
Atmospheric pollution and the prevalence of asthma: study among schoolchildren of 2 areas in Rio de Janeiro, Brazil

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Background: Air pollutants have been associated with the exacerbation of respiratory diseases. They may intensify the inflammatory allergic response and airways reactivity to inhaled allergens. However, it is still not clear if air pollution contributes to the increased prevalence of asthma.

Objective: To investigate if different levels of air pollution exposure can be related to differences in the prevalence of asthma.

Methods: The International Study of Asthma and Allergies in Childhood (ISAAC) protocol was used to determine and compare the prevalence of asthma among schoolchildren in 2 cities of the metropolitan region of Rio de Janeiro, Brazil, Duque de Caxias (DC) and Seropédica (SR), which have different levels of atmospheric pollution. The research involved 4,064 students aged 13 to 14 years from 49 schools in DC and 1,129 from 17 schools in SR. Air pollution was evaluated by the concentration of inhalable particulate matter (PM₁₀).

Results: ISAAC's written questionnaire was answered by 4,040 students aged 13 to 14 years in DC and 1,080 in SR. Between 1998 and 2000, the PM₁₀ annual arithmetic mean was 124 $\mu\text{g}/\text{m}^3$ in DC and 35 $\mu\text{g}/\text{m}^3$ in SR (acceptable level is up to 50 $\mu\text{g}/\text{m}^3$). The prevalence of wheezing ever was 35.1% in DC and 29.9% in SR ($P = .001$), and the prevalence of wheezing in the last 12 months was 19.0% in DC and 15.0% in SR ($P = .002$). In DC, 14.5% of the adolescents presented 1 to 3 crises of wheezing in the last year, whereas in SR only 11.0% presented 1 to 3 crises ($P = .003$).

Conclusions: In this study, the prevalence of asthma in adolescents was directly related to atmospheric pollution.

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INTRODUCTION

Asthma is the most common chronic disease in childhood.¹ In the last few years, its prevalence has increased significantly,^{2,3} probably due to the effect of environmental factors, since this period is too short to consider the significance of genetic mutations.⁴ Among these factors, the following are outstanding: changes in hygiene and eating habits, changes in the profile of respiratory infections in childhood, changes in housing standards and work environment, increasing exposure to indoor allergens, maternal tobacco smoking, and atmospheric pollution.^{5,6}

The contribution of air pollution on the increase in allergic respiratory diseases has been attributed to gaseous and air-borne particulate pollutants, generated as by-products of industrialization. Sulfur dioxide (SO₂), nitrogen dioxide (NO₂), ozone (O₃), and inhalable particulate matter (PM₁₀) have been the most implicated.^{7,8} Worsening symptoms of allergic rhinitis, coughing, mucus production, and reduction in morning peak flow and the increase in the use of emergency services

due to asthma in adults and children have been associated with the atmospheric concentration of these pollutants.^{9–11} Nevertheless, it still cannot be confirmed that air pollution is involved in increasing prevalence of asthma and allergic diseases. This has been a source of controversy and the object of various studies.¹² The objective of this study is to investigate if different levels of atmospheric pollution exposure can be related to differences in prevalence of asthma.

MATERIALS AND METHODS

The International Study of Asthma and Allergies in Childhood (ISAAC) protocol was used to determine and compare the prevalence of asthma among schoolchildren in 2 cities closely situated in Rio de Janeiro State, Duque de Caxias (DC), which is industrialized and has high levels of air pollutants, and Seropédica (SR), which is rural and unpolluted. The research involved 4,064 students aged 13 to 14 years from 49 schools in DC and 1,129 from 17 schools in SR. Both public and private schools participated. They were selected at random in a proportional manner.¹³

Atmospheric pollution was determined by measuring the concentration of PM₁₀ in each city weekly from May 1998 to October 2000. Measurements were obtained by Fundação Estadual de Engenharia do Meio Ambiente (State Environmental Engineering Foundation). The national standards of air quality, determined by Conselho Nacional do Meio Ambiente, were used to characterize air pollution: the annual

