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Examining the effect of the COVID-19 pandemic on community virus prevalence and healthcare utilisation reveals that peaks in asthma, COPD and respiratory tract infection occur with the re-emergence of rhino/enterovirus

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ABSTRACT

Introduction Airway disease exacerbations are cyclical related to respiratory virus prevalence. The COVID-19 pandemic has been associated with reduced exacerbations possibly related to public health measures and their impact on non-COVID-19 respiratory viruses. We aimed to investigate the prevalence of non-COVID-19 respiratory viruses during the pandemic compared with prior in Ontario, Canada and healthcare utilisation related to asthma, chronic obstructive pulmonary disease (COPD) and respiratory tract infection.

Methods This is a population-based retrospective analysis of respiratory virus tests, emergency department (ED) visits and hospitalisations between 2015 and 2021 in Ontario. Weekly virus testing data were used to estimate viral prevalence for all non-COVID-19 respiratory viruses. We plotted the %positivity and observed and expected counts of each virus to visualise the impact of the pandemic. We used Poisson and binomial logistic regression models to estimate the change in %positivity, count of positive viral cases and count of healthcare utilisation during the pandemic.

Results The prevalence of all non-COVID-19 respiratory viruses decreased dramatically during the pandemic compared with prior. Comparing periods, the incidence rate ratio (IRR) for positive cases corresponded to a >90% reduction for non-COVID-19 respiratory viruses except adenovirus and rhino/enterovirus. Asthma-related ED visits and hospital admissions fell by 57% (IRR 0.43 (95% CI 0.37 to 0.48)) and 61% (IRR 0.39 (95% CI 0.33 to 0.46)). COPD-related ED visits and admissions fell by 63% (IRR 0.37 (95% CI 0.30 to 0.45)) and 45% (IRR 0.55 (95% CI 0.48 to 0.62)). Respiratory tract infection ED visits and admissions fell by 85% (IRR 0.15 (95% CI 0.10 to 0.22)), and 85% (IRR 0.15 (95% CI 0.09 to 0.24)). Rather than the usual peaks in disease condition, during the pandemic, healthcare utilisation peaked in October when rhino/enterovirus peaked.

Conclusions The prevalence of nearly all non-COVID-19 respiratory viruses decreased during the pandemic and was associated with marked reductions in ED visits and hospitalisations. The re-emergence of rhino/enterovirus was associated with increased healthcare utilisation.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The COVID-19 pandemic has been associated with a reduced prevalence of non-COVID-19 respiratory viruses as well as a reduced incidence of asthma and chronic obstructive pulmonary disease (COPD) exacerbations requiring healthcare utilisation. Large population-based studies pairing community viral prevalence with common respiratory presentations are lacking.

WHAT THIS STUDY ADDS

⇒ This large population-based retrospective study found a drastic reduction in all non-COVID-19 respiratory viruses aside from rhino/enterovirus, associated with a reduction in emergency department visits and hospitalisations due to asthma, COPD and respiratory tract infection, with a subsequent combined peak of healthcare utilisation occurring in October, that paralleled a rising rhino/enterovirus prevalence.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This is the first study to demonstrate that during the pandemic, increased rhino/enterovirus prevalence, likely related to alleviation of public health measures, may have contributed to a 'rebound' of healthcare utilisation due to asthma, COPD and respiratory tract infection. Going forward, non-COVID-19 respiratory virus patterns may be altered and lead to atypical peaks in respiratory-related healthcare utilisation, which could have implications on the timing of vaccine administration, development of novel vaccines, hospital bed planning and public health policy.

BACKGROUND

Epidemics of airway disease exacerbations follow a cyclic nature related to peaks in respiratory viruses and subsequent respiratory viral infections.[1] Asthma exacerbations in the young peak in September secondary to rhinovirus infections.[2]

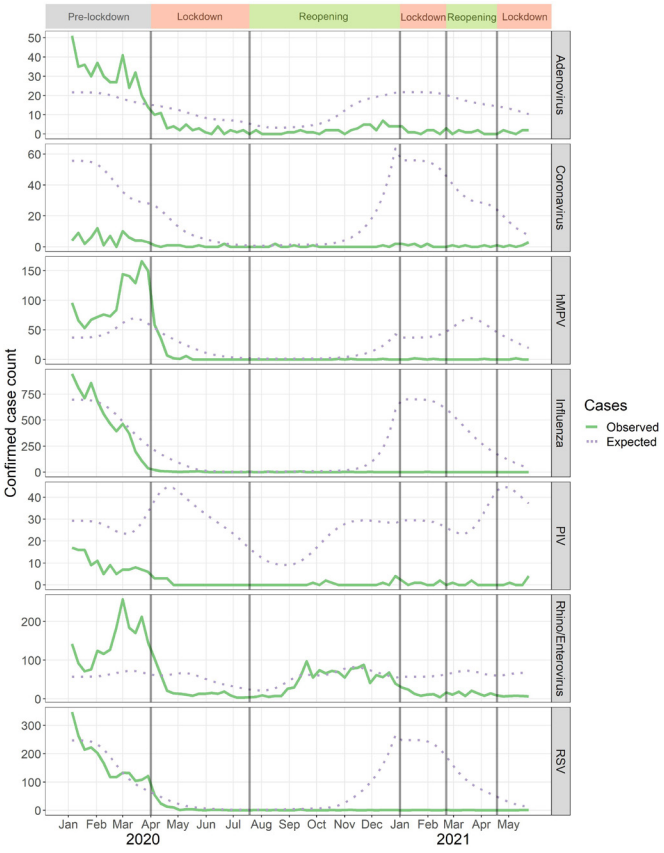

Figure 1 Respiratory virus prevalence by number of positive tests during and prior to the COVID-19 pandemic. hMPV, human metapneumovirus; PIV, parainfluenza; RSV, respiratory syncytial virus.

