

The effect of the COVID-19 pandemic on pediatric asthma-related emergency department visits and hospital admissions in Montréal, Quebec: a retrospective cohort study

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Abstract

Background: Asthma is a chronic respiratory condition that affects 10% of Canadian children and is often exacerbated by viral respiratory infections, prompting concerns about the severity of SARS-CoV-2 disease in children with asthma. We compared socio-demographic and clinical characteristics of children presenting to the emergency department and the incidence of these visits, before and during the pandemic.

Methods: We included children aged 0 to 17 years presenting with asthma to 2 tertiary pediatric emergency departments in Montréal, Quebec, between the prepandemic (Jan. 1, 2017, to Mar. 31, 2020) and pandemic (Apr. 1, 2020, to June 30, 2021) periods. We compared the number of emergency department visits and hospital admissions with an interrupted time series analysis and compared the sociodemographic characteristics based on the Canadian Index of Multiple Deprivation (CIMD) and clinical characteristics (including triage level, intensive care admissions, etc.) with Mann–Whitney and χ^2 tests.

Results: We examined 22 746 asthma-related emergency department visits. During the pandemic, a greater proportion of patients presented a triage level 1 or 2 (19.3% v. 14.7%) and were admitted to the intensive care unit (2.5% v. 1.3%). The patients' CIMD quintile distributions did not differ between the 2 periods. We found a 47% decrease (relative risk [RR] 0.53, 95% confidence interval [CI] 0.37 to 0.76) in emergency department visits and a 49% decrease (RR 0.51, 95% CI 0.34 to 0.76) in hospital admissions during the pandemic.

Interpretation: The decrease in asthma-related emergency department visits was observed through the third wave of the pandemic, but children presented with a higher acuity and with no identified sociodemographic changes. Future studies are required to understand individual behaviours that may have led to the increased acuity at presentation observed in this study.

Asthma is a chronic respiratory condition that affects 10% of Canadian children and is often exacerbated by viral respiratory infections,¹ prompting concerns about the severity of COVID-19 in children with asthma. Despite initial concerns that children with asthma would be at risk of severe COVID-19, several studies have since shown that pediatric asthma is not a risk factor for COVID-19 morbidity and death.^{2–8}

Studies in the United States, Japan and Slovenia have reported a decrease in pediatric asthma-related emergency department visits and hospital admissions of 36%–85% during the first wave of the pandemic.^{9–14} Hypothesized drivers of this decrease include decreased asthma triggers during lockdowns, such as decreased circulation of non-SARS-CoV-2 respiratory viruses and outdoor air pollution.^{15–18} However, it is unknown if this lower incidence persisted in the months after the first wave, as in-person schooling resumed and some public health measures were lifted. Pediatric asthma exacerbations typically show biannual peaks in the fall (September) and

spring, thought to be owing to increased transmission of respiratory viruses and pollen exposure.^{19,20} Yet, the effect of the pandemic on those peaks has not been studied.

Disparities in asthma-related morbidity are well established, with patients from lower socioeconomic status being more severely affected.^{21,22} The COVID-19 pandemic has magnified many health inequities in children.^{23–25} However, the studies that reported a decrease in exacerbation during the initial wave of the pandemic did not document whether the pandemic has disparately affected subgroups of Canadian children with asthma (i.e., resulting in increased exacerbations).

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The identification of a subgroup of children who may be at higher risk for asthma exacerbations during the pandemic may inform policies, for instance, prioritization of vaccination.

We analyzed the incidence of asthma-related emergency department visits and hospital admissions by comparing the pre-pandemic (Jan. 1, 2017, to Mar. 31, 2020) and pandemic periods (Apr. 1, 2020, to June 30, 2021, which encompasses the first 3 waves of the pandemic in Quebec²⁶). In addition, we compared the sociodemographic and clinical characteristics of children presenting to 2 pediatric tertiary care emergency departments for asthma during the pre-pandemic and pandemic periods, focusing specifically on an area-level index of deprivation and visit acuity at emergency department presentation and hospital admissions.