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arithmetic mean should not exceed $50 \mu\text{g}/\text{m}^3$, and the maximum concentration per 24 hours should not exceed $150 \mu\text{g}/\text{m}^3$ more than once a year.¹⁴

We used the asthma component of ISAAC's written questionnaire (WQ), translated into Portuguese (Brazilian culture) and validated by Solé et al.¹⁵ The WQ was complemented with questions about tobacco smoking exposure, number of inhabitants in the household, and the length of time living in the region. With the aim of distinguishing true asthmatic patients from nonasthmatic patients on the WQ, the following criteria were used: wheezing in the last 12 months, wheezing ever, and Global Cut-off Score. The Global Cut-off Score encompasses replies to the 8 questions by means of a scoring system and establishes a cut-off from which is defined the presence of asthma for the Brazilian population.¹⁵

Some variables that could act as factors of confusion were controlled for: socioeconomic level through the composition of the sample involving students from public (supposedly lower socioeconomic level) and private schools (supposedly higher level), in accordance with the ISAAC recommendation.¹³ Tobacco smoking, number of inhabitants per household, time of residence in the area, and distribution of the sample by sex were also considered. The replies were grouped into dichotic categories and analyzed in each area considering the criteria cited herein for definition of asthma.

The data collection was performed between April and August 2000, and the Epi Info version 6 program (Centers for Disease Control and Prevention, Atlanta, GA) was used for analysis of the data. To compare the results between the 2 municipalities, the χ^2 test was used. Differences with $P < .05$ were considered statistically significant. This protocol was approved by the Hospital Universitário Clementino Fraga Filho, Universidade Federal do Rio de Janeiro ethical committee for research. The informed consent had been obtained from the parents of the children to be subjected to the research.

RESULTS

The annual arithmetic mean concentration of PM_{10} in DC was $147 \mu\text{g}/\text{m}^3$ in 1998, $115 \mu\text{g}/\text{m}^3$ in 1999, and $110 \mu\text{g}/\text{m}^3$ in 2000, whereas in SR these values were $37 \mu\text{g}/\text{m}^3$, $31 \mu\text{g}/\text{m}^3$, and $37 \mu\text{g}/\text{m}^3$, respectively. Figure 1 shows the evolution of air pollution, evaluated by the concentration of PM_{10} in the cities studied, from May 1998 to October 2000. According to these data, DC presented high levels of atmospheric pollution (PM_{10} annual arithmetic mean, $124 \mu\text{g}/\text{m}^3$), almost always more than double the recommended standard ($<50 \mu\text{g}/\text{m}^3$), thereby characterizing their population as exposed to air pollution. SR maintained a good level of air quality (PM_{10} annual arithmetic mean, $35 \mu\text{g}/\text{m}^3$), and its population can be regarded as not exposed.

A total of 4,040 students correctly filled out the WQ in DC and 1,108 in SR. This corresponds to a proportion of correctly filled out questionnaires of 99.4% in the first city and 98.1% in the second. Table 1 shows the frequencies of affirmative replies for each question in the 2 cities. The percentage of each reply was calculated in relation to the number of correctly filled out questionnaires. The prevalence of wheezing ever was 35.1% in DC and 29.9% in SR ($P = .001$), and the prevalence of wheezing in the last 12 months was 19.0% in DC and 15.0% in SR ($P = .002$). In DC, 14.5% of the adolescents presented with 1 to 3 attacks of wheezing in the last year, whereas in SR, only 11.0% had 1 to 3 attacks ($P = .003$). The number of adolescents with a score above the Global Cut-off Score was also significantly greater in DC than in SR (18.8% and 16.1%, respectively; $P = .03$). By these criteria, the prevalence of asthma was also significantly higher in DC, the more polluted city.