Influenza, respiratory syncytial virus (RSV) and parainfluenza are responsible for peaks in emergency department (ED) visits seen in December for asthma, chronic obstructive pulmonary disease (COPD) and respiratory tract infections most commonly in older adults.[1]

Currently, we are in the midst of a global pandemic related to SARS-CoV-2. Since the pandemic began, asthma-related and COPD-related ED visits and admissions have fallen ~50%.[3–8] Explanations posited for this observation relate to physical interventions, such as masking and distancing, and other public health measures, and subsequent reductions of non-COVID-19 respiratory virus infections. Lower rates of exacerbation may also be related to interactions between respiratory viruses, improved inhaler adherence, reduced air pollution and reallocation of healthcare resources emphasising telehealth.[8 9]

The current literature has focused predominantly on airway disease related admissions only. A complete estimate of respiratory viral prevalence has been limited and has been only associated with healthcare utilisation in a single study from a small US state.[9] Furthermore, no studies have examined healthcare utilisation for asthma, COPD and respiratory tract infection in the same population, which is particularly important as there may be overlap or misdiagnosis between the conditions. There is a need for a large population-based study to further understand how the COVID-19 pandemic has altered non-COVID-19 respiratory virus prevalence, and subsequent effects on respiratory-related healthcare utilisation. This will build an evidence base for recommending physical measures in the prevention of airways disease exacerbations, and to predict future patterns of healthcare utilisation for the studied respiratory conditions.

The objectives of this study were to investigate the prevalence of non-COVID-19 respiratory viruses during the COVID-19 pandemic compared with prior to the pandemic and to determine if healthcare utilisation related to asthma, COPD and respiratory tract infection was associated with an altered non-COVID-19 respiratory virus prevalence. We hypothesised that in Ontario there would be a lower prevalence of non-COVID-19 respiratory viruses, and that this will have contributed to the reduced healthcare utilisation related to asthma, COPD and respiratory tract infection.

METHODS

Study design and setting

We conducted a population-based retrospective time series analysis of weekly respiratory virus testing results, ED visits and hospitalisations between 26 April 2015 and 1 May 2021 in Ontario, Canada. Ontario is the largest province in Canada by population, with approximately 14 million in 2021 and a population density of 15.9 persons per km^2. The population is 51% female and ethnically diverse, with an average age of 41.8 years.[10] Individuals in Ontario who meet residency requirements are covered by a publicly funded health insurance plan which includes physician services, emergency services, hospital stays, other types of healthcare, and investigations including respiratory virus testing. Administrative data for all hospital admissions and ED presentations for the Ontario population are available for research and evaluation purposes.

Data sources

All data were obtained in aggregated form directly from organisations acting as data curators. Each organisation has standard procedures for data cleaning and quality assurance.

The Respiratory Virus Detection Surveillance System of The Public Health Agency of Canada collects and reports the number of tests performed and the number of tests positive for respiratory viruses from laboratories across Canada. Data for eight viruses (influenza A and B, RSV, parainfluenza, adenovirus, human metapneumovirus (hMPV), human rhino/enterovirus and coronavirus) were collected for the entire study period (2015–2021). We accessed publicly available COVID-19 testing data in Ontario, including the number of tests performed and the number of positive tests from April 2020 until May 2021. Publicly availably quarterly Ontario population estimates were obtained from Statistics Canada.[11]

Weekly aggregated data for all ED visits (National Ambulatory Care Reporting System) and in-patient hospitalisations (Discharge Abstract Database) were obtained from the Canadian Institute for Health Information (CIHI) for calendar years 2015–2021 for Ontario. These data are collected using a standardised protocol for all Ontario hospitals which includes a centralised quality assurance protocol. CIHI is an independent and not-for-profit organisation which provide data and information to study and improve healthcare systems and population health. Data were aggregated by: age groups, primary diagnosis and geographical region. The chronology of public health measures was determined using publicly available data from CIHI.[12] We created a hierarchical public health measure variable that ranged from 0 (fewest public health restrictions) to 3 (greatest public health restrictions) based on closures of schools, indoor dining and non-essential businesses. Closure of any of these settings was scored as 1 point, and the total score was determined by summation of these points.

Table 1 Total number of tests, confirmed cases and per cent positivity by respiratory virus

	Prepandemic (5 years)*			Pandemic†		
Virus	# tests	# positive	% positivity	# tests	# positive	% positivity
Influenza A/B	395 466	54 379	13.8%	52 338	62	0.12%
Respiratory syncytial virus	366 195	19 978	5.5%	51 567	47	0.09%
Parainfluenza	260 818	6816	2.6%	40 825	23	0.06%
Adenovirus	257 295	3345	1.3%	39 773	98	0.25%
Human metapneumovirus	256 201	6211	2.4%	40 803	19	0.05%
Rhino/enterovirus	147 604	15 067	10.2%	40 488	1535	3.79%
Non-COVID-19 coronavirus	112 873	5069	4.5%	25 109	28	0.11%
COVID-19	–	–	–	13 263 201	508 118	3.83%

*Prepandemic period: January 2015–March 2020.
†Pandemic period: April 2020–May 2021.

Analysis

Respiratory virus testing data were visualised by plotting the observed and expected weekly proportion of positive tests and weekly count of positive tests for each virus from 26 April 2015 to 1 May 2021. The expected proportions and counts were produced using Poisson and binominal logistic regression models trained on the prepandemic data from January 2015 to December 2019, controlling for seasonality via restricted cubic splines, changes in population with an offset term and secular trends with a linear term on years since 2015 (model fit metrics summarised in online supplemental table S1). Using similar methods, we additionally plotted the number of ED visits and hospital admissions with a primary diagnosis of asthma (ICD-10-CA (International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Canada): J45, J46) COPD (ICD-10-CA: J40–44 and 47) and respiratory tract infections (ICD-10-CA: J00–J22). The use of ICD codes has been validated for asthma, COPD, respiratory tract infection, as well as COVID-19.[13–16]

The effect of the COVID-19 pandemic on viral testing results and health service use was estimated using an interrupted times series framework with level change only.[17] We analysed a level change only as we expected an immediate and drastic impact of the pandemic on viral testing results and health service use, but had no hypothesis of change in ongoing secular trends, the proper analysis of which will require years more follow-up data. We fit the Poisson models previously described across the entire study period including an indicator variable for the COVID-19 pandemic period (April 2020–May 2021). Autocorrelation and overdispersion were accounted for using heteroskedasticity and autocorrelation-consistent SEs. Seasonality was controlled for with restricted cubic splines as previously. We expressed the change in the rate of positive viral cases and ED visits and hospitalisations observed during the pandemic period in terms of incidence rate ratios (IRR) with 95% CIs.