We hypothesized that the decreased incidence of emergency department visits and hospital admissions persisted after the first wave of the pandemic, and is consistent with major public health measures that result in limitation of social contacts. Similarly, we expected that the biannual peaks of asthma would be decreased if not absent. We also hypothesized that children from lower socioeconomic neighbourhoods would be disproportionately represented among asthma-related emergency department visits during the pandemic, compared with before the pandemic.

Methods

We conducted a retrospective cohort study of the 2 pediatric tertiary care emergency departments in Montréal (Sainte-Justine Hospital University Centre and the Montreal Children's Hospital). We retrieved data from Jan. 1, 2017, to June 30, 2021. We further defined the pre-pandemic period between Jan. 1, 2017, and Mar. 31, 2020. The pandemic period was therefore set as Apr. 1, 2020, to June 30, 2021. We chose these dates given the declaration of a public health emergency in Quebec on Mar. 13, 2020, which mandated extensive school and daycare closures and resulted in a presumed decrease in the transmission of respiratory viruses.²⁶ In addition, we assumed a lag time of 2 weeks for public health measures to have an effect on asthma exacerbations. This report follows the Strengthening the Reporting of Observational Studies in Epidemiology Statement.²⁷

Participants

We included children aged younger than 18 years with an asthma-related emergency department visit, defined as an emergency department visit with a primary discharge diagnosis of asthma or bronchospasm or with an *International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Canada* (ICD-10-CA) code J45 or ICD-9 code 493. These codes are widely used in other asthma studies using administrative data, and both the principal diagnosis and ICD codes have been validated for identifying acute asthma exacerbations.²⁸ Although not perfect, using ICD codes provides a fair sensitivity and specificity based on a Canadian study.²⁹ In addition, although we acknowledge that a single diagnosis of bronchospasm does not equate to an asthma diagnosis per the

Canadian Pediatric Society guidelines,³⁰ we expect an equal effect on the pre-pandemic and pandemic periods. Children who left the emergency department before being assessed by a physician were excluded from this study as they did not have a discharge diagnosis.

Data sources

We retrieved data from the electronic databases of the 2 participating pediatric emergency departments. Missing variables (i.e., age, sex, length of stay in the emergency department, triage level) were retrieved manually by one of the authors (K.C.) using a standardized study data collection form (form available on request).

Outcomes and variables

Our primary outcome was the monthly number of asthma-related emergency department visits during the study period, which was further divided into the pre-pandemic period (Jan. 1, 2017, to Mar. 31, 2020) and the pandemic period (Apr. 1, 2020, to June 30, 2021). Our secondary outcome was the monthly number of asthma-related hospital admissions during the study period. Admission to the intensive care unit (ICU) was defined as an ICU stay at any time during a hospital admission.

We evaluated the characteristics related to the emergency department visit or hospital admission, including the length of stay in the emergency department, the length of stay of the hospital admission, if applicable, and the triage level at emergency department presentation. A triage level is assigned to each patient based on the Canadian Paediatric Triage and Acuity Scale³¹: level 1 (resuscitation), level 2 (emergent), level 3 (urgent), level 4 (less urgent) and level 5 (nonurgent). Whereas most of these data were extracted from the emergency department electronic databases, we complemented the database with a medical chart review when data were missing for selected patients and variables.

Patient-related characteristics that were collected included age, sex and the patients' 6-character postal code, which was used to derive the Canadian Index of Multiple Deprivation (CIMD).³² The CIMD is an index of deprivation and marginalization and provides a quintile based on the subject's postal code for each of the 4 dimensions of deprivation (residential instability, economic dependency, ethnocultural composition, situational vulnerability). It allows the comparison of measures of social well-being between an individuals' residency area. For each of the 4 dimensions, the first quintile represents the least deprived and the fifth quintile represents the most deprived. To derive the CIMD, the individual's residential 6-character postal code was converted through the Postal Code Conversion File³³ and then mapped to the CIMD.

