

Nasal inflammation and personal exposure to fine particles PM_{2.5} in asthmatic children

Lydia Nikasinovic, PhD,^a Jocelyne Just, PhD,^{a,b} Fatiha Sahraoui, MD,^b Nathalie Seta, PhD,^a Alain Grimfeld, MD,^b and Isabelle Momas, PhD^a Paris, France

Background: Outdoor and indoor air pollutants are suspected to induce harmful effects on respiratory health, raising the question of their involvement in allergic asthma and rhinitis.

Objective: The potential effect of short-term personal exposure to particulate matter with a diameter of less than 2.5 μm (PM_{2.5}) on nasal inflammation was examined in children living in the Paris area.

Methods: Forty-one children with allergic asthma and 44 healthy children participated in this study. They were monitored during 48 hours for their personal exposure to PM_{2.5}. At the end of the measurement period, children underwent one nasal lavage. Nasal lavage fluid was investigated for cellular (neutrophils and eosinophils) and soluble (albumin, urea, elastase, α 1-antitrypsin, IL-6, and IL-8) mediators.

Results: Pollutant concentrations did not differ between the 2 groups. In asthmatic subjects, but not in healthy children, personal PM_{2.5} levels were correlated to nasal percentage of eosinophils and to albumin, urea, and α 1-antitrypsin concentrations after adjustment for confounders (age, sex, house dust mites, pollens, cat, environmental tobacco smoke through urinary cotinine, barometric pressure, and respiratory infection).

Conclusion: The association observed with the percentage of eosinophils supports recent speculations on fine particle involvement in allergic phenotype overexpression.

Clinical implications: This study highlights the link between personal fine particle exposures and nasal inflammation in asthmatic allergic children living in urban areas. Because the view of united airways is still not completely understood, the question of pulmonary inflammation in such a situation deserves further investigation. (*J Allergy Clin Immunol* 2006;117:1382-8.)

Key words: Nasal lavage fluid, inflammation, allergy, asthma, eosinophil, children, personal exposure, fine particle, PM_{2.5}

Allergic respiratory diseases have recently become a major public health concern in most industrialized countries.¹ There is increasing evidence from epidemiologic and laboratory-based studies that exposure to air pollutants could play a role in the clinical manifestation of allergic and nonallergic airway diseases. Epidemiologic studies have revealed a consistent association between outdoor and indoor air pollutants and various health-related respiratory outcomes.²⁻⁸ These epidemiologic observations are supported by experimental studies on bronchial and nasal epithelium responses after environmental tobacco smoke (ETS),⁹ ozone,¹⁰ and diesel exhaust particle (DEP) exposure.¹¹⁻¹³

The nose is an easily assessable mucosal surface for assessing inflammatory reactions because it is the first region of the respiratory tract in contact with airborne pollutants. The nasal lavage (NAL) fluid (NALF) is rich in inflammatory mediators,¹⁴ particularly in subjects exposed to allergen¹⁵ or ozone.¹⁶ Moreover, NAL is a useful method for epidemiologic studies because it fulfills conditions for large-scale use: it is simple, noninvasive, and atraumatic. However, those rare epidemiologic studies dealing with air pollution and nasal inflammation failed to demonstrate a significant effect of particulate matter (PM) on NALF inflammatory biomarkers.¹⁶⁻¹⁸

In this context the aim of this study was to determine the effect of short-term personal exposure to particulate matter (PM) less than 2.5 μm in diameter (PM_{2.5}) on nasal inflammation in healthy and allergic asthmatic children living in the Paris area.

METHODS

Study design

This cross-sectional study consisted of a 48-hour personal measurement of PM_{2.5} and indoor air pollutants, followed by NAL and skin prick tests. The study was approved by the hospital ethics committee, and written consent was obtained from all parents and children.