Table 2 shows the analysis of the other variables grouped in dichotic categories. Distribution by sex was similar in both cities, and asthma was more prevalent among girls. In both sexes, asthma was more frequent in DC. Exposure to domestic tobacco smoke was observed in half of the students of

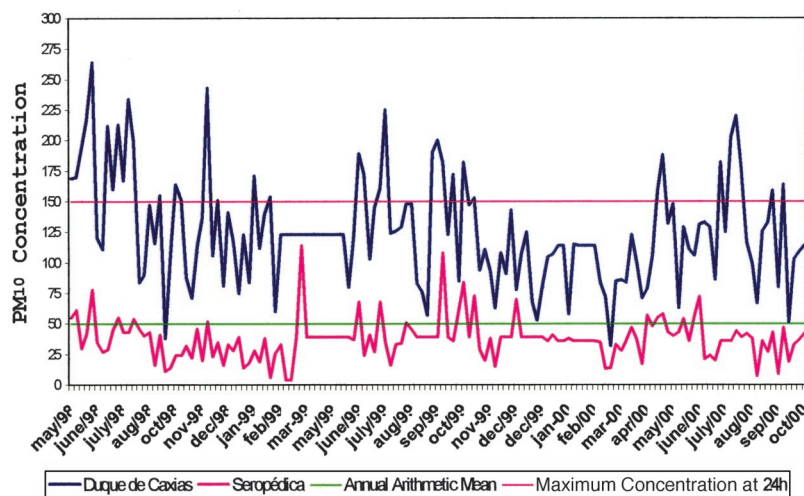


Figure 1. Concentration of inhalable particulate matter (PM_{10}) in Duque de Caxias and Seropédica from May 1998 to October 2000.

Table 1. Affirmative Answers to the ISAAC Questionnaire

Question	No. (%) of schoolchildren		χ^2 test P value
	Duque de Caxias (N = 4,040)	Seropédica (N = 1,108)	
Wheezing ever	1,417 (35.1)*	331 (29.9)	.001
Wheezing last 12 months	768 (19.0)*	167 (15.0)	.002
Attacks last 12 months			
1–3	585 (14.5)*	122 (11.0)	.003
4–12	81 (2.0)	17 (1.5)	.30
>12	41 (1.0)	13 (1.2)	.64
Sleep disturbed by wheezing (times per week)			
<1	223 (5.5)	51 (4.6)	.22
≥1	122 (3.0)	34 (3.0)	.93
Speech limited by wheezing	155 (3.8)	48 (4.3)	.45
Asthma some time	400 (10.0)	110 (9.9)	.97
Wheezing with exercise	855 (21.2)	244 (22.0)	.53
Cough at night	1,511 (37.4)	404 (36.5)	.56
Global Cut-off Score	762 (18.8)*	179 (16.1)	.03

Abbreviation: ISAAC, International Study of Asthma and Allergies in Childhood.

* $P < .05$.

Table 2. Analyses of the Prevalence of Asthma Controlled by Sex, Type of School, Time of Residence, Domestic Smoking, and Inhabitants per Household

Controlled variable	No. of schoolchildren		Wheezing ever, %		Wheezing last 12 months, %		Global Cut-Off Score, %	
	DC	SR	DC	SR	DC	SR	DC	SR
Sex								
Male	1,920	530	30.8*	24.9	15.8*	12.0	15.0	12.3
Female	2,120	578	38.9*†	34.4†	21.9*†	17.8†	22.3†	19.7†
Type of school								
Private	798	120	34.2	31.6	16.9	16.6	16.6	28.3*†
Public	3,242	988	35.3*	29.6	19.5*	14.8	19.4*	14.7
Time of residence								
<5 y	62	37	33.8	29.7	20.9	10.8	20.9	10.8
>5 y	689	194	35.3*	25.2	16.7	13.9	16.8	16.5
Domestic smoking								
Not exposed	2,005	547	35.0*	28.3	18.6*	13.5	17.6	14.8
Exposed	2,001	535	35.4	31.7	19.4	16.8	20.4†	18.3
Residents per home								
Up to 4	2,100	524	34.9*	30.0	19.0*	14.5	18.4	15.6
5 or more	1,912	556	35.2*	29.5	19.0*	15.3	19.5	17.4

Abbreviations: DC, Duque de Caxias; SR, Seropédica.

* Significantly higher comparing the cities in the same controlled variable ($P < .05$; χ^2 test).

† Significantly higher comparing the controlled variable in the same city ($P < .05$; χ^2 test).

each town, and among those not exposed, the prevalence of asthma was higher in the more polluted city.