Statistical analysis

We performed a descriptive analysis of the weekly number of asthma-related emergency department visits and hospital admissions and conducted an uncontrolled interrupted time series analysis to analyze the effect of the pandemic on asthma-related emergency department visits. Specifically, we compared the monthly number of asthma-related emergency department

visits between the prepandemic period and the pandemic period, assuming a level change model and a quasi-Poisson distribution. Furthermore, analyses were adjusted for seasonality through a Fourier term.³⁴ In a sensitivity analysis, we compared the number of asthma-related emergency department visits in the second and third wave of the pandemic to the prepandemic period by excluding the first wave (April–July 2021) in the analysis to show the variable effect of the pandemic through the different waves. Given the distinctive asthma phenotypes between preschool- and school-aged children, we also conducted an analysis stratified by age (≤ 5 yr v. ≥ 6 yr). We performed a similar analysis for asthma-related hospital admissions. We described and compared the visit- and patient-related characteristics using the Mann–Whitney test for continuous data and calculated the differences in proportions for variables with 2 or fewer categories. The 95% confidence intervals (CIs) for differences in medians and proportions are presented for these analyses. We used the χ^2 goodness-of-fit test to compare the distribution of variables with more than 2 categories (statistical significance was set at $p < 0.05$). Analyses were performed with R software version 4.0.5 (www.r-project.org, packages ltmtest and splines).

Ethics approval

The institutional research ethic boards of the Sainte-Justine Hospital University Centre (no. 21-2021-3292) and the Montreal Children’s Hospital (no. 21-2021-7573) approved this study and waived the need for participant consent.

Results

Between Jan. 1, 2017, and June 30, 2021, there were 22 746 asthma-related emergency department visits between the 2 centres, with 19 408 during the prepandemic period and 3338 during the pandemic. Missing variables ($n < 150$ entries) were retrieved manually. The median age of these children

was 2.7 (interquartile range [IQR] 1.7 to 5.0) years and 14 256 (62.7%) were male (Table 1). Most children came from neighbourhoods with high residential instability and more diverse ethnocultural composition (Figure 1 and Appendix 1, available at www.cmajopen.ca/content/11/1/E152/suppl/DC1) and presented with a triage level 3 ($n = 15 990$, 70.3%), representing a serious but non-life-threatening health problem. Throughout the study period, 1939 (8.5%) children presenting to the emergency department for asthma were admitted to the hospital, with 334 (17.3%) requiring admission to the ICU.

Asthma-related emergency department visits and hospital admissions

The observed yearly trends for asthma-related emergency department visits between Jan. 1, 2017, and Mar. 31, 2020, were similar, with biannual peaks in the fall and spring and a decrease in visits from June to August (Figure 2A). Adjusting for seasonality, there was a 47% decrease (relative risk [RR] 0.53, 95% CI 0.37 to 0.76) in the number of asthma-related emergency department visits during the pandemic period compared with the prepandemic period. Two nadirs in emergency department visits were identified, the first from April to June 2020, and the second in January 2021. Whereas the typical peak of asthma emergency department visits in September was nonetheless observed during the pandemic, it is attenuated compared with the peaks from 2017 to 2019 (448 visits in September 2020 v. an average of 637 visits in September from 2017 to 2019). Although asthma-related emergency department visits usually decrease after May and throughout the summer, we observed an increasing trend in emergency department visits through June 2021, with an average increase of 87 visits per month for the period of January to June 2021. In comparison, for the same period during 2017 to 2019, an average decrease of 19 visits per month was observed. The decrease in emergency department visits remained significant

Table 1: Sociodemographic and clinical characteristics of patients presenting to the emergency department for an asthma-related visit for the study period and comparing the prepandemic and pandemic periods