Subjects

The recruitment took place among children living since birth in Paris and its close suburbs and included in a French multicenter study on asthma and transport.¹⁹ A total of 85 children aged 7 to 14 years participated in the present study from October 1999 through June 2002.

Asthmatic children were recruited from attendees of the Asthma Center of Trousseau Hospital (Paris, France) and from a network of private pediatricians and general practitioners. The diagnosis of asthma was supported by a history of recurrent wheezing and dyspnea

From ^aService de Santé Publique-Environnement, Faculté des Sciences Pharmaceutiques et Biologiques, Université René Descartes; and ^bService de Pneumologie et d'Allergologie Pédiatrique, Hôpital d'Enfants Armand Trousseau, Assistance Publique-Hôpitaux de Paris.

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Reprint requests: Lydia Nikasinovic, PhD, Service de Santé Publique-Environnement, Faculté de Pharmacie, 4, avenue de l'Observatoire, 75270 Paris cedex 06, France. E-mail: lydia.nikasinovic@univ-paris5.fr.

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Abbreviations used

DEP:	Diesel exhaust particle
ETS:	Environmental tobacco smoke
NAL:	Nasal lavage
NALF:	Nasal lavage fluid
PM:	Particulate matter
PM2.5:	Particulate matter with diameter less than 2.5 μm
PM10:	Particulate matter with diameter less than 10 μm

attacks, with proved β_2 -agonist-reversible airways obstruction characterized by an increase of at least 15% in FEV₁. All asthmatic children had mild-to-moderate persistent asthma and received conventional treatment.²⁰ Children who had nasal corticosteroid treatment the week before NAL were excluded.

Healthy participants, recruited by the same network of private pediatricians or general practitioners, had no history of asthma, rhinitis, or personal or familial atopy, as evidenced by the interview and a normal physical examination.

Method

All children were screened at the hospital by using skin prick tests with the following allergens: cat, *Dermatophagoides pteronyssinus*, *Alternaria tenuis*, timothy grass, *Blatta germanica*, olive tree, birch tree, pellitory, and ragweed, all provided by Allerbio (Paris, France). A positive skin test response was defined as a mean wheal diameter of greater than 3 mm. In addition, an anterior rhinoscopy was performed, and no child presented with nasal polyps or septal deviation or previous nasal surgery.

Personal exposure to fine particles was carried out during the 48 hours preceding the NAL. Measurements were performed from Monday (7 AM) to Wednesday (7 AM) or from Thursday (7 AM) to Saturday (7 AM). Asthmatic and healthy children were randomly assessed. Before the sampling period, the sampler was brought by an interviewer to the home, where a validated environmental questionnaire²¹ was completed. Personal exposure to PM2.5 was measured according to a standardized procedure. Fine particles were collected with a special active sampler, and the device was carried in a rucksack by children whenever they moved (for more details, see additional text in the Online Repository at www.jacionline.org).

Meteorologic data (temperature, barometric pressure, and relative humidity) and ambient 8-hour mean and maximal ozone values for the 2 days preceding NAL were provided, respectively, by Météo France and by the local air quality monitoring network.

Pollen data were supplied by the National Monitoring Network for Aerobiology and are expressed as the number of total and specific grain pollens per cubic meter counted during the 48 hours before NAL.

ETS was assessed by measuring urinary cotinine in a sample of first void urine stored at -20°C until analysis. Cotinine concentrations, controlled by creatinine levels, were measured on a Beckman CX7 automated analyzer by using an enzyme immunoassay adapted by our team²² with a detection limit of 1 $\mu\text{g/L}$.

Current exposure to house dust mites was assessed by collecting dust from the mattress and the floor of the bedroom of the child and from the living room with a vacuum cleaner.²³ Acarex test kits (Karapharm, Marseilles, France) were used for a semiquantitative assessment with a 4-step color scale (negative, mild, moderate, and strong).