We also fit binomial logistic regression models to estimate the change in per cent positivity during the pandemic period in terms of ORs. To better quantify the likely impact of the reduction in positive viral cases on ED visits and hospitalisations, we conducted an attribution calculation. The calculation uses the observed and expected viral counts and ED visits and hospital admissions, as well as parameters from the Poisson models, to estimate the proportion of the drop in ED visits and hospital admissions that were attributable to the drop in viral counts. Specifically, we estimated the impact of the drop in influenza cases on COPD ED visits and hospital admissions and the impact of the drop in rhino/enterovirus on asthma ED visits and hospital admissions.

Sensitivity analysis

Using the hierarchical public health measure variable, we examined whether the impact of COVID-19 pandemic period on respiratory viral counts varied by degree of restriction. We also examined whether the impact of the pandemic period on viral

Table 2 Change in count of confirmed cases and per cent positivity during pandemic period* compared with prepandemic period† by respiratory virus

	Confirmed cases	% Positivity
Respiratory virus	IRR (95% CI)	OR (95% CI)
Influenza A/B	0.01 (0.00 to 0.08)	0.02 (0.00 to 0.08)
Respiratory syncytial virus	0.03 (0.00 to 0.28)	0.05 (0.01 to 0.33)
Parainfluenza	0.04 (0.02 to 0.08)	0.03 (0.01 to 0.08)
Adenovirus	0.23 (0.10 to 0.53)	0.20 (0.13 to 0.29)
Human metapneumovirus	0.07 (0.01 to 0.34)	0.06 (0.02 to 0.20)
Rhino/enterovirus	0.52 (0.18 to 1.54)	0.25 (0.13 to 0.45)
Non-COVID-19 coronavirus	0.08 (0.02 to 0.36)	0.09 (0.03 to 0.25)

*Pandemic period: April 2020–May 2021.
†Prepandemic period: January 2015–March 2020.
IRR, incidence rate ratio.

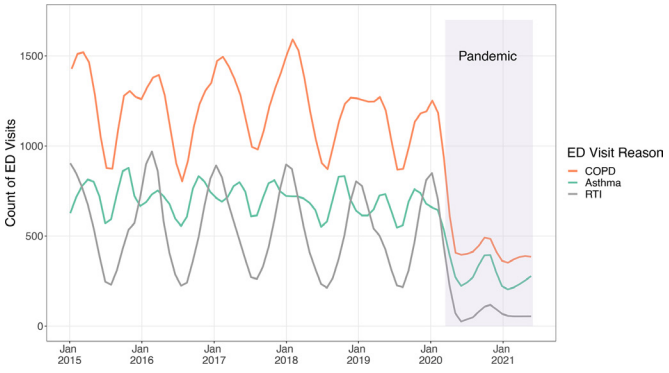

Figure 2 Respiratory-related emergency department (ED) visits during and prior to the COVID-19 pandemic. COPD, chronic obstructive pulmonary disease; RTI, respiratory tract infection.

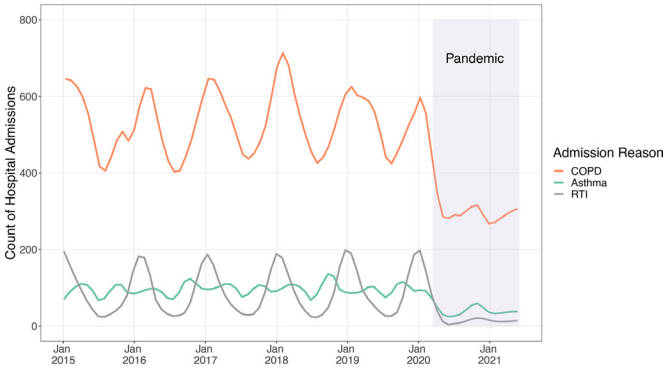

Figure 3 Respiratory-related hospital admissions during and prior to the COVID-19 pandemic. COPD, chronic obstructive pulmonary disease; RTI, respiratory tract infection.

counts varied by region of the province and by children (0–15) vs adults (16 and older).

RESULTS

Prevalence of non-COVID-19 respiratory viruses during the pandemic

The prevalence of all non-COVID19 respiratory viruses decreased dramatically during the pandemic compared with prepandemic periods, when estimated by either percent positivity (online supplemental figure S1) or number of positive tests (figure 1; table 1). Model estimates demonstrate that positive cases for influenza (IRR 0.01 (95% CI 0.00 to 0.08)), RSV (IRR 0.03 (95% CI 0.00 to 0.28)), parainfluenza (IRR 0.04 (95% CI 0.02 to 0.08)), hMPV (IRR 0.07 (95% CI 0.01 to 0.34)) and coronavirus (IRR 0.08 (95% CI 0.02 to 0.36)) were nearly eliminated during the pandemic period (table 2). Rates of adenovirus were greatly reduced (IRR 0.23 (95% CI 0.10 to 0.53)). Interestingly, positive rhino/enterovirus cases decreased by the least amount (IRR 0.52 (95% CI 0.18 to 1.54)), a reduction which did not reach statistical significance. Furthermore, unlike other non-COVID-19 respiratory viruses, rhino/enterovirus appeared to maintain its seasonal pattern (online supplemental figure S1).

Using the hierarchical public health measure variable, we found that most non-COVID-19 respiratory viruses continued to have low prevalence regardless of the degree of public health restrictions compared with prepandemic periods. Rhino/enterovirus was the sole virus that did not follow this pattern, and in fact demonstrated an incidence rate as high as 71% (least restrictive period) and as low as 15% (most restrictive period) compared with prepandemic periods (online supplemental table S2).