Characteristic	Total Jan. 1, 2017– June 30, 2021 <i>n</i> = 22 746	Prepandemic Jan. 1, 2017– Mar. 31, 2020 <i>n</i> = 19 408	Pandemic Apr. 1, 2020– June 30, 2021 <i>n</i> = 3338	Difference between the time periods (95% CI)
Age, yr, median (IQR)	2.7 (1.7 to 5.0)	2.6 (1.6 to 5.0)	3.1 (1.8 to 5.7)	0.5 (0.3 to 0.7)
Sex, male, no. (%)	14 256 (62.7)	12 085 (62.3)	2171 (65.0)	2.7 (1.0 to 4.5)
Emergency triage level, no. (%)				
1 or 2	3513 (15.4)	2855 (14.7)	658 (19.7)	5.0 (3.5 to 6.5)
3, 4 or 5	19 233 (84.6)	16 553 (85.3)	2680 (80.3)	–
Length of stay in ED, h, median (IQR)	4.8 (3.5 to 6.7)	4.8 (3.5 to 6.8)	4.7 (3.4 to 6.5)	–0.1 (–0.2 to –0.1)
Hospital admission, no. (%)	1939 (8.5)	1667 (8.6)	275 (8.2)	–0.4 (–0.6 to 1.4)
Length of hospital stay, d, median (IQR)	2.0 (1.0 to 3.0)	2.0 (1.0 to 3.0)	2.0 (1.0 to 3.0)	0
Admission to ICU, no. (%)	334 (1.5)	253 (1.3)	84 (2.5)	1.2 (0.6 to 1.8)

Note: CI = confidence interval, ED = emergency department, ICU = intensive care unit, IQR = interquartile range.