In addition, parents were asked to fulfill a questionnaire about their home habits to identify other sources of pollution (number of

cigarettes smoked at home, gas cooking, recent refurbishment, pets [and particularly cats], report of molds, and home ventilation frequency).

A dichotomous variable named “sensitivity and exposure to allergens,” which takes into account both allergen exposure and allergen sensitization of each child, was built to assess relevant allergen exposure. A child was considered exposed to allergen if he or she was exposed to at least one of those allergens for which he or she was sensitized (cat, specific pollen, and house dust mite). Conversely, a child who was not sensitized to a given allergen was considered not exposed, even if he or she was exposed to it.

Nasal response was evaluated by using an NAL method adapted from the Hilding procedure for children.²⁴ NAL consisted of irrigation of the nasal cavity (3 instillation/aspiration cycles for each nostril) with saline solution (NaCl 9%) through a transparent inflated pediatric Foley catheter (Porgès SA, Le Plessis Robinson, France). The NALFs recovered from each nostril were pooled and centrifuged (500g) for 15 minutes at $+4^\circ\text{C}$. The supernatant was placed in aliquots and stored at -70°C for later analysis. The pellet was treated with an equivalent volume of 2,3-dihydroxy 1,4-dithiolbutane (Digest-EUR; Eurobio, Les Ulis, France) in RPMI media (Sigma Aldrich, Saint-Quentin Fallavier, France) and kept at room temperature for 45 minutes. Total cell count, including leukocytes and epithelial cells, was determined on a hemocytometer. Differential cell count was performed on cytopsin preparations (Shandon cytopsin; Shandon, Eragny/Oise, France), and 2 slides were stained with May-Grünwald Giemsa (Sigma Aldrich). A minimum of 200 nucleated cells was counted in a blind manner, and percentages of neutrophils and eosinophils were calculated.

Two permeability markers, albumin and urea, were measured on an analyzer (Monarch Instrumental Laboratory, Paris, France) by using immunonephelometric and enzymatic methods, respectively. The lower detection limits were 2 mg/L and 30 $\mu\text{mol/L}$, respectively. Inflammatory status was evidenced by the proinflammatory cytokine IL-6 and the chemoattractant IL-8 by using an ELISA kit (R&D systems Europe, Lille, France). The lower detection limits were 3 ng/L and 10 ng/L, respectively. Protease-anti-protease balance was assessed by measuring total neutrophil elastase (ELISA kit; VWR International, Fontenay/Bois, France) and α 1-antitrypsin by using the ELISA method.²⁵ The lower detection limits were 3 $\mu\text{g/L}$ and 1 $\mu\text{g/L}$, respectively.

Statistical analysis

Data were processed with the BMDP software package (University of California, Los Angeles, Calif). Because most of these distributions were skewed, we used log transformation for mediator concentrations (except urea), urinary cotinine, and PM2.5. For each group of asthmatic and healthy children, univariate (Student *t* test and Pearson correlation test), and multivariate analyses were performed. A multiple linear regression model was built for each group, including confounders, such as age, exposure to ETS (as assessed by urinary cotinine levels), infection status, and all variables statistically associated in the univariate analysis, to evaluate the association between air pollutants and nasal mediator levels. A stepwise selection procedure was then applied. Results of the associations are expressed as the coefficient of determination (R^2), the *P* value of the model, and the standardized regression coefficient (with 95% CI) specific to each regressor. For all tests, a *P* value of less than .05 was considered statistically significant.

