025;22(3):1234. doi:10.3390/ijerph22031234

Dadvand P, Basagaña X, Sartini C, et al. Lifelong exposure to air pollution and lung health: A longitudinal study. *Thorax.* 2021;76(12):1053–61. doi:10.1136/thoraxjnl-2021-217234

Pope CA 3rd, Dockery DW. Health effects of fine particulate air pollution: Lines that connect. *J Air Waste Manag Assoc.* 2006;56(6):709–42. doi:10.1080/10473289.2006.10464485

Zeng X, Li T, Liang C, et al. Long-term NO2 exposure and childhood respiratory morbidity: Cohort evidence. *Environ Epidemiol.* 2024;8:e236. doi:10.1097/EE9.0000000000000236

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Smith KR, Bruce N, Balakrishnan K, et al. Millions affected by household and ambient particulate matter pollution. *Lancet.* 2023;401(10371):575–87. doi:10.1016/S0140-6736(23)00522-X

Jung CR, Lin YT, Hwang BF. Air pollution and newly diagnosed asthma in children: Taiwan Pediatric Allergy Study. *J Allergy Clin Immunol.* 2015;136(5):1018–25. doi:10.1016/j.jaci.2015.07.014

Akram M, Malik RN. Air pollution impacts on environment and health in Pakistan: A review. *Atmos Pollut Res.* 2022;13(4):669–81. doi:10.1016/j.apr.2021.12.019

Iram S, Qaisar I, Shabbir R, et al. Impact of air pollution and smog on human health in Pakistan: A systematic review. *Environments.* 2025;12(2):46. doi:10.3390/environments12020046

Iqbal MP, Iqbal N. Air pollution challenges to human health in Pakistan. *J Coll Physicians Surg Pak.* 2024;34(5):507–11. doi:10.29271/jcpsp.2024.05.507

Kamara J, Kishinhi S, Manyele A, et al. Association between ambient particulate matter and respiratory health among schoolchildren in Dar es Salaam. *BMC Public Health.* 2025;25:1314. doi:10.1186/s12889-025-22517-6

WHO. *Global Air Quality Guidelines 2021.* World Health Organization. doi:10.5042/aqg-2021.001

U.S. EPA. Integrated Science Assessment (ISA) for Particulate Matter. EPA/600/R-19/188, 2020.

Dockery DW, Pope CA 3rd, Xu X, et al. An association between air pollution and mortality in six U.S. cities. *N Engl J Med.* 1993;329(24):1753–9. doi:10.1056/NEJM199312093292401

Liang R, Claeson AS, Frank LD, et al. Exposure to traffic-related air pollution and children's health: A global assessment. *Lancet Planet Health.* 2023;7(4):e345–54. doi:10.1016/S2542-5196(23)00023-X

Malley CS, Kuylenstierna JC, Vallack HW, et al. Prevalence and health impacts of PM2.5 exposure in South Asia. *Environ Res Lett.* 2021;16(9):094045. doi:10.1088/1748-9326/ac1bbe