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Evaluating the impact of coronavirus disease 2019 on asthma morbidity

A comprehensive analysis of potential influencing factors

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ABSTRACT

Background: The coronavirus disease 2019 (COVID-19) pandemic period is experiencing better asthma control, fewer exacerbations, and health care utilization, with limited data on factors that could explain this phenomenon.
Objective: To confirm these improved asthma outcomes during COVID-19 and evaluate potential contributing factors.
Methods: In 18,912 pediatric patients with asthma treated in the Children's Hospital of Orange County network from 2017 to 2020, monthly asthma-related encounters and medication summaries were extracted from electronic health records, particulate matter 2.5 ($PM_{2.5}$) air pollution from the California Air Resources Board, and influenza-like illness from Illness Surveillance Network for the first 6 months of each year. Changes in outcomes between January to March and April to June (post−COVID-19 shutdown in 2020) were compared with historical data using generalized estimating equations analyses for patient outcomes and generalized linear models for pollution exceedance, influenza-positive, and telehealth visit rates.
Results: During COVID-19, we found 78%, 90%, 68% reductions in hospitalization, emergency department visits, and exacerbations, respectively, compared with pre−COVID-19 2020, with significantly greater changes than the same time period of 2017 to 2019 and significant reductions in albuterol and inhaled corticosteroid use ($P < .05$). Emergency department visit reduction was not seen for African Americans. The $PM_{2.5}$ and influenza rates were also significantly reduced during COVID-19 ($P < .05$). Increased rates in telehealth visits were greater in the publicly insured group when compared with commercially insured.
Conclusion: Our data confirm reduced health care utilization and suggest better asthma control during COVID-19, except for African Americans. This was associated with a significant increase in telehealth visits and reductions in $PM_{2.5}$ and influenza infections, but not better asthma controller adherence.
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Introduction

According to the World Health Organization (WHO), the pandemic of coronavirus disease 2019 (COVID-19) caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has posed a serious threat to global health since December 2019. As of February 26, 2021, the COVID-19 pandemic has resulted in 28,212,548 cases and 506,834 deaths in the United States and increasing daily.[1] There has since been interest in understanding the impact of COVID-19 on patients with many chronic conditions including asthma.

Asthma affects more than 6 million children under the age of 18, making it the most common pediatric diagnosis in the United States.[2] It has been well known, for many decades, that respiratory infections trigger asthma exacerbations.[3] In fact, more than 80% of asthma exacerbations have been attributed to viral illness in school-age children, mostly caused by human rhinovirus (HRV), followed by seasonal coronaviruses and influenza A and B.[4] Increased morbidity in children with asthma was noted during the 2009 H1N1 influenza pandemic.[5]

It was anticipated that patients with asthma would experience increased asthma-associated morbidity because of the respiratory virus SARS-CoV-2 infection, based on experience with other respiratory viral infections.[3-5] Unexpectedly, children with asthma have not contracted SARS-CoV-2 at higher rates than children without asthma, nor have children with asthma experienced more asthma

exacerbations during the current pandemic, even in those who have been presumptively infected with SARS-CoV-2.[6,7] Studies suggest a protective effect owing to the reduced number of SARS-CoV-2 spike protein receptors on respiratory epithelial cell membranes in those highly allergic or on inhaled corticosteroids (ICS).[8-10]

The clinical effect of the COVID-19 pandemic on children with asthma has been investigated in several epidemiologic studies.[6,11-14] In summary, they have noted a dramatic reduction in asthma morbidity associated with school closures in mid-March 2020, compared with previous years.[6,11-14] This has been illustrated by better asthma control,[6] fewer exacerbations requiring oral corticosteroids (OCS)[14] and decreased emergency department (ED) visits,[11-14] and hospitalizations.[11,14] The proposed explanations for this observation include spending more time at home, school closures, reduced rates of viral upper respiratory infections including HRV,[14] reduced air pollution,[14] better asthma medication adherence,[6] and better access to medical care by means of video–telemedicine (TM).[14] Improvements in asthma outcomes during the COVID-19 pandemic have been less prominent or absent in African American children or those with publicly-funded health care,[14] though there are conflicting studies in these demographics.[12] There has also been an overall decrease in in-person health care utilization for non–asthma-related diagnosis, suggesting a widespread fear of acquiring COVID-19 in the clinic, ED, or hospital.[12,13]