Analysing by regions within Ontario demonstrated variation in the effect that the pandemic had on non-COVID-19 respiratory virus prevalence. In some cases, including influenza, RSV, parainfluenza and non-COVID-19 coronavirus viral prevalence was significantly reduced among all regions compared with prepandemic periods. On the other hand, adenovirus, hMPV and rhino/enterovirus demonstrated variability from region to region, being most concentrated in the North. Unfortunately, due to prepandemic testing for rhino/enterovirus and non-COVID-19 coronavirus was sparse in the North and Waterloo-Hamilton-Niagara regions, which complicates interpretation of the seemingly elevated IRRs (online supplemental table S3).

Table 3 Change in counts of asthma/COPD/respiratory tract infection-related emergency department visits and hospital admissions during the pandemic period* compared with the prepandemic period†

Outcome	IRR (95% CI)
Emergency department visit	
Asthma	0.43 (0.37 to 0.48)
COPD	0.37 (0.30 to 0.45)
Respiratory tract infection	0.15 (0.10 to 0.22)
Hospital admission	
Asthma	0.39 (0.33 to 0.46)
COPD	0.55 (0.48 to 0.62)
Respiratory tract infection	0.15 (0.09 to 0.24)

*Pandemic period: April 2020–May 2021.
†Prepandemic period: January 2015–March 2020.
COPD, chronic obstructive pulmonary disease; IRR, incidence rate ratio.

Effect of the pandemic on asthma, COPD and respiratory tract infection healthcare utilisation

Compared with the prepandemic period, ED visits and hospital admissions related to asthma, COPD and respiratory tract infection were reduced (figures 2 and 3). Asthma-related ED visits and hospital admissions fell by 57% (IRR 0.37 (95% CI 0.33 to 0.48)) and 61% (IRR 0.39 (95% CI 0.33 to 0.46)), respectively. COPD-related ED visits fell by 63% (IRR 0.37 (95% CI 0.30 to 0.45)), and hospital admissions by 45% (IRR 0.55 (95% CI 0.48 to 0.62)). Finally, respiratory tract infection had the greatest reduction, with ED visits decreased by 85% (IRR 0.15 (95% CI 0.10 to 0.22)) and hospitalisations by 85% (IRR 0.15 (95% CI 0.09 to 0.24)) (table 3). Of note, rather than the usual and distinct peaks in disease condition (asthma exacerbations occurring in September, and COPD exacerbations and respiratory tract infection occurring in January), during the pandemic, the greatest number of hospital visits for all three conditions occurred in October, during a period when public health measures were relaxed in Ontario.

As there were reductions noted for all non-COVID-19 respiratory viruses, an estimate for the reduction in healthcare utilisation attributable to influenza A/B, RSV and parainfluenza for COPD and respiratory tract infection, and rhino/enterovirus for Asthma was calculated, given that community peaks of these viruses are reliably associated with disease-related ED visits and admissions year after year. The attributable reduction in COPD ED visits and hospital admissions related to influenza during the pandemic, were 13.1% and 14.6%, respectively. For RSV, the attributable reduction in respiratory tract infection ED visits and hospitalisations during the pandemic were 27.6% and 10.7%, respectively. For rhino/enterovirus, the attributable reduction in asthma ED visits and hospitalisations during the pandemic were 7.5% and 8.4%, respectively (data for all viruses of interest presented in table 4; full calculation available in online supplemental tables S4A–D).

Respiratory viral prevalence and their impact are known to differ between children and adults . Therefore, we compared ED visits and hospital admission for asthma and respiratory tract infection between children (0–15) and adults (16 and older). We found an overall greater reduction in healthcare utilisation in children as compared with adults. As compared with adults, children exhibited a greater reduction in asthma-related ED visits (IRR 0.25 (95% CI 0.19 to 0.33) vs IRR 0.51 (95% CI 0.46 to 0.57) and hospitalisations (IRR 0.25 (95% CI 0.17 to 0.36) vs 0.56 (95% CI 0.50 to 0.61)), as well as for respiratory tract infection-related ED visits (IRR 0.09 (95% CI 0.05 to 0.15)

Table 4 Change in healthcare utilisation attributable to specific viruses and diseases

Outcome	Influenza A/B	Respiratory syncytial virus	Parainfluenza	Rhino/enterovirus
COPD ED visits	13.1%	3.5%	8.5%	
COPD admissions	14.6%	6.4%	9.4%	
Respiratory tract infection ED visits	9.7%	27.6%	8.1%	
Respiratory tract infection admissions	0.7%	10.7%	0.5%	
Asthma ED visits				7.5%
Asthma admissions				8.4%

COPD, chronic obstructive pulmonary disease; ED, emergency department.

vs IRR 0.20 (95% CI 0.15 to 0.27)) and hospitalisations (IRR 0.09 (95% CI 0.05 to 0.17) vs IRR 0.38 (95% CI 0.32 to 0.45) (summarised in online supplemental table S5). Interestingly, the peaks of highest incidence were similar between age groups, and did not coincide with the first return to school in January 2021 (online supplemental figures S2 and S3).

DISCUSSION

In this study, we demonstrate that, during the first year of the COVID-19 pandemic, there was a drastic reduction in all non-COVID-19 respiratory viruses aside from rhino/enterovirus, associated with a reduction in ED visits and hospitalisations due to asthma, COPD and respiratory tract infection, with a combined peak of healthcare utilisation occurring in October, rather than in the usual condition-specific seasonal manner. This unified peak was associated with a peak in rhino/enterovirus.