A greater proportion of students was registered in private schools in DC than in SR. Among these pupils considering Global Cut-off Score criterion, asthma was more prevalent in SR. However, the prevalence of asthma was significantly higher in DC due to the number of students in public schools, which was higher in both cities. The number of residents in SR for a period of less than 5 years was greater than in DC. Among those who lived for more than 5 years, wheezing ever was more frequent in the inhabitants from DC (Table 2).

There was a predominance of residences with 3 to 4 inhabitants in DC and a greater number of residents per household in SR. However, considering homes with more than 5 inhabitants, there were no differences in the prevalence of asthma between the 2 cities.

DISCUSSION

Atmospheric pollution is the result of organic material and fuel burning by industries and motorized vehicles. Exposure to airborne pollutants, such as SO₂, NO₂, and O₃, may increase airways reactivity to inhaled allergens.^{16,17} These ef-

fects may last 1 to 2 days. Exposure to PM₁₀ has been associated with reduction in pulmonary function, increase in respiratory symptoms, a higher number of emergency department visits, and more rescue medication use for asthma.^{11,12}

Particulate matter in the ambient air is a complex mixture. The composite of airborne particles depends on their sources, and their toxicity varies with size and physical-chemical composition, which are highly variable. Acid aerosols, bioaerosols, and metals are important components of PM₁₀ that can affect the respiratory health.^{18,19} One of the principal components of PM₁₀ is diesel exhaust particles (DEPs), which constitute approximately 40% of PM₁₀.²⁰

DEPs, as well as NO₂ and O₃, are capable of damaging bronchial mucosa, increasing bronchial epithelium permeability, and reducing the ciliary activity.^{7,21} These effects allow a more close contact of allergens with the immune system through the respiratory mucosa. Bronchial epithelial cells exposed to these pollutants synthesize and release inflammatory mediators, such as interleukin (IL)-4, IL-8, granulocyte-macrophage colony-stimulating factor, tumor necrosis factor α , and soluble intercellular adhesion molecule 1, among others. These mediators regulate the action of inflammatory cells and contribute to the clinical expression of the allergic respiratory disease.^{7,21,22}

Due to the deep inflammatory effects of DEPs on respiratory mucosa²³ and its capacity to act on the immune system,²⁴ inducing and diversifying the production of IgE,²⁵ DEPs have been considered capable of promoting a primary sensitization of human beings to new allergens,²⁶ as well as contributing to the development of allergy.^{22,27}

In Japan, at the end of the World War II, pollinosis by Japanese cedar was considered nonexistent, but currently its prevalence exceeds 10%. This increase coincides with the rapid expansion of the number of diesel vehicles in that country.²⁸ Ishizaki et al²⁹ observed that pollinosis was more frequent among those who lived near highways carrying heavy traffic, surrounded with Japanese cedar, than among those who lived in forests with Japanese cedar, despite the similar pollen count in the 2 areas. These data suggest that pollutants from motorized vehicles may be involved in the sensitization to airborne allergens.

Both DC and SR are integral parts of the Rio de Janeiro metropolitan region, a large, urban conglomerate. The average distance between the 2 towns is 50 km, but although DC possesses a well developed industrial park, heavy traffic, and high population density, SR is characterized by a predominance of farming activity, low population density, and a small concentration of motorized vehicles. The geographic configuration of the region, with plains areas surrounded by mountains, contributes to the distinction in atmospheric conditions between the cities.

The atmospheric concentration of PM₁₀ has been used as a marker of the degree of air pollution.³⁰ In this research, the difference in air quality between the 2 towns was very clear, as were the geographical conditions that determine it. It can, therefore, be supposed that other atmospheric pollutants are

present in concentrations proportional to PM₁₀ in the 2 cities, because they are generated by the same sources.