RESULTS

Subject characteristics

A total of 85 participants completed the study protocol. There were 41 asthmatic (19 boys and 22 girls; mean age,

TABLE I. Air pollutant exposures and meteorologic data for healthy (n = 44) and asthmatic (n = 41) children

Parameters	Healthy children	Asthmatic children
Air pollutant data		
PM10, $\mu\text{g}/\text{m}^3$	24.0 (8.2)	21.9 (7.9)
Ozone, $\mu\text{g}/\text{m}^3$	27.5 (21.2)	30.8 (21.7)
Ozone, 8-h max, $\mu\text{g}/\text{m}^3$	54.9 (34.7)	62.4 (31.1)
Pollen, grains/ m^3	70 (126)	77 (114)
Cigarettes smoked at home, no	3 (6)	2 (5)
Urinary cotinine, $\mu\text{g}/\text{L}$	12.2 (16.6)	10.8 (15.8)
Personal PM2.5,* $\mu\text{g}/\text{m}^3$	42.4 (63.4)	30.4 (25.1)
Meteorologic data		
Temperature, $^{\circ}\text{C}$	11.3 (5.1)	10.9 (5.4)
Relative humidity, %	74.5 (11.6)	72.9 (11.7)
Barometric pressure, hPa	1010 (9)	1006 (9)

Data are expressed as the mean (SD) calculated (or measured) for each parameter for the previous 2 days before NAL.

*n = 37 healthy and n = 37 asthmatic children.

10.2 $\pm$ 2.0 years) and 44 healthy (22 boys and 22 girls; mean age, 9.4 $\pm$ 2.0 years) children. Asthmatic children were significantly older than healthy children ($P < .05$). In the 4 weeks preceding NAL, 3 asthmatic and 6 healthy children experienced a common cold.

Thirty-four percent of asthmatic children were sensitized to cat, 73% to house dust mites, and 34% to timothy grass; 94% of asthmatic children presented with rhinorrhea, sneezing, or nasal obstruction in the last year; 71% had inhaled corticosteroid treatment; and 90% had nasal corticosteroid treatment in the last year.

Environmental data

Home characteristics were similar for both groups. Homes were flats for 80% of the children, with a mean inhabitant density of about 1.2 $\pm$ 0.6 inhabitants per room. Gas was used in 50% of homes for heating and 38% of homes for cooking. Home ventilation occurred more than 3 times per week for 77% of homes. Reports of humidity concerned 54% of homes. Pets were present in 36% of homes. A cat was present in 4 (9%) of the 41 asthmatic homes. House dust mite levels were mostly negative or mild. Parental tobacco smoke at home concerned 15 (34%) healthy and 13 (32%) asthmatic children. Regular maternal smoking was reported for 33% of the children. Regular paternal smoking was reported for 65% of asthmatic children and 43% of healthy children ($P < .05$).

Air pollutant and meteorologic data are presented in Table I. There was no significant difference between asthmatic and healthy children, neither for air pollutants nor for meteorologic data. Cotinine levels were poorly but significantly correlated with the number of cigarettes smoked at home and reported by parents ($r = 0.35$, $P < 10^{-3}$).

Sensitivity and exposure to allergens concerned 83% of asthmatic subjects who were exposed to at least one allergen of relevance: cat (32%), specific pollen (12%), and house dust mite (71%).

NAL data

A total of 85 NALs, one for each child, were performed during the study period outside the summer holidays. The mean volume instilled was 9.2 $\pm$ 1.5 mL for control subjects and 8.8 $\pm$ 1.3 mL for asthmatic subjects. Mean recovery was similar in both groups (67%). Cellular and soluble mediator concentrations are described in Tables II and III, respectively. For technical reasons (lavage fluid too viscous or without a sufficient number of cells), total cellular and differential counts were available for 33 healthy and 35 asthmatic children. In healthy children the cellular profile was marked by a majority of epithelial cells, and 13.5% (median value) of total cells were neutrophils. In asthmatic children the cellular profile consisted of a leukocytes infiltration (median values, 18% neutrophils and 19% eosinophils). The percentage of eosinophils was significantly higher in asthmatic children ($P < .05$) compared with that in healthy children. Exudation mediators were measurable in all samples. IL-6, IL-8, and $\alpha 1$ -antitrypsin levels were greater than the detection limit in all samples, except one issued from an asthmatic child. Soluble mediator concentrations did not differ significantly between the 2 groups.