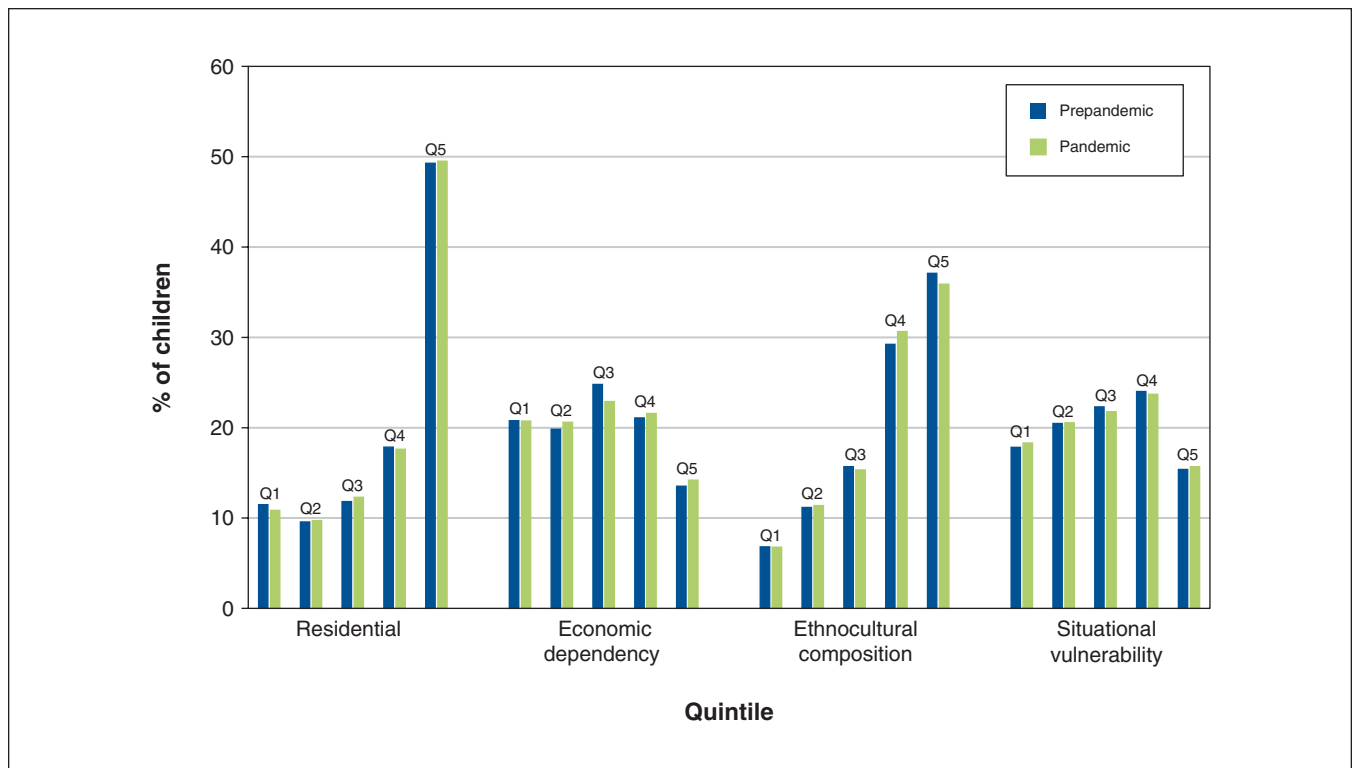


Figure 1: Comparison of the CIMD during the prepandemic and pandemic periods. The distribution of the 4 dimensions of the CIMD did not significantly differ between the prepandemic and the pandemic periods. Note: CIMD = Canadian Index of Multiple Deprivation, Q1 = quintile 1, Q2 = quintile 2, Q3 = quintile 3, Q4 = quintile 4, Q5 = quintile 5.

when we focused only on the second and third wave of the pandemic, with a 35% decrease (RR 0.65, 95% CI 0.48 to 0.87) compared with the prepandemic period. Among children aged 5 years or younger and those 6 years or older, there was a 49% decrease (RR 0.51, 95% CI 0.34 to 0.74) and a 38% decrease (RR 0.62, 95% CI 0.45 to 0.87) in the number of asthma-related emergency department visits during the pandemic, respectively.

Similar trends were observed for asthma-related hospital admissions (Figure 2B). Adjusting for seasonality, there was a 49% decrease (RR 0.51, 95% CI 0.34 to 0.76) in the number of asthma-related hospital admissions during the pandemic period, compared with the prepandemic period (Appendix 2, available at www.cmajopen.ca/content/11/1/E152/suppl/DC1). An increasing trend in hospital admissions through June 2021 was also observed, with an average increase of 8 hospital admissions per month for the period of January to June 2021. In comparison, for the same period during 2017 to 2019, an average decrease of 3 hospital admissions per month was observed. The decrease in hospital admissions remained significant when we focused on the second and third wave of the pandemic, with a 39% decrease (RR 0.61, 95% CI 0.43 to 0.86) compared with the prepandemic period. Among children aged 5 years or younger, there was a 48% decrease (RR 0.52, 95% CI 0.35 to 0.78) in the number of asthma-related hospital admissions during the pandemic. The change was not significant among children aged 6 years or older (33% decrease, RR 0.67, 95% CI 0.42 to 1.10), although the total

number of hospital admissions among this age group was small (389 hospital admissions throughout the study period, with only 75 during the pandemic).

Clinical and patient characteristics before and during the pandemic

There was no difference in the proportion of children requiring hospital admission between the pandemic and the prepandemic periods (difference in proportions of -0.4% , 95% CI -0.6% to 1.4%). A higher proportion of children were admitted to the ICU during the pandemic ($n = 84$, 2.5% pandemic v. $n = 253$, 1.3% prepandemic of all children presenting to the emergency department or 29.7% pandemic v. 15.2% prepandemic of all children who were admitted to the hospital). The median length of stay in the emergency department was only slightly lower during the pandemic (0.1 h) and is likely clinically insignificant.

Compared with the prepandemic period, a slightly higher proportion of males presented to the emergency department during the pandemic period (difference in proportions of 2.7%, 95% CI 1.0% to 4.5%). There was no difference in the CIMD quintile distributions of children presenting before and during the pandemic (Figure 1). A higher proportion of children presented with triage level 1–2 (condition requiring immediate or rapid intervention) during the pandemic ($n = 658$, 19.7% pandemic v. $n = 2855$, 14.7% prepandemic, 95% CI for difference in proportions 3.5% to 6.5%).