While the prevalence of non-COVID-19 respiratory viruses has been reported within Canada during the pandemic,[18] this is the first study to pair population-level reporting of non-COVID-19 respiratory viruses in a large region during the pandemic with healthcare utilisation. Viral prevalence data revealed that rhino/enterovirus was the sole virus to avoid near-complete suppression, suggesting that the COVID-19 virus itself, subsequent effects on the environment (eg, air quality) and/or related public health measures contributed to reduced non-COVID-19 respiratory virus prevalence, but were less influential in the case of rhino/enterovirus, which remained communicable in the community. In addition, this family of viruses was the non-COVID respiratory virus most affected by the degree of public health restrictions. National community viral surveillance studies of Canada[18] and the USA[19] showed similar initial similar suppression of non-COVID-19 respiratory viruses, though the Canadian study did not demonstrate a significant reduction in rhino/enterovirus during the pandemic compared with previous years, and the US study demonstrated an earlier rebound in most non-COVID-19 respiratory viruses, many to prepandemic levels. Differences in rates may have been related to variability in public health measures between provinces and countries.

This study, including healthcare utilisation data for three common conditions closely associated with respiratory viruses, found reductions in ED visits and hospitalisations for all three conditions, most apparent for respiratory tract infection. Most interestingly, rather than maintaining condition-specific seasonal peaks, all three conditions shared a peak, occurring in October. In the setting of reduced non-COVID-19 respiratory viruses, we estimated that prior to the pandemic approximately 15% of COPD exacerbations could be attributed to influenza, more than one-quarter of respiratory tract infection ED visits could be attributed to by RSV, and nearly 8% of asthma exacerbation could be attributed to rhino/enterovirus. Finally, analysing based on age revealed that reductions in asthma-related and respiratory tract infection-related events were greater in children than adults. While the degree of reduction in asthma-related and COPD-related events we observed were similar to previously published literature, our study demonstrated a significantly greater reduction in non-COVID-19 respiratory tract infection compared with a previous ED-based study,[5] as well as a national US study.[20] Other studies that examined viral prevalence and healthcare utilisation for asthma or COPD during the pandemic focused on smaller populations, a single non-COVID-19 respiratory virus with testing of individuals only during hospitalisation, or without examination of temporal trends for individual viruses.[3 4 9 21–23] These studies found a 48%–73% reduction in influenza prevalence. A study of children admitted to hospital for respiratory tract infection found a subtle reduction in the prevalence of most non-COVID-19 respiratory viruses, but an increase in rhino/enterovirus.[22]

The initial suppression of rhino/enterovirus followed by increasing prevalence during the pandemic has been previously noted and summarised recently. This phenomenon is potentially related to the non-enveloped structure of this virus.[24] In Ontario, rhino/enterovirus behaved similarly, being the first non-COVID-19 respiratory virus to re-emerge after public health measures were relieved, which was associated with a peak in ED visits and hospital admissions for all three conditions. While rhino/enterovirus is considered to be responsible for the 'September epidemic' for asthma-related healthcare utilisation[2] the change in viral patterns associated with the COVID-19 pandemic implicates it for changes in healthcare utilisation patterns in COPD and respiratory tract infection. The postpandemic impact of rhino/enterovirus on respiratory tract infection includes an increased number of ED visits due to this virus in the USA, and hospitalisations in China[25] and South Korea.[26] However, to our knowledge, rhino/enterovirus has not yet been implicated in COPD-related healthcare utilisation.

The main strength of this study is the use of community surveillance viral testing in a large population and pairing that with healthcare utilisation for three common respiratory conditions. This allowed us to demonstrate that rhino/enterovirus prevalence increased in October 2021, which was associated with increased healthcare utilisation for asthma, COPD and respiratory tract infection. There are several limitations to this study. With the use of administrative databases, we were not able to collect baseline characteristics for individual patients, nor confirm that they have asthma or COPD. However, a similarly sampled data set from prepandemic periods showed peaks in the three conditions that were distinct from each other. It was beyond the scope of this study to characterise individuals' behavioural changes related to the pandemic, which may have affected presentation for virus testing. A proportion of individuals may be more prone to present for testing, while others may be less prone, and therefore, it is unclear how behaviours might

change the number or percent of positive tests. Still, we believe that this is the best estimate for viral prevalence, and are reassured that there were a similar number of viral tests completed during the first year of the COVID-19 pandemic compared with the preceding years. Furthermore, the nature of the study does not allow us to comment on the mechanism (eg, viral interference, public health measures) by which non-COVID-19 respiratory viruses are suppressed. That being said, rhino/enterovirus did show increasing prevalence with lower degrees of public health related restrictions. Finally, this is a study of Ontario, Canada and the findings may not be completely generalisable to other regions or countries. However, our viral prevalence data, including the re-emergence of rhino/enterovirus, mirror findings from studies of other regions, which suggests that the effect on respiratory-related healthcare utilisation may have also occurred elsewhere.

CONCLUSIONS

This study confirmed associations between the COVID-19 pandemic, non-COVID-19 respiratory virus prevalence and healthcare utilisation in a large population in Canada. Closely examining healthcare utilisation revealed a new, shared peak for asthma, COPD and respiratory tract infection, which is associated with the re-emergence of rhino/enterovirus.

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Contributors TH, NR, ML and NJ conceived of and designed the study. AS extracted the data. TH and AJ analysed the data. TH and AJ wrote the manuscript. TH, AJ, NR, ML and NJ edited the manuscript. Acting as the guarantor, TH accepts full responsibility for the work and/or the conduct of the study, had access to the data, and controlled the decision to publish. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Patient consent for publication Not applicable.

Ethics approval This study received ethical approval from the Hamilton Integrated Research Ethics Board (Project #13734).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. The protocol and analytical code are available on request. Part of the data (respiratory viral surveillance) is publicly available. The rest cannot be shared publicly due to privacy considerations but is available on request from the Canadian Institute for Health Information and the Public Health Agency of Canada.