DC as much as SR must have areas with open sewers and problems with waste collection, because they are poor towns on the outskirts of a metropolis. Certainly, some of the students researched experience the influences of this insalubrious environment. Increased levels of bioaerosols from sewage or dump sites or inside humid residences (eg, house dust mites, fungal spores, endotoxins) have been associated with the exacerbation of asthma.^{19,31} Some studies suggest that, besides the DEPs, transition metals in the PM environment could be linked to allergic sensitization and increases in allergic inflammation and airway hyperresponsiveness.¹⁹

One of the great questions in relation to the ISAAC protocol consists of defining the criteria for distinguishing the true asthmatic patients based on the replies to the WQ. It has been demonstrated that the prevalence of asthma ever is lower than that of wheezing in the last 12 months, suggesting that asthma is underdiagnosed.³² Some studies suggest that the question regarding wheezing in the last 12 months is the more sensitive for detection of asthma.³³ Camelo-Nunes et al,³⁴ using an unspecific methacholine bronchoprovocation test in adolescents who had responded to ISAAC's WQ, demonstrated that the question concerning wheezing in the last 12 months was the best to discriminate asthmatic patients from nonasthmatic patients.

The Global Cut-off Score, obtained during the ISAAC's WQ validation for Portuguese language, was used in this research as an accessory instrument in the identification of asthmatic adolescents. For children 13 to 14 years of age, the score of 6 made it possible to distinguish cases of asthma with 89% sensitivity and 100% specificity.¹⁵

Our results demonstrate that the prevalence of asthma was greater in the city with higher concentration of air pollutants. Our findings suggest a positive association between the levels of atmospheric pollution and the prevalence of asthma in this age group. The analysis of the other variables, including sex, time of residence, type of school, exposure to domestic tobacco smoke, and number of inhabitants per household, revealed that some of them were associated with the prevalence of asthma. However, these associations explain neither the rates found in DC and SR nor the difference between them. In this study, air pollution, clearly distinct between the 2 cities, was the principal risk factor associated with the difference between the prevalence of asthma in the 2 areas.

Studnicka et al,³⁵ using the ISAAC's WQ in 843 children 7 years of age who were residents for at least 2 years in 8 cities in Austria with distinct levels of air pollution, found a significant association between atmospheric concentration of NO₂ and prevalence of asthma and respiratory symptoms. Wjst et al³⁶ found a positive association among the density of highway traffic close to schools, the decrease in the peak expiratory flow, and the prevalence of wheezing and recurrent dyspnea among 4,320 children aged 9 to 11 years in Munich, Germany. Shima et al,³⁷ studying a cohort of 2,056 schoolchildren in 8 different communities in Japan during a

4-year period, detected higher prevalence of asthma among girls who lived less than 50 m from trunk roads compared with girls in the other areas studied. Whereas in boys, the incidence of asthma increased among those living in roadside areas relative to rural areas. Riikj  r et al,³⁸ comparing the prevalence of asthma and respiratory symptoms and atopic sensitization among schoolchildren in 2 towns in Estonia with different levels of atmospheric pollution, detected a greater prevalence of wheezing and positive skin test results for inhalants in the more polluted place. Kim et al,³⁹ comparing the prevalence of asthma among schoolchildren in 2 close areas in Korea with distinct levels of air pollutants, detected a higher prevalence of wheezing ever and of wheezing in the last 12 months, besides higher bronchial responsiveness to hypertonic saline, among the inhabitants of the more polluted place, although the atopic sensitization to inhaled antigens measured by skin prick tests was similar in the 2 areas. These studies show that the prevalence of asthma is positively associated with air pollution, just as in our results.

The absence of information about individual exposure to each pollutant is perhaps the most serious limitation on epidemiologic studies about the effects of environmental factors on health. Experimental studies, on the other hand, do not reflect the innumerable possible situations capable of influencing the airways response. The complex relation between immune responses and the development of asthma are still difficult to understand. It is possible that the increasing prevalence of asthma means an increase in the proportion of people with allergy who begin to wheeze due to an increase in the bronchial inflammatory response to inhaled allergens, which could be a response to the exposure to environmental factors, such as the atmospheric pollutants.⁴⁰

In this study, air pollution, measured by the concentration of PM₁₀, was associated with a higher prevalence of asthma among adolescents. This observation was not influenced by other risk factors, such as exposure to domestic tobacco smoke, number of residents per household, and socioeconomic level. These findings suggest that atmospheric pollution may be contributing to the increasing prevalence of asthma.

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