The COVID-19 epidemiologic studies presented in Table 1 have varied in their assessment of asthma status and exploration of several key factors, which could provide insight into the clinical impact of COVID-19 on a child with asthma.[6,11-14] Poorly studied factors include demographics, geography, medication adherence, rate of viral infections, and air pollution.[6,11-13]

The purpose of this study is to comprehensively characterize the effect of COVID-19, as presented in Table 1, on asthma status in Orange County, California, by assessing asthma control using standardized metrics, severe asthma exacerbations defined by treatment with OCS, and health care utilization. In addition, this study seeks to establish the role of demographics in our predominantly Hispanic neighborhoods, influenza viral infections, and air pollution by particulate matter 2.5 ($PM_{2.5}$) for the time periods of January 1 to June 30, 2020 compared with comparable periods between 2017 and 2019.

Methods

Study Population

Data for the study were retrieved from the Population Health Enterprise Data Warehouse of the Children's Hospital of Orange County (CHOC) health system in California that comprises both electronic medical records and Medicaid claims data. The CHOC health system is a regional pediatric healthcare network that includes a central and secondary hospital, in addition to a number of primary and specialty care clinics, and more than 100 additional programs and services such as Allergy & Immunology, Pharmacy, and Emergency Medicine. All patients with a diagnosis for asthma based on the International Classification of Diseases, Tenth Revision, Clinical Modification codes were identified in addition to the date of the first diagnosis. Patients with chronic lung diseases were excluded. Hospital and ED encounters of patients, after the first diagnosis of asthma, were selected between 2017 and 2020. Encounters of patients older than 18 were excluded from the study.

Variable Selection

Health care utilization (hospitalizations and ED visits) and medication use (OCS, ICS, and albuterol prescriptions) were aggregated at the patient level by month and year during the study period. Demographic data on patients such as age at the time of encounter, sex, race, and payer type (public vs commercial) were retrieved and aggregated by year and month of encounter. Patients were assigned a deidentified number before analyses, which was used to link health care utilization, medication prescription, demographic, and diagnosis data. The CHOC institutional review board declared the study exempt from review (with institutional review board number 2008100) because all patient data were deidentified before analyses.

Air Pollution Data

Particulate matter 2.5 daily average data for the Orange County, California area were obtained from the California Air Resources Board data website (https://www.arb.ca.gov/aqmis2/aqdselect.php) for the time periods of January 1 to June 30 for the years 2017 to 2020. Air Quality and Meteorological Information System database is a web-based source for real-time and official (historical) air quality and meteorologic data. The Air Quality and Meteorological Information System database contain the most recent data (measured within the past 2 hours) from more than 200 air quality sites and more than 800 meteorologic sites. Orange County air quality data were collected by the South Coast Air Quality Management District and reported to the California Air Resources Board. The $PM_{2.5}$ data were obtained from monitoring sites located in Anaheim, La Habra, and Mission Viejo, California, and recorded as the daily maximum 1-hour average at the highest of the 3 sites.

Influenza Data

Data were obtained for the California region from the US Outpatient Influenza-like Illness (ILI) Surveillance Network (ILINet) for the California region for the months of January to June for the years 2017 to 2020. Information on patient visits to health care providers for ILI is collected by ILINet. ILINet consists of outpatient healthcare providers in all 50 states. Each week, approximately 3000 outpatient health care providers around the country report data to the Centers for Disease Control and Prevention on the total number of patients seen for any reason and the number of those patients with ILI. For data reporting purposes, an ILI is defined as those with fever (temperature of 100°F [37.8°C] or greater) or a cough or a sore throat without a known cause other than influenza.

Telehealth Care Utilization Before vs During Coronavirus Telemedicine Visits

The video TM data were obtained from billing data in the electronic health record for the dates January 1, 2020, to June 30, 2020. Video TM data includes all outpatient visits (not specific to asthma) to the CHOC Primary Care Network, not including mental health.