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Table S1: Model fit metrics

Model 1: Respiratory virus incidence (Table 2)				
Outcome	**AIC**	**Null Deviance**	**Residual Deviance**	**DF**
Influenza A/B	17826	120197	16219	320
Respiratory syncytial virus	5957	37507	4522	320
Parainfluenza	3103	5917	1723	320
Adenovirus	2472	3042	1239	320
Human metapneumovirus	3729	10471	2596	320
Rhino/enterovirus	12078	13005	10269	320
Non-COVID coronavirus	6693	14135	5745	320
Model 2: Respiratory virus positivity (Table 2)				
Outcome	**AIC**	**Null Deviance**	**Residual Deviance**	**DF**
Influenza A/B	10809	60093	9229	320
Respiratory syncytial virus	4324	18442	2899	320
Parainfluenza	3009	6435	1638	320
Adenovirus	1969	1680	739	320
Human metapneumovirus	2431	5459	1304	320
Rhino/enterovirus	4292	12700	2534	320
Non-COVID coronavirus	2778	7111	1839	320
Model 3: Respiratory-related ED visits and hospital admissions (Table 3)				
Outcome	**AIC**	**Null Deviance**	**Residual Deviance**	**DF**
Asthma ED	1783	28039	3016	320
Asthma Hospital Admission	2931	4670	833	320
COPD ED	10118	61476	7171	320
COPD Hospital Admission	5129	13382	2434	320
Respiratory Tract Infection ED	7243	68932	4657	320
Respiratory Tract Infection Hospital Admission	3306	17432	1353	320

Table S2: Change in count of confirmed viral cases during the COVID-19 pandemic by strength of public health measures

	Public Health Measures[1]			
	0 (least)	**1**	**2**	**3 (most)**
Respiratory Virus	**IRR (95% CI)**	**IRR (95% CI)**	**IRR (95% CI)**	**IRR (95% CI)**
Influenza A/B	0.01 (0.00, 0.03)	0.01 (0.00, 0.14)	0.01 (0.00, 0.08)	0.04 (0.01, 0.14)
Respiratory syncytial virus	0.01 (0.00, 0.02)	0.01 (0.00, 0.11)	0.01 (0.00, 0.07)	0.04 (0.01, 0.18)
Parainfluenza	0.03 (0.02, 0.05)	0.03 (0.01, 0.19)	0.04 (0.01, 0.22)	0.06 (0.03, 0.13)
Adenovirus	0.21 (0.08, 0.53)	0.10 (0.04, 0.27)	0.19 (0.07, 0.51)	0.22 (0.07, 0.57)
Human metapneumovirus	0.01 (0.00, 0.03)	0.01 (0.00, 0.02)	0.01 (0.00, 0.02)	0.07 (0.02, 0.67)
Rhino/enterovirus	0.71 (0.24, 2.11)	0.26 (0.09, 0.74)	0.31 (0.11, 0.91)	0.15 (0.05, 0.40)
Non-COVID coronavirus	0.04 (0.01, 0.18)	0.05 (0.00, 0.88)	0.09 (0.02, 0.48)	0.15 (0.04, 0.53)

1. Based on mandated closures of public schools, indoor dining, and non-essential businesses.

Table S3. Change in count of confirmed cases and percent positivity by region during pandemic period compared to pre-pandemic period by respiratory virus

	Central	**East**	**GTA**	**North**	**Southwest**	**WHN**
	Confirmed Cases	**Confirmed Cases**	**Confirmed Cases**	**Confirmed Cases**	**Confirmed Cases**	**Confirmed Cases**
Respiratory Virus	**IRR (95% CI)**	**IRR (95% CI)**	**IRR (95% CI)**	**IRR (95% CI)**	**IRR (95% CI)**	**IRR (95% CI)**
Influenza A/B	0.00 (0.00, 0.01)	0.06 (0.06, 0.13)	0.00 (0.00, 0.00)	0.00 (0.00, 0.02)	0.01 (0.01, 0.02)	0.00 (0.00, 0.02)
Respiratory syncytial virus	0.01 (0.01, 0.03)	0.05 (0.05, 0.11)	0.02 (0.02, 0.04)	0.12 (0.12, 0.36)	0.01 (0.01, 0.02)	0.08 (0.08, 0.24)
Parainfluenza	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.06 (0.06, 0.10)	0.02 (0.02, 0.15)	0.02 (0.02, 0.14)	0.05 (0.05, 0.14)
Adenovirus	0.03 (0.03, 0.14)	0.41 (0.41, 0.64)	0.18 (0.18, 0.28)	0.53 (0.53, 0.91)	0.09 (0.09, 0.23)	0.44 (0.44, 0.74)
Human metapneumovirus	0.02 (0.02, 0.16)	0.12 (0.12, 0.37)	0.03 (0.03, 0.08)	0.31 (0.31, 0.96)	0.07 (0.07, 0.28)	0.08 (0.08, 0.43)
Rhino/enterovirus	0.20 (0.20, 0.37)	0.75 (0.75, 1.08)	0.18 (0.18, 0.27)	2.21 (2.21, 3.67)	0.30 (0.30, 0.49)	1.72 (1.72, 3.05)
Non-COVID coronavirus	0.00 (0.00, 0.00)	0.16 (0.16, 0.49)	0.08 (0.08, 0.16)	0.00 (0.00, 0.00)	0.11 (0.11, 0.36)	0.00 (0.00, 0.00)

1. Pandemic period: April 2020 to May 2021
2. Pre-pandemic period: January 2015 to March 2020

GTA, greater Toronto area. WHN, Waterloo-Hamilton-Niagara.

Table S4A. Full calculation of the change in healthcare attributable to influenza.

Measure	Influenza			
	COPD ED	**COPD Admission**	**Respiratory Tract Infection ED**	**Respiratory Tract Infection Admission**
Expected viral counts	9,523	9,523	9,523	9,523
Actual viral counts	102	102	102	102
Expected outcome cases based on expected viral count	5,580	2,057	2,371	162
Expected outcome cases based on actual viral count	60	22	25	2
Difference in expected in number of outcomes based on drop in viral counts	5,521	2,035	2,346	160
Expected number of outcomes	66,819	31,530	28,474	28,474
Actual number of outcomes	24,677	17,547	4,174	4,174
Difference between expected and actual number of outcomes	42,142	13,983	24,300	24,300
% difference between expected and actual outcomes attributed to drop in viral counts	13.1%	14.6%	9.7%	0.7%

1. All expected and actual counts cover the period April 1 2020 to May 29 2021

Table S4B. Full calculation of the change in healthcare attributable to RSV.