Associations between environmental exposures and nasal mediators

Univariate analysis showed that determinants of NALF mediator concentrations were mostly age, sex, barometric pressure, ETS, and PM2.5 (see Figs E1 through E4 in the Online Repository at www.jacionline.org).

Multivariate analysis was conducted separately for each group, with a multivariate model including these latter variables and infection status (for healthy children) or sensitivity and allergen exposures (for asthmatic children). For each NALF mediator, standardized regression coefficients with their 95% CIs are presented in asthmatic children (Figs 1 and 2) and healthy children (see Fig E5 in the Online Repository at www.jacionline.org).

In asthmatic children a consistent relation between PM2.5 and several biomarkers was evidenced after adjustment for potential confounders. PM2.5 concentrations were significantly associated with the percentage of eosinophils, with the determination coefficients of the model being 44%. The stepwise process showed that PM2.5 and allergen exposures were the only selected variables associated with the percentage of eosinophils. Exudation markers (albumin, urea, and $\alpha 1$ -antitrypsin) levels were highly correlated to PM2.5 concentrations. The stepwise process showed that PM2.5 was the only selected variable statistically associated with albumin, urea, and $\alpha 1$ -antitrypsin levels. Because the PM2.5 distribution revealed 4 outliers, all statistics were rerun to determine whether the correlations were driven by these 4 points. Results of this influential points analysis are described in Tables E1 and E2 (in the Online Repository at www.jacionline.org) and show that even when these 4 outliers are excluded from analyses, the associations remain significant.

TABLE II. Cells in NALF for healthy (n = 33) and asthmatic (n = 35) children

	Healthy children		Asthmatic children	
	Geometric mean (% CV)	Median (first-third quartile)	Geometric mean (% CV)	Median (first-third quartile)
Total cells × 10 ³ /mL	67.6 (202)	84.2 (22-187)	53.6 (130)	54.9 (10.6-229.5)
Neutrophils, %	3.7 (118)	13.5 (1.0-40.8)	5.8 (93)	18.0 (4.0-49.5)
Eosinophils, %	0.8 (149)	3.0 (0.0- 18.5)	3.5 (93)	19.0 (2.0-40.5)*

CV, Coefficient of variation.
**P* < .05, *t* test, healthy compared with asthmatic children.

TABLE III. Soluble mediators in NALF for healthy (n = 44) and asthmatic (n = 41) children

	Healthy children		Asthmatic children	
	Geometric mean (% CV)	Median (first-third quartile)	Geometric mean (% CV)	Median (first-third quartile)
Albumin (mg/L)	41.8 (99)	33.0 (22.3-76.5)	32.3 (183)	30.5 (13.9-82.2)
Urea (μmol/L)	607 (48)	586 (445-870)	626 (44)	596 (462-896)
α1-Antitrypsin (μg/L)	1022 (102)	978 (437-1918)	896 (99)	9356 (437-2021)
Elastase (μg/L)	3.2 (121)	3.4 (1.3-8.6)	2.6 (192)	2.6 (0.8-11.3)
IL-6 (ng/L)	10.0 (213)	7.4 (2.9-32.5)	7.8 (131)	7.9 (1.5-50.9)
IL-8 (ng/L)	833 (70)	895 (528-1459)	601 (105)	693 (259-1512)

CV, Coefficient of variation.

Being exposed to relevant allergens, the 2 days before NAL resulted in a significant increase of NALF elastase and the percentage of eosinophils. The regression model failed to demonstrate any significant relation between PM2.5 and IL concentrations.

In healthy subjects no relation could be evidenced between PM2.5 and NALF biomarkers. In this group our analysis revealed the role of ETS and barometric pressure on several NAL biomarkers, such as urea and IL-6.

DISCUSSION

The present study shows, for the first time, an association between both NALF percentage of eosinophils and exudation mediators and short-term personal PM2.5 exposure in children with mild-to-moderate allergic asthma living in Paris. These associations with PM2.5 are not observed in healthy children.