Statistical Analysis

Patient demographic characteristics and year of asthma diagnosis were described by number and percentage with a defining trait. Morbidity and medication prescription rates per 1000 patients per month were assessed across periods of January to March and April to June of each year using generalized estimating equations (GEE) analyses with the specification of Poisson distribution, and within-subject repeat measures were performed. Incidence rate ratios (IRR) and corresponding 95% confidence intervals comparing April to June to January to March of 2020 and concurrent time period comparisons during previous years (2017 to 2019) were derived from the Poisson regression results. GEE analyses were extended to assess differential effects of COVID-19 on ED visits and OCS use rates by demographic characteristics. This was achieved by running a separate model for each demographic and outcome that included the following terms: (1) main effects; (2) each 2-way interaction effect; and (3) a 3-way interaction effect between year (2020 vs 2017 to 2019), month (January-March vs April-June), and the respective demographic characteristic

Table 1
Characterization of Epidemiologic Studies Evaluating Asthma During Coronavirus Disease 19

Name	Location	Sample size	Demographics	Asthma control measured	OCS	ED visits	IP visits	Key viral infections reported pre/post-2020	Adherence measured	Air pollution pre/post 2020	Observation time pre/post (d)
Taquechel et al,[14] 2020	Philadelphia	13,640	Sex, birth year, race or ethnicity, insurance	ND	Decreased	Decreased	Decreased	Human rhinovirus decreased	ND	PM2.5, PM10, NO2, Ozone, none decreased	60/60 2020 vs 2015-2019
Kenyon et al,[13] 2020	Philadelphia, Pennsylvania	6000	ND	ND	ND	Decreased	Decreased	ND	ND	ND	120 2020 vs 2016-2019
Oreskovic et al,[11] 2020	Boston, Massachusetts	ND	ND	ND	ND	Decreased	ND	ND	ND	ND	120 2020 vs 2019
Simoneau et al,[12] 2020	Boston, Massachusetts	2543	Age, race or ethnicity, insurance	ND	ND	Decreased	No change	ND	ND	ND	62/60 2020 vs 2018-2019
Papadopoulos et al,[6] 2020	International	133,000	ND	ACT or ACQ	ND	ND	ND	ND	Self-reported by survey	ND	Survey reflects events before April 1, 2020
Guijon et al—current study	Orange County, California	18,912	Sex, age (birth year), race or ethnicity, insurance	ACT, Albuterol use, age ≥3/mo	Decreased	Decreased	Decreased	Influenza decreased	Established by ICS prescriptions	PM2.5, decreased	90/90 2020 vs 2017-2019

Abbreviations: ACT, asthma control test; ACQ, asthma control questionnaire; COVID-19, coronavirus disease 19; ED, emergency department; ICS, inhaled corticosteroid; IP, inpatient; ND, not done or not reported; NO2, nitric dioxide; PM2.5, particulate matter with diameter less than 2.5 μm; PM10, particulate matter with diameter less than 10 μm.

(eg, sex). Generalized linear models (GLM) analyses assessed days per month daily $PM_{2.5}$ ($\mu g/m^3$) that exceeded the WHO threshold of 10.0 $\mu g/m^3$ by the specification of count data. Monthly influenza rates per 1000 patients, based on reporting practices within California during the respective time period, were also assessed using GLM analyses. Rate differentials in January to March compared with April to June of 2020 vs 2017 to 2019 were tested for significance by the inclusion of a 2-way interaction effect between the 90-day period and year group in each model. The GLM approach was also used to assess the significance of differential rates between care network groups in TM visits initiated after the stay-at-home orders in March of 2020. A subset analysis was performed in patients who had an asthma control test (ACT) measurement between April and June of 2019 and 2020. The GEE analyses with a specification of binomial distribution were used to compare the odds of patient uncontrolled by ACT survey,[15] and OCS prescriptions during April 2020 to June 2020 to outcomes from April 2019 to June 2019. A similar analysis was performed for the administration of 3 or more albuterol canisters per 6-month period,[16] in which the period January to June 2020 was compared with January to June 2019. Demographic characteristics of the 166 patients were also evaluated and reported. All analyses were performed using the Statistical Package for the Social Sciences, version 18.0 (IBM SPSS Statistics, IBM Corporation, Armonk, New York).

Results

Demographic Characteristics of Patient Population

There were 18,912 pediatric patients with asