Original article

Respiratory Exacerbations and their Association with Particulate Matter Fluctuations at Hugo Mendoza Pediatric Hospital

Exacerbaciones respiratorias y su asociación con fluctuaciones de material particulado en Hospital Pediátrico Hugo Mendoza

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ABSTRACT

Introduction: Millions of children are exposed daily to air pollution, one of whose components is particulate matter, which is especially harmful to the pediatric population and can worsen the course of respiratory diseases.

Objective: To describe the association between respiratory disease exacerbations and particulate matter fluctuations at the Dr. Hugo Mendoza Pediatric Hospital, between 2017 and 2022.

Methods: An observational, analytical and longitudinal study was conducted using secondary data. The study population comprised 344 670 patients, with a sample size of 56 734 cases. A Poisson regression was performed to analyze the association between exacerbations of respiratory disease and particulate matter concentration.

Results: The findings indicated that the predominant respiratory exacerbation was bronchial asthma, mainly affecting children aged 1-2 years, mostly males. It was shown that for each unit increase in the average concentration of fine particulate matter and coarse particulate matter, exacerbations of respiratory diseases increased by 4,7% and 3,0%, respectively.

Conclusions: Bronchial asthma was the predominant disease with respiratory exacerbations, and a higher average concentration of particulate matter was significantly related to an increase in the number of respiratory exacerbations. These findings could have implications for a better understanding of the relationship between exposure to particulate matter and the frequency of respiratory exacerbations in our context, suggesting the need for environmental prevention and control measures to mitigate adverse effects on respiratory health.

Keywords: disease exacerbation; respiration disorders; particulate matter; association; pediatric hospital.

RESUMEN

Introducción: Millones de niños se exponen diariamente a la polución aérea, uno de cuyos componentes es el material particulado, que es especialmente dañino para la población pediátrica y puede empeorar el curso de enfermedades respiratorias.

Objetivo: Describir las asociaciones entre las exacerbaciones de enfermedades respiratorias y las fluctuaciones de material particulado en el Hospital Pediátrico Dr. Hugo Mendoza, entre 2017 y 2022.

Métodos: Se realizó un estudio observacional, analítico y longitudinal a partir de datos secundarios. La población del estudio comprendió 344 670 pacientes, con un tamaño

de muestra de 56 734 casos. Se realizó una regresión de Poisson para analizar la asociación entre las exacerbaciones respiratorias y la concentración de material particulado.

Resultados: Los hallazgos indicaron que la exacerbación respiratoria predominante fue el asma bronquial, que afectó principalmente a niños de 1-2 años, sobre todo varones. Se mostró que, por cada unidad de incremento en la concentración promedio de material particulado fino y grueso, aumentaron las exacerbaciones de enfermedades respiratorias en un 4,7 % y un 3,0 %, respectivamente.

Conclusiones: La exacerbación respiratoria predominante correspondió al asma bronquial y una mayor concentración promedio de material particulado se relacionó de manera significativa con un incremento en el número de exacerbaciones respiratorias. Estos hallazgos podrían tener implicaciones para una mejor comprensión de la relación entre la exposición a material particulado y la frecuencia de exacerbaciones respiratorias en el entorno, lo que sugiere la necesidad de medidas de prevención y control ambiental para mitigar los efectos adversos en la salud respiratoria.

Palabras clave: exacerbación; enfermedad respiratoria; material particulado; asociación; hospital pediátrico.