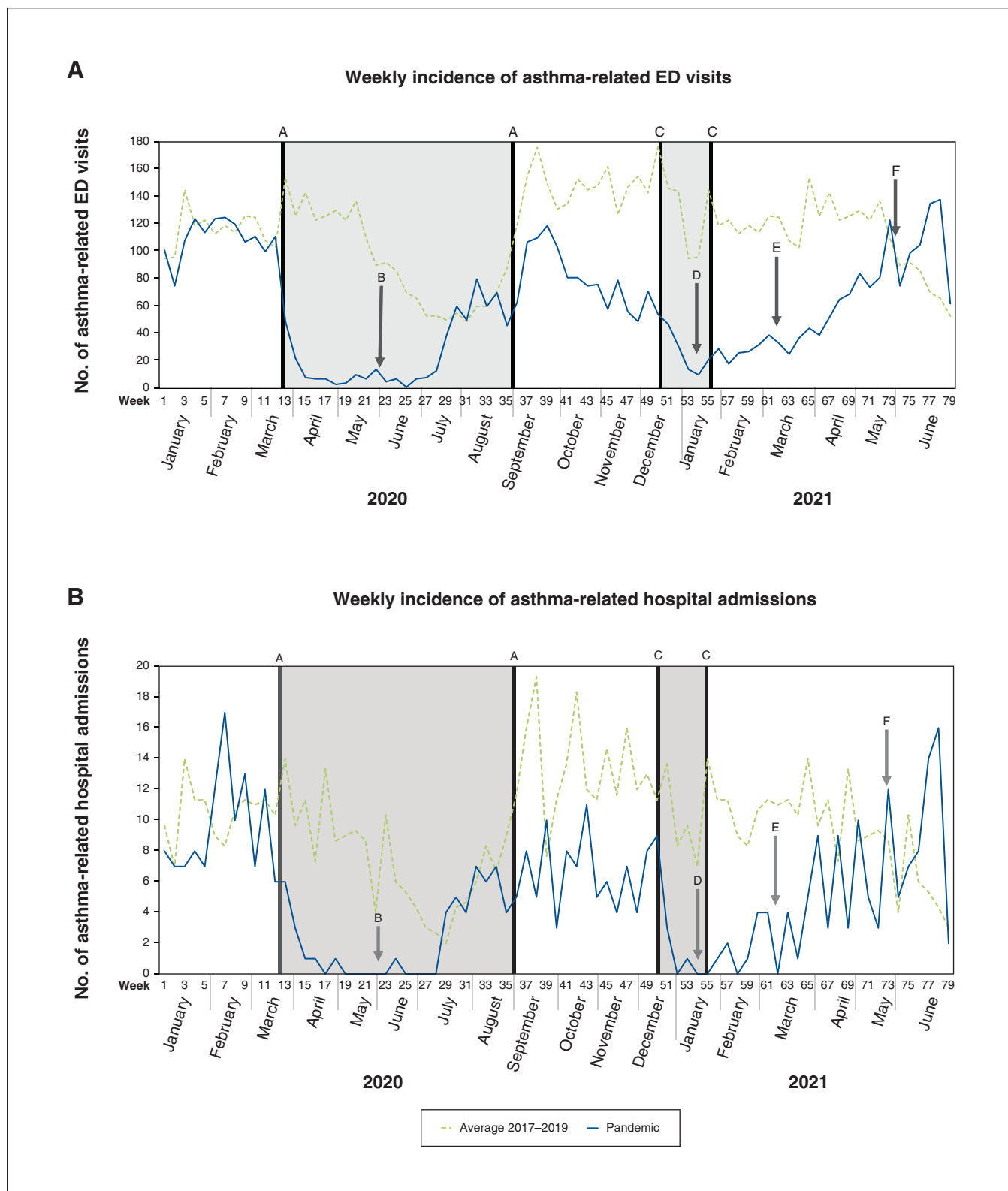


Figure 2: Weekly incidence of asthma-related emergency department visits (A) and of asthma-related hospital admissions (B) during the COVID-19 pandemic (solid line) compared with the average of 2017–2019 (dotted line). (A) Closure of primary schools and high schools (Mar. 13 to Sept. 1, 2020). (B) Opening of daycare services (June 1, 2020). (C) Closure of primary schools and high schools (Dec. 20, 2020, to Jan. 18, 2021) and implementation of mandatory procedural masking at all times in high schools. (D) Procedural masking in primary schools (at all times for grades 5 and 6 and in shared spaces for grades 1–4) (Jan. 11, 2021). (E) Procedural masking in primary schools at all times for grades 1–6 (Mar. 8, 2021). (F) Start of relaxation of public health measures relaxation in Quebec (May 28, 2021).