	RSV			
Measure	**COPD ED**	**COPD Admission**	**Respiratory Tract Infection ED**	**Respiratory Tract Infection Admission**
Expected viral counts	4,110	4,110	4,110	4,110
Actual viral counts	139	139	139	139
Expected outcome cases based on expected viral count	1,512	925	6,946	2,684
Expected outcome cases based on actual viral count	51	31	235	91
Difference in expected in number of outcomes based on drop in viral counts	1,461	893	6,711	2,593
Expected number of outcomes	66,819	31,530	28,474	28,474
Actual number of outcomes	24,677	17,547	4,174	4,174
Difference between expected and actual number of outcomes	42,142	13,983	24,300	24,300
% difference between expected and actual outcomes attributed to drop in viral counts	3.5%	6.4%	27.6%	10.7%

1. All expected and actual counts cover the period April 1 2020 to May 29 2021

Table S4C. Full calculation of the change in healthcare attributable to parainfluenza.

	Parainfluenza			
Measure	**COPD ED**	**COPD Admission**	**Respiratory Tract Infection ED**	**Respiratory Tract Infection Admission**
Expected viral counts	755	755	755	755
Actual viral counts	32	32	32	32
Expected outcome cases based on expected viral count	3,752	1,374	2,054	138
Expected outcome cases based on actual viral count	159	58	87	6
Difference in expected in number of outcomes based on drop in viral counts	3,593	1,316	1,967	132
Expected number of outcomes	66,819	31,530	28,474	28,474
Actual number of outcomes	24,677	17,547	4,174	4,174
Difference between expected and actual number of outcomes	42,142	13,983	24,300	24,300
% difference between expected and actual outcomes attributed to drop in viral counts	8.5%	9.4%	8.1%	0.5%

1. All expected and actual counts cover the period April 1 2020 to May 29 2021

Table S4D. Full calculation of the change in healthcare attributable to rhino/enterovirus.

	Rhino/Enterovirus	
Measure	**Asthma ED**	**Asthma Admission**
Expected viral counts	3,439	3,439
Actual viral counts	1,722	1,722
Expected outcome cases based on expected viral count	3,370	604
Expected outcome cases based on actual viral count	1,688	303
Difference in expected in number of outcomes based on drop in viral counts	1,683	302
Expected number of outcomes	39,028	5,867
Actual number of outcomes	16,498	2,275
Difference between expected and actual number of outcomes	22,530	3,592
% difference between expected and actual outcomes attributed to drop in viral counts	7.5%	8.4%

1. All expected and actual counts cover the period April 1 2020 to May 29 2021

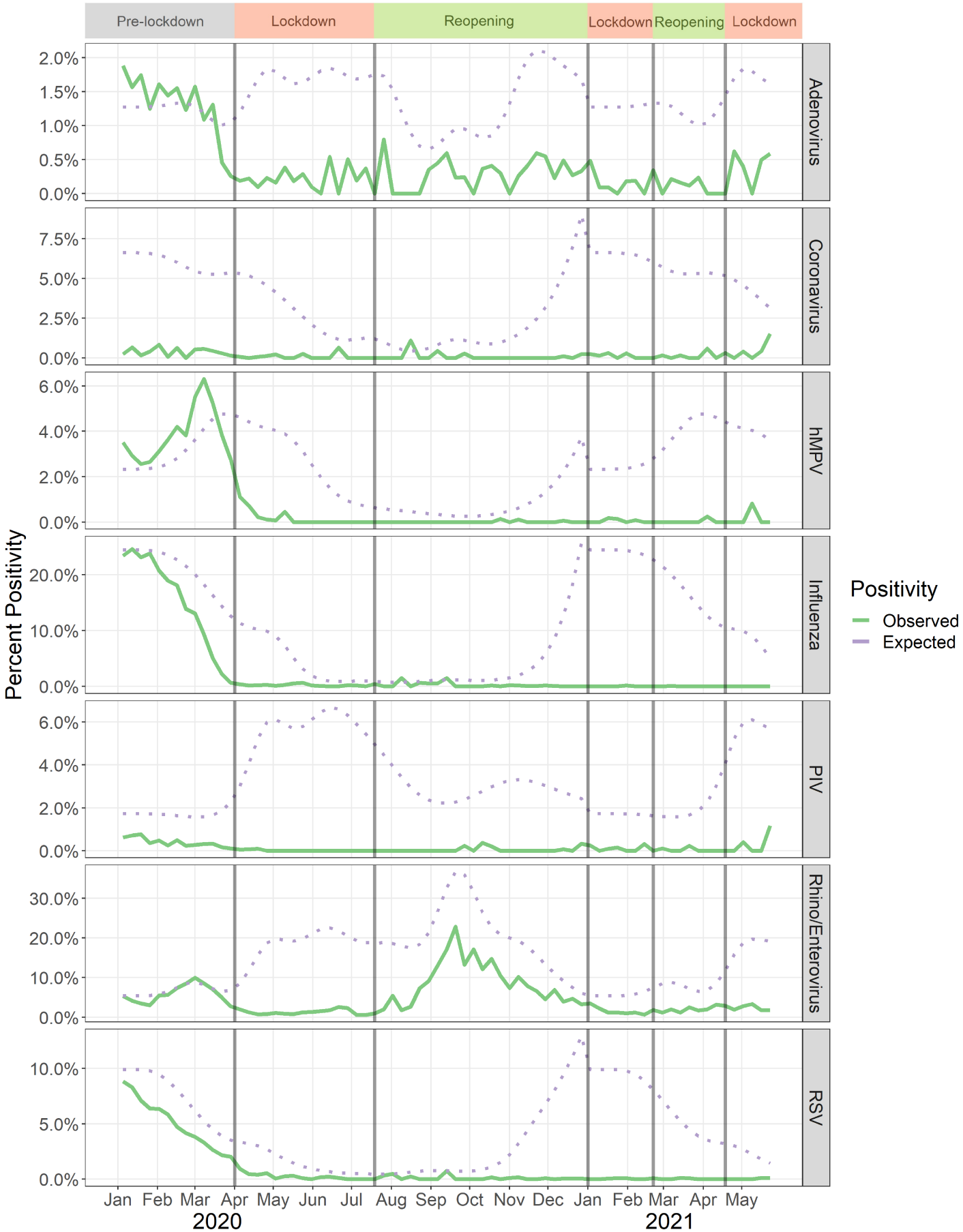
Table S5. Change in count Asthma/COPD/Respiratory Tract Infection-related emergency department visits and hospital admissions during the pandemic period compared to the pre-pandemic period, by age group