Methodological issues

To the best of our knowledge, this is the first epidemiologic study dealing with nasal inflammation that uses personal PM2.5 measurements. In all previous works, assessment of PM exposure has been based on fixed-site measurements of particulate matter with a diameter of less than 10 μm (PM10),^{17,18,26,27} which reflect only a part of the true exposure. In this work PM2.5 exposure, now regarded as the state of the art in the field of environmental epidemiology,²⁸⁻³⁰ was measured in a personal manner to limit misclassifications. However, the origin of this PM is questioned. Although our work was not designed to determine fine particle source apportionment, one can generate some speculations about PM2.5 sources. The total

personal PM exposure involves both indoor- and outdoor-generated particles. In our study personal PM2.5 measurements were marked by substantial between-subject variability. It is likely that much of this variability can be accounted for by indoor sources of particles; by indoor-outdoor air exchange rates, which have been shown to influence significantly the relationship between indoor and personal exposure; and finally by outdoor-generated particle levels.^{31,32} Indoor PM concentrations are possibly influenced by the number of cigarettes smoked in the home, cooking activities, and resuspended house dust related to human activities.³³ Nevertheless, because of lower deposition velocities, PM2.5 tends to be spatially homogeneous in indoor environments; as demonstrated by Janssen et al,³⁴ resuspended house dust particles are dominated by particles in the coarse fraction (particles larger than 2.5 μm). Consequently, the most important indoor contributor to personal PM2.5 is generally ETS. Wallace³³ and Janssen et al³⁵ consider that one cigarette is responsible for a 24-hour increase of 2.3 μg/m³ PM10 and 1 to 2 μg/m³ fine particles, respectively. However, PM2.5 and ETS were not significantly correlated in the present study. This result is not surprising because children were not exposed to high ETS levels. It is thus assumed that the relative component of ETS in personal PM2.5 levels is moderate. Nevertheless, this variable was taken into account in the regression model with urinary cotinine concentrations, which are generally agreed to be the best indicator of 48-hour ETS exposure.³⁶

Concerning outdoor-generated particles, a number of studies have been performed to assess the correlation between personal exposure and outdoor PM concentration. Wallace and Williams³⁷ used, in a longitudinal study, personal indoor-outdoor sulfur concentrations to estimate, in

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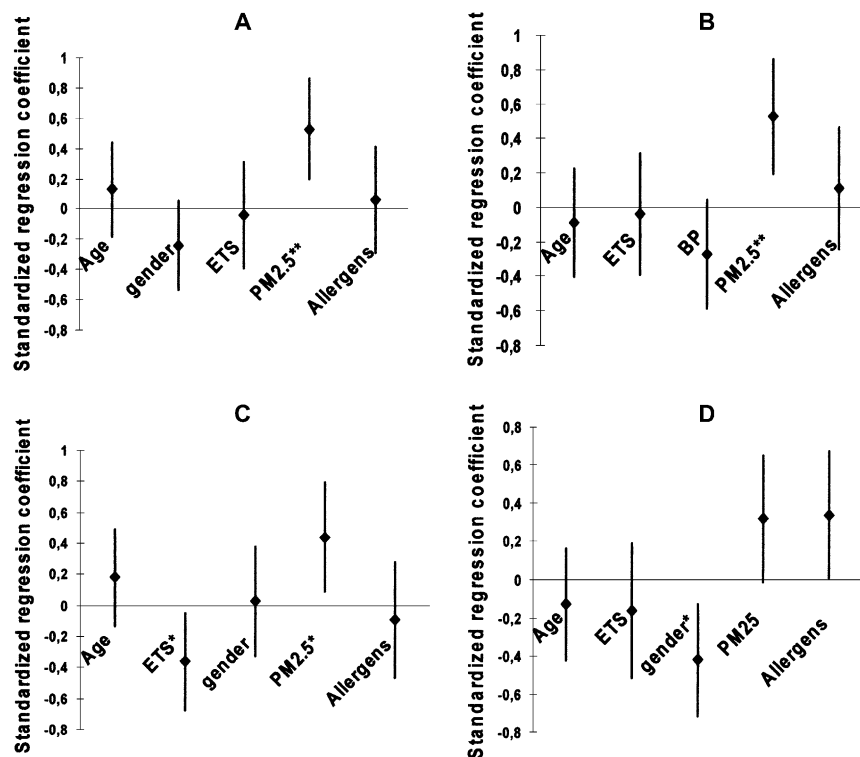