Interpretation

We documented an overall 47% decrease in asthma-related emergency department visits and a 49% decrease in asthma-related hospital admissions through the third wave of the pandemic compared with the prepandemic period. This decrease was most notable during the initial months of the pandemic and in January 2021, although a steep increase in the number of asthma-related emergency department visits and hospital admissions was observed from January to June 2021.

Asthma-related visits during the pandemic were characterized by more severe clinical acuity and a higher proportion of ICU hospital admissions. The distribution of the index of deprivation among children presenting to the emergency department for asthma did not differ between the prepandemic and pandemic periods, suggesting that prepandemic socio-demographic inequalities did not widen during the pandemic.

The decrease in asthma-related emergency department visits and hospital admissions during the pandemic may be explained by several factors. Public health measures likely led to a decreased transmission of other respiratory viruses, a common trigger of asthma exacerbations. Indeed, data from the Respiratory Virus Detection Surveillance System¹⁵ showed a decrease in the percentage of positive tests for 7 common respiratory viruses in September 2020 compared with prepandemic years for Canada and Quebec. Furthermore, decreased exposures to air pollution, a trigger of asthma exacerbations, may have contributed to the decrease in adverse asthma events. In fact, the city of Montréal reported a 10% improvement in air quality from March to April 2020 compared with the same period in 2017–2019 with important decreases in particulate matter 2.5 and nitrogen dioxide levels,^{16,17} corroborating observations around the world.^{10,18} Finally, families may have an increased threshold for medical consultations during the pandemic and there may have been an increased adherence to asthma controller medication.³⁵ This may be triggered by the fear associated with the potential effect of COVID-19 on children with asthma and a study suggesting that inhaled corticosteroids was associated with reduced angiotensin-converting enzyme 2 messenger RNA expression, the receptor of SARS-CoV-2,^{36,37} although this association remains controversial.³⁸

We observed an increasing trend in the incidence of asthma-related emergency department visits following the nadir in January 2021, culminating with the highest incidence in June 2021 at the end of our study period. Typically, before the pandemic, asthma exacerbations start to decrease in June through the summer months. Interestingly, this surge of asthma exacerbations follows the general relaxation of public health measures in Quebec (reopening of restaurants, indoor and outdoor gatherings allowed) at the end of May 2021 and removal of mandatory masking in school in May 2021. This also coincides with an increase in the number of positive tests for common respiratory viruses in Quebec, particularly for respiratory syncytial virus and parainfluenza.¹⁵ Thus, we hypothesize that the relaxation of public health measures led to increased transmission of common respiratory viruses, which in turn led to increased asthma exacerbations.

Since the effect on asthma-related emergency department visits and hospital admissions is likely multifactorial, we chose not to analyze the effect of individual public health measures on the outcome. However, we identified the timing of the implementation and lifting of key public health measures pertaining to children based on the COVID-19 timeline in Quebec and denoted the dates in Figure 2.²⁶ We observed that changes in the trends in asthma-related emergency department visits and hospital admissions were related to the implementation and lifting of public health measures, particularly those affecting daycares and schools. The drastic decrease in asthma-related emergency department visits and hospital admissions observed between April and June 2020 follows school and daycare closures on Mar. 13, 2020, and a generalized lockdown on Mar. 24, 2020, in Quebec. Subsequently, in July 2020, the weekly incidence of emergency department visits rapidly increased to numbers similar to those seen in 2017–2019. This follows the reopening of daycares in June 2020, and the reopening of restaurants, businesses and gatherings in early July 2020. Quebec schools subsequently reopened for full or partial in-person attendance as of August to September 2020. Interestingly, even during the pandemic, we observed the typical annual peak in asthma-related emergency department visits in September 2020. However, this peak was attenuated compared with the same period prepandemic. Of note, a partial return to school (50% in person) was instituted for children in grades 10 and 11, and mandatory masking in schools was implemented for all children 12 years and older. The second nadir in asthma-related emergency department visits and hospital admissions in January 2021 follows a prolonged closure of primary and secondary schools for the holidays. Although the effect of individual measures is hardly quantifiable, we note a temporal association between pandemic-related public health measures and the incidence of asthma exacerbations. Whereas some of these measures, such as school closures, would not be implementable outside of the pandemic context, other measures such as masking to prevent viral transmission could be considered as a public health strategy for asthma management.