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Introduction

Millions of children are exposed to polluted air every day, which could seriously harm their health. In 2019, the World Health Organization (WHO) determined that 93% of

children live in environments with high levels of air pollution, making them particularly vulnerable to respiratory diseases such as asthma, pneumonia, acute bronchitis, and bronchiolitis.[1,2]

An important component of air pollution is particulate matter (PM), which is a heterogeneous mixture of organic and inorganic, solid and liquid particles suspended in the air. Many of these particles are primarily of anthropogenic origin and are generated by pollution associated with industrial globalization, the expansion of megacities, traffic, fossil fuel-based power plants, agriculture, and polluting waste, among others.[1,3,4] PM represents one of the environmental risk factors with the greatest impact on human health, particularly on children's health.[5]

Given their small size, particles can be transported through the air and are inhaled daily by humans, depositing in the lungs, particularly in the alveoli. Based on their size, they are classified as coarse particulate matter (PM_{10}), fine particulate matter ($PM_{2.5}$), and ultrafine particulate matter ($PM_{0.1}$), measuring $\leq$ 10 μm, $\leq$ 2.5 μm, and $\leq$ 0.1 μm, respectively. PM_{10} particles tend to accumulate in the upper airways, while $PM_{2.5}$ and $PM_{0.1}$ penetrate deeply into the respiratory tract, with $PM_{2,5}$ agglomerating in the lower airways and $PM_{0.1}$ reaching the alveoli, from where it can subsequently enter the bloodstream.[2,6,7]

The Children's Environmental Health Collaborative documented that nearly half of all lower respiratory tract infection deaths in children under five years of age are caused by particulate matter produced by household air pollution from the use of solid fuels (such as firewood, agricultural waste, charcoal, mineral waste, and animal excrement) in homes. This finding was confirmed by the WHO in 2023 when it reported that, in 2020, household air pollution caused 3,2 million deaths, including 237 000 children under five years of age.[8]

In addition, it was highlighted that the combined effects of ambient and household air pollution are associated with 6,7 million premature deaths each year, concentrated in low- and middle-income countries, mainly during the autumn and winter months (cold season) due to the intense consumption of biomass for heating purposes.[6,8]

All of these factors have a greater impact during childhood due to the immaturity of the developing alveolar mucosa, a respiratory epithelium that is more permeable to contaminants, as well as the need for higher air volumes per kilogram of body weight than in adults, rapid respiratory rate (which favors the inhalation of a greater quantity of pollutants), greater vulnerability to oxidative stress, narrower bronchi and a low immune capacity with decreased oxidative capacity of detoxification systems. All these factors add up to greater exposure, which also facilitates increased inhalation of particulate matter.[7]

Following exposure to these particles, direct damage occurs in the respiratory tract, leading to the deterioration of airway cell function. This process induces oxidative stress, resulting in damage to the respiratory membrane, inflammation, and bronchoconstriction, which collectively impair the ability to clear pathogens and contaminants from the airways. Consequently, lung function declines, reducing the blood's oxygenation capacity.[2,3,8,9]

In fact, a meta-analysis published in 2020 documented that the incidence of pneumonia in children increases by 1.5% and 1.8% for every 10 $\mu g/m^3$ increase in PM_{10} and $PM_{2.5}$, respectively.[10] Based on this, in 2021 the WHO recommended lowering the annual $PM_{2.5}$ air quality guideline from 10 to 5 $\mu g/m^3$.[7] However, despite significant global efforts to control these pollutants, some countries still have high levels. The Dominican Republic, in particular, has had fluctuations in these concentrations, along with an increase in respiratory pathologies, especially infectious-contagious diseases.[10,11]

The aforementioned motivated the development of this study, which general objective is to describe the association between respiratory disease exacerbations and particulate matter fluctuations at the Dr. Hugo Mendoza Pediatric Hospital, between 2017 and 2022. In addition, the description of the exacerbation of respiratory diseases was disaggregated based on age and sex.

Methods

An observational, analytical, and longitudinal study was conducted between June 30 and July 25, 2024, utilizing open-access databases from the Dr. Hugo Mendoza Pediatric Hospital and the Ministry of Environment and Natural Resources. Both databases are available through the National Open Data Portal of the Dominican Republic.[12,13] The environmental data were obtained from monitoring stations strategically located in Haina, ONAMET, Puerto Plata, Santiago, and San Pedro de Macoris.

The study population consisted of 344 670 patients who visited the emergency room at Dr. Hugo Mendoza Pediatric Hospital between 2017 and 2022. After applying the inclusion and exclusion criteria, the final sample comprised 56 734 cases.

The inclusion criteria for the study required patients who presented with a respiratory exacerbation to the emergency room at Dr. Hugo Mendoza Pediatric Hospital within the specified period. Additionally, eligible participants were between 0 and 18 years of age.

The exclusion criteria aimed to ensure the accuracy and relevance of the sample. Patients were excluded if they did not have a confirmed diagnosis of respiratory disease or if their respiratory condition was classified as a non-exacerbated consultation during medical care. Furthermore, cases with incomplete medical records were omitted. Neonatal respiratory diseases of intrinsic causes, as well as infectious respiratory diseases acquired within the first 72 hours of life, were also grounds for exclusion.

Moreover, the dependent variable in the study was the exacerbation of a respiratory disease while the independent variables included age group, sex, and average concentrations of fine and coarse particulate matter. Additionally, quantitative variables corresponding to exacerbations of respiratory diseases and average concentrations of fine and coarse particulate matter were grouped annually.

Regarding the statistical methods, Microsoft Excel 2019 was used to tabulate the data for each variable. STATA version 18 software was then employed to estimate the Poisson regression between the dependent variable (exacerbation of respiratory disease) and the independent variables (average concentrations of fine and coarse particulate matter). The tables were prepared in Microsoft Word 2019.

Subsequently, the percentage change was calculated to estimate the incidence rate ratio (IRR) in the group of interest using the following formula:

$$Percentage\ change = (IRR - 1)\,.100$$

Results

The results of the study indicated that 16,82% (n=57 966) of the population who attended the emergency room at the Hugo Mendoza Pediatric Hospital (n=344 670) presented a respiratory exacerbation, with the highest peak in 2022, when 25,16% (n=14 583) of the total reports were respiratory exacerbations. Bronchial asthma was the most common disease producing exacerbations, it predominated with 63,14% (n=36 598) of the total cases. Likewise, bronchiolitis and acute tonsillitis occupied second and third place, with 13,12% (n=7608) and 6.72% (n=3898), respectively (table 1).

Table 1 - Respiratory disease exacerbations at Dr. Hugo Mendoza Pediatric Hospital (2017-2022)

Respiratory diseases	Year						
	2017	2018	2019	2020	2021	2022	Total cases by pathology
Bronchial asthma	7087	6066	3829	3732	6844	9040	36 598 (63,14%)

Acute bronchiolitis	1521	1641	1300	696	1197	1253	7608 (13,12%)
Acute tonsillitis	399	732	602	378	908	879	3898 (6,72%)
Pneumonia	209	455	279	403	859	1133	3338 (5,76%)
ARIs*	193	400	215	271	752	946	2777 (4,79%)
Flu-like illness	78	115	56	151	573	831	1804 (3,11%)
Croup	132	116	129	38	99	195	709 (1,22%)
Other respiratory conditions**	53	86	182	66	87	185	659 (1,14%)
Common cold	96	67	0	93	110	102	468 (0,81%)
Acute bronchitis	21	4	1	14	48	19	107 (0,18%)
Total cases per year	9789 (16,89%)	9682 (16,70%)	6593 (11,37%)	5842 (10,08%)	11 477 (19,80%)	14 583 (25,16%)	57 966 (100%)

Note: * Acute respiratory infections. ** Pharyngitis, whooping cough (pertussis), coqueluchoid syndrome, pulmonary tuberculosis, acute respiratory failure, glanders, and other conditions.

Source: Prepared by the authors using secondary data from the National Open Data Portal of the Dominican Republic.

In addition, the most affected age group was toddlers (1-2 years) accounting for 26,81% (n=15 212) of the exacerbations, followed by school-age children (6-11 years) with 20,87% (n=11 842), preschoolers (3-5 years) with 2027% (n=11 498), and newborns and young infants (under 1 year) with 19,51% (n=11 071). To a lesser extent, pubescent children (12-14 years) and adolescents (15-18 years) represented 6,84% (n=3880) and 5,69% (n=3231), respectively. Additionally, males were more affected, representing 53,72% (n=30 476), while females accounted for 46,28% (n=26 258) (table 2).

Table 2 - Age groups and sex distribution of patients with respiratory disease exacerbations at Dr. Hugo Mendoza Pediatric Hospital (2017-2022)

Age (years)	Sex	Total cases (n)	% of total	% by sex	2017	2018	2019	2020	2021	2022

< 1	Total	11 071	19,51	-	2486	2368	1292	928	2368	1629
	Female	5145	-	46,47	1105	1094	625	427	1098	796
	Male	5926	-	53,53	1381	1274	667	501	1270	833
1-2	Total	15 212	26,81	-	2635	2484	1664	1612	2990	3827
	Female	6998	-	46,00	1166	1076	773	768	1396	1819
	Male	8214	-	54,00	1469	1408	891	844	1594	2008
3-5	Total	11 498	20,27	-	1825	1916	1383	1089	2163	3122
	Female	5269	-	45,83	803	868	606	493	1007	1492
	Male	6229	-	54,17	1022	1048	777	596	1156	1630
6-11	Total	11 842	20,87	-	1802	1851	1519	1239	2176	3255
	Female	5329	-	45,00	771	824	712	539	955	1528
	Male	6513	-	55,00	1031	1027	807	700	1221	1727
12-14	Total	3880	6,84	-	603	673	454	432	661	1057
	Female	1784	-	45,98	285	315	205	196	296	487
	Male	2096	-	54,02	318	358	249	236	365	570
15-18	Total	3231	5,69	-	391	446	393	417	628	956
	Female	1733	-	53,64	234	255	194	231	342	477
	Male	1498	-	46,36	157	191	199	186	286	479

Source: Prepared by the authors based on secondary data obtained from the National Open Data Portal of the Dominican Republic.

On the other hand, the average concentrations of fine particulate matter ($PM_{2.5}$) and coarse particulate matter (PM_{10}) were highest in 2021, reaching 46.37 $\mu g/m^3$ and 66.24 $\mu g/m^3$ respectively, compared to lower levels in the other years studied (table 3).

Table 3 - Average annual concentration of fine ($PM_{2.5}$) and coarse (PM_{10}) particulate matter in the Dominican Republic (2017-2022)

Year	Fine particulate matter ($PM_{2.5}$) ($\mu g/m^3$)	Coarse particulate matter (PM_{10}) ($\mu g/m^3$)
2017*	45,10	64,43
2018*	43,77	62,52
2019	41,36	59,24
2020	41,53	59,33
2021	46,37	66,24

2022**	41,61	59,30

Note: * Data unavailable for Santiago and San Pedro de Macoris stations. ** The San Pedro de Macoris Station was out of service in mid-2022.

Source: Prepared by the authors based on secondary data obtained from the Environmental Quality Directorate of the Ministry of Environment and Natural Resources of the Dominican Republic.

Likewise, it was determined that for each unit increase in the average concentration of fine particulate matter ($PM_{2.5}$), exacerbations of respiratory diseases increased by 4,7% (95% CI: 4,3%-5,1%) (table 4).

Table 4 - Relationship between the average annual concentration of fine particulate matter ($PM_{2.5}$) and coarse particulate matter matter (PM_{10}), and exacerbations of respiratory diseases at Dr. Hugo Mendoza Pediatric Hospital (2017-2022)

Respiratory exacerbations	IRR*	SE**	*P****	Confidence Interval (95%)
$PM_{2,5}$	1,047	0,002	< 0,001	1,043-1,051
PM_{10}	1,030	0,002	< 0,001	1,027-1,033

Note: * Incidence rate ratio. ** Standard error. *** Statistical significance.