FIG 1. Personal PM_{2.5} exposure and NALF soluble mediators in asthmatic children. *ETS*, Environmental tobacco smoke assessed on the basis of urinary cotinine; *BP*, barometric pressure; R^2 , coefficient of determination. Vertical lines indicate the 95% CI of the standardized regression coefficient related to each variable. * $P < .05$; ** $P < .01$. **A**, Albumin ($R^2 = 29\%$, $P = .06$). **B**, Urea ($R^2 = 31\%$, $P < .05$). **C**, $\alpha 1$ -Antitrypsin ($R^2 = 27\%$, $P = .08$). **D**, Elastase ($R^2 = 34\%$, $P < .05$).

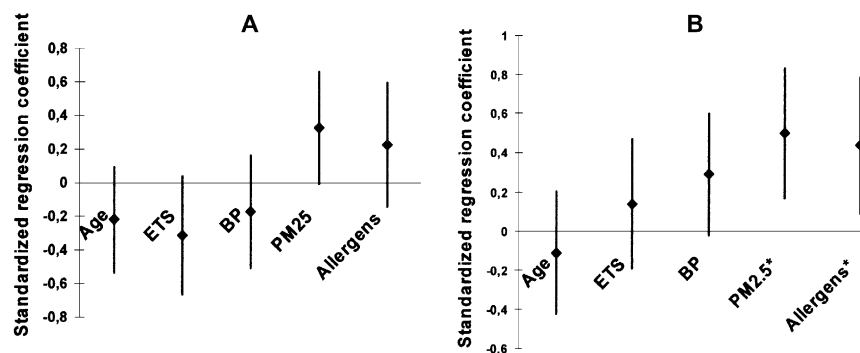


FIG 2. Personal PM_{2.5} and NAL total cells ($n = 35$) and percentage of eosinophils ($n = 30$) after adjustment for potential confounders in asthmatic children. *ETS*, Environmental tobacco smoke assessed on the basis of urinary cotinine; R^2 , coefficient of determination. Vertical lines indicate the 95% CIs of the standardized regression coefficient related to each variable. ** $P < .01$. **A**, Total cells ($R^2 = 30\%$, $P = .06$). **B**, Percentage of eosinophils ($R^2 = 44\%$, $P < .01$).

37 residents of North Carolina, the infiltration factor and outdoor exposure factor for individual homes and persons. They demonstrated that (1) the infiltration factor of the outdoor-generated PM_{2.5} to indoor PM_{2.5} exposure is more than 60% during cold seasons (in their study the outdoor contribution [$5\text{--}22 \mu\text{g}/\text{m}^3$] exceeded the indoor-generated contributions in 27 of 36 homes); (2) the contribution of outdoor-generated PM_{2.5} is about 50% of the personal

PM_{2.5} exposure; and (3) this contribution depends on a local factor because residential concentration is a better regressor than the fixed-site measurement. It has been proposed that diesel exhaust, issued from vehicle gas combustion, is one of the major contributors to outdoor PM in urban areas.³⁸ This contributor could be related to a considerable increase in France in sales of diesel vehicles without particle filters over the past 2 decades.^{39,40}

We also studied ozone by considering for each child the mean and maximal 8-hour ozone concentrations measured by the closest monitor of the air quality monitoring network. Because of the low concentrations registered during the study period (September through June), we did not use personal measurements. Indeed, as usual in Paris, the mean ozone concentration for the 48 hours preceding the NAL was less than $30 \mu\text{g}/\text{m}^3$, and the maximal ozone concentration never reached $60 \mu\text{g}/\text{m}^3$. These concentrations are too low to induce measurable effect, with all experimental studies having used at least $200 \mu\text{g}/\text{m}^3$ to evaluate nasal response.