Whereas characteristics of children presenting to the emergency department for asthma were relatively unchanged during the pandemic, we found that children presented with a higher level of acuity and a greater percentage were admitted to the ICU despite an unchanged rate of hospital admissions. The higher presenting acuity was also observed for all-cause emergency department visits.³⁵ Decreased in-person outpatient visits, the temporary suspension of pulmonary function testing and increased parental thresholds for medical consultations, which may all lead to poorer acute and chronic management of asthma, may have contributed to the increased acuity in presentation.³⁵

During the pandemic, children who presented to the emergency department were slightly older (median age of 3.1 yr v. 2.6 yr prepandemic, 95% CI for the difference 0.3 to 0.7 yr). In our analyses stratified by age, we also observed a larger decrease in asthma-related emergency department visits and hospital admissions among children 5 years or

younger. For preschool-aged children, respiratory viruses are the main triggers for asthma exacerbations, and viral respiratory illnesses overall have drastically decreased during the pandemic. Although we do not have school or daycare attendance data, it is possible that while school attendance was mandatory as of September 2020 in Quebec, a higher number of preschool-aged children may have been kept home from daycares, further decreasing their exposure to respiratory viruses. Given these factors, we hypothesize that the pandemic has disproportionately reduced the risk of asthma exacerbations in younger children, which could explain the older age of children presenting to the emergency department during the pandemic.

Based on the multidimensional CIMD, children presenting to the emergency department for asthma pre-pandemic were not different from those presenting during the pandemic. Whereas previous studies did not examine the disparities in the incidence of asthma exacerbations during the pandemic in children with lower socioeconomic status or in minority groups, studies have reported higher COVID-19-related morbidity in minorities.^{23–25,39–41} Suggested mechanisms for these inequalities included differential access to care, increased viral exposure and lower income, which may put these subgroups of children at higher risk of adverse health outcomes.⁴¹ Our findings suggest that the pandemic did not widen existing disparity in children from more deprived neighbourhoods in Montréal with regard to asthma-related emergency department visits and hospital admissions compared with the pre-pandemic period.

Limitations

Our study has noteworthy limitations. First, owing to the retrospective nature of our study, we did not have data on other potential confounding variables such as medication adherence or other patient-level data such as comorbidities. We also did not have environmental data to control for variations in outdoor allergens, another trigger of asthma exacerbations, although the effect of this trigger is modest at the population level.⁴² Second, although we did not have individual-level data on the race or ethnicity of the patient, the CIMD captures multiple dimensions of deprivation at a granular level. In fact, its calculation is based on the 6-digit postal code, and in Quebec, there is on average 39 residents per postal code. Third, our data were restricted to 2 pediatric tertiary care centres in Montréal, Quebec. Although the catchment area of our 2 centres is large, our findings may not be generalizable to children living in nonurban settings or other regions of Quebec and Canada, particularly given region- and province-specific public health measures during the pandemic. Fourth, children who left the emergency department before being assessed by a physician were excluded from this study as they did not have a discharge diagnosis. Finally, although there are national guidelines for the diagnosis of asthma,^{30,43} including in preschoolers, misclassification is possible (e.g., a first episode of wheeze that was labelled as asthma). However, this misclassification would have affected the pre-pandemic and pandemic data equally.

Conclusion

We did not find a difference in the existing overrepresentation of children from more deprived neighbourhoods presenting with asthma exacerbations during the pandemic. We observed a decrease (about 50%) in pediatric asthma-related emergency department visits and hospital admissions over the first 15 months of the pandemic, although the incidence varies with the implementation and relaxation of public health measures. Whereas some measures are exceptional (e.g., school closures), others may be more easily implemented and socially acceptable after the pandemic, such as masking in public spaces when one is symptomatic to limit the transmission of respiratory viruses. This in turn could lead to decreased asthma exacerbations. Further studies should focus on individual behaviours and how these affect the risk of asthma exacerbations.

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