Source: Prepared by the authors based on secondary data obtained from the National Open Data Portal of the Dominican Republic.

Additionally, it was estimated that for each unit increase in the average concentration of coarse particulate matter (PM_{10}), exacerbations of respiratory diseases would increase by 3,01% (95% CI: 2,7%-3,3%).

Discussion

The results of this study indicate that bronchial asthma predominated among respiratory disease exacerbations, with a notable increase in cases in 2022, followed by bronchiolitis and acute tonsillitis. *Young et al*,[9] highlighted that bronchial asthma exacerbations are associated with high concentrations of particulate matter. For their

part, *Zhang et al*[14] documented that $PM_{2.5}$ particles play a significant role in the onset, progression, and worsening of childhood asthma, with exposure contributing to lung inflammation and airway hyperreactivity. Although our study does not establish causality, our results also show that a higher concentration of PM_{10} and $PM_{2.5}$ particles was associated with an increased number of respiratory exacerbations (particularly asthma cases).

Additionally, it was shown that the most affected age group was toddlers (1 to 2 years). Since the classification by age group was based on the developmental and growth stages of children, newborns and infants (under one year of age) would constitute the second most affected group if the age categories were standardized across equal intervals. Furthermore, males were more affected than females. In particular, *Zhang et al*[2] highlighted that $PM_{2.5}$ and PM_{10} have strong effects on male pediatric patients in the age group of 5 to 14.

On the other hand, the average concentrations of fine ($PM_{2.5}$) and coarse (PM_{10}) particulate matter were higher in 2021, while lower levels were recorded in the other years studied. This could partly be attributed to the fact that 254 forest fires occurred in the Dominican Republic in 2021, which affected 48 770 hectares.[15] Likewise, the first Sahara dust cloud reached the country in April 2021 and, by the end of August, led to an unusual increase in temperatures, reaching up to 35ºC.[16,17]

In addition, it was found that for each unit increase in the concentrations of fine particulate matter ($PM_{2.5}$) and coarse particulate matter (PM_{10}), exacerbations of respiratory diseases increase considerably. Likewise, *Remaggi et al*[18] found a significant effect of particulate matter pollution and respiratory emergency care in three communes of Chile. Similarly, *Young et al*[9] confirmed the effects of short- and long-term particulate matter exposure on exacerbations of respiratory diseases.

This study presents several key strengths that reinforce the validity and relevance of the findings. These include its longitudinal design, which facilitates the analysis of trends over time, as well as a rigorous analytical approach, a large and representative sample, and precise statistical methods. However, its limitations include the absence of particulate matter concentration records at the Santiago and San Pedro de Macoris

monitoring stations in 2017 and 2018, as well as the temporary decommissioning of the San Pedro de Macoris station in mid-2022, which may have introduced gaps in the dataset. These factors could impact the accuracy of the observed associations between air pollution levels and respiratory exacerbations. Additional limitations include the lack of continuous monthly particulate matter records, insufficient nationwide monitoring stations, and limited data on indoor pollution by sector.

Conclusions

This research found that the most frequent exacerbated respiratory disease at the Dr. Hugo Mendoza Pediatric Hospital was bronchial asthma, the most affected age group was toddlers, and males were more affected than females. Likewise, a significant association was observed between higher concentrations of fine ($PM_{2.5}$) and coarse (PM_{10}) particulate matter and increased respiratory disease exacerbations.

To better understand the implications of these findings, further research through the use of disaggregated data from pediatric medical centers nationwide is necessary to construct a more comprehensive picture of the effects of air pollution on public health in the Dominican Republic. This would provide stronger evidence supporting the need for stricter air quality control measures.

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Conflict of interests

The authors declare that there is not conflict of interests.

Authors' contribution

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