Another key point in our study is that ETS and allergen exposure, the most important confounders in this work, were assessed by measuring personal ETS exposure and indoor house dust mite exposure, thus reducing misclassification. Although ETS exposure can be assessed by using questionnaires, recall bias and underestimation of ETS exposure caused by social desirability can lead to validity problems, especially if parental willingness to report smoking differs according to child health status. Short-term ETS exposure assessment was based on personal measure of an internal exposure biomarker to reduce this bias.

In addition, we built a specific variable called “sensitivity and allergen exposures,” which integrates those allergens for which each child is sensitized. This variable is relevant for our study, with the objective focusing on the role of PM_{2.5} on nasal inflammation in an allergic context.

Nasal inflammation was assessed by using a noninvasive, well-tolerated, and reproducible method.²⁴ All nasal biomarkers, apart from eosinophils, did not differ between asthmatic and healthy children. One possible explanation is that all children living in urban areas could present with increased NALF mediators, whatever their health status. This hypothesis is supported by Frischer et al,²⁶ who demonstrated that urban healthy children had significantly higher mean levels of IL-8, urea, uric acid, albumin, and nitric oxide metabolites in NALF than suburban children.

Issues on associations

This study is the first epidemiologic work to show the association between short-term personal PM_{2.5} exposure and both nasal percentage of eosinophils and exudation mediators in asthmatic allergic children. This suggests that this PM is able to generate, at levels considered to be safe according to World Health Organization guidelines,⁴¹ an inflammatory reaction with an increased membrane permeability of nasal epithelium and subsequent inflammatory cell influx. Previous epidemiologic works have found that NALF inflammatory mediators are related to ETS exposure in children⁴² and to ozone levels,⁴³ but none of them demonstrated leukocyte increase in relation to ambient PM₁₀ exposures.^{17,18,26,27} When PM₁₀ concentrations were introduced in our multivariate models, we also failed to evidence any association between outdoor PM₁₀ levels and nasal mediators (data not shown). These results indicate that environmental

measurements of PM₁₀ might not be relevant for study of respiratory inflammation.

The association found between PM_{2.5} and NALF inflammatory mediators from asthmatic children is thus in line with experimental studies recently conducted on DEPs.⁴⁴ Short-term DEP exposure resulted in marked epithelial inflammation and demonstrated that DEP exposure led to intrinsic effects, as well as adjuvant-like effects, when DEPs were coadministered with allergens.^{45,46} This latter experimental design better suits an environmental atmosphere where particulate and allergens often coexist, with particles being carriers of allergens.^{47–49}

In contrast to asthmatic children, in healthy children nasal biomarkers were associated with barometric pressure but not with PM_{2.5}. The role of barometric pressure on nasal epithelium is not yet documented, but this meteorologic parameter was included in our analyses. This result suggests that the effect of PM_{2.5} on NALF biomarkers studied in this research, at levels commonly measured in urban areas, might be restricted to those individuals with allergic phenotype. This result deserves further investigations, which should focus on the interaction between PM_{2.5} and allergen exposure in allergic children.

In conclusion, this study shows that in an urban area such as Paris, short-term personal PM_{2.5} exposure is related to nasal allergic inflammation in children with allergic asthma but not in healthy children. The association observed with the percentage of eosinophils supports recent speculations on fine particle involvement in allergic phenotype overexpression.

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