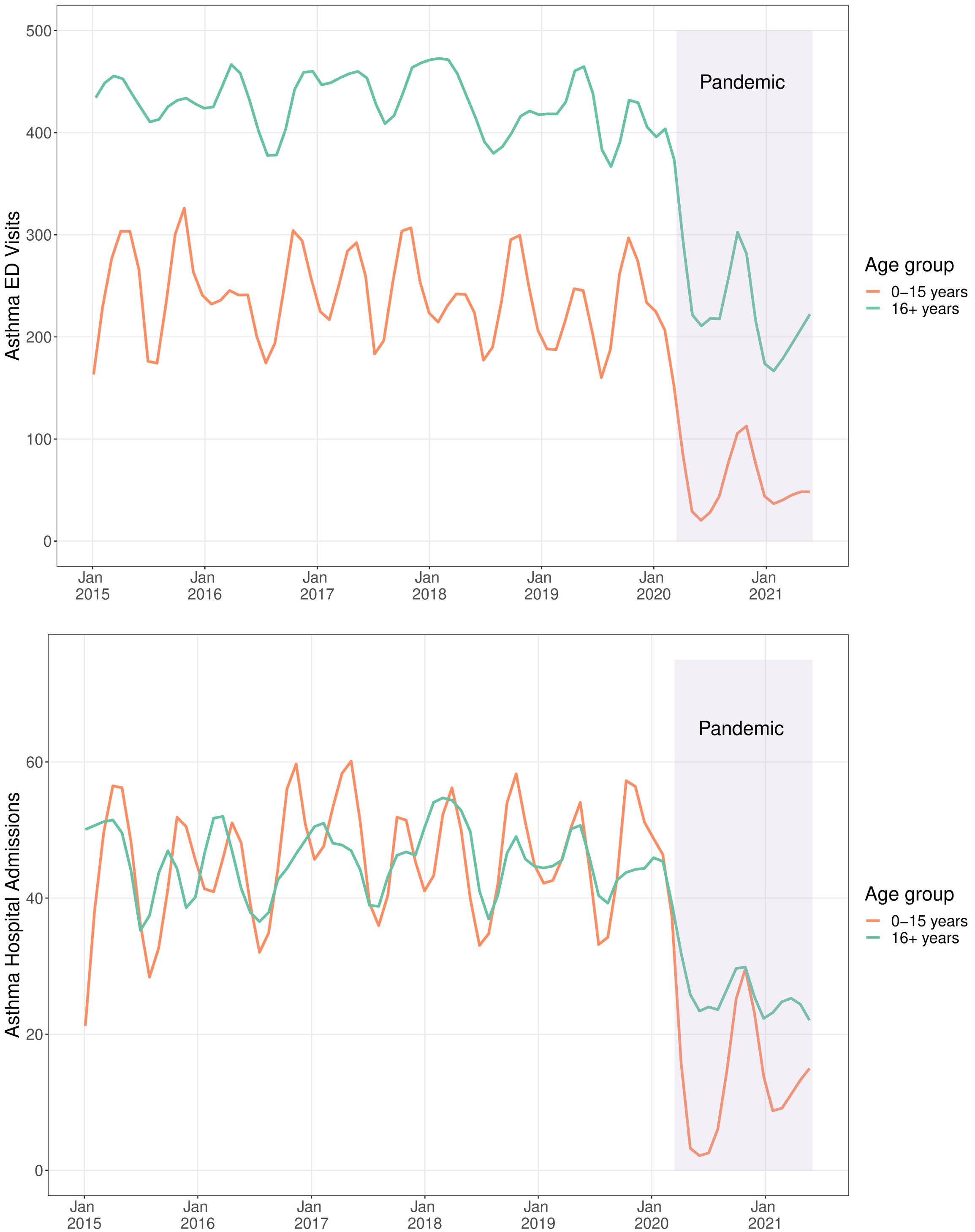
	0-15 years	16+ years
Outcome	**IRR (95% CI)**	**IRR (95% CI)**
Emergency Department Visit		
Asthma	0.25 (0.19, 0.33)	0.51 (0.46, 0.57)
Respiratory tract infection	0.09 (0.05, 0.15)	0.20 (0.15, 0.27)
Hospital Admission		
Asthma	0.25 (0.17, 0.36)	0.56 (0.50, 0.61)
Respiratory tract infection	0.09 (0.05, 0.17)	0.38 (0.32, 0.45)

1. Pandemic period: April 2020 to May 2021

2. Pre-pandemic period: January 2015 to March 2020

COPD, chronic obstructive pulmonary disease.


Pre-lockdown
Lockdown
Reopening
Lockdown
Reopening
Lockdown
Adenovirus
Coronavirus
hMPV
Influenza
PIV
Rhino/Enterovirus
RSV
Percent Positivity
Positivity
Observed
Expected
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
2020
2021


Asthma ED Visits
500
400
300
200
100
0
Pandemic
Jan 2015
Jan 2016
Jan 2017
Jan 2018
Jan 2019
Jan 2020
Jan 2021
Age group
0–15 years
16+ years
Asthma Hospital Admissions
60
40
20
0
Pandemic
Jan 2015
Jan 2016
Jan 2017
Jan 2018
Jan 2019
Jan 2020
Jan 2021
Age group
0–15 years
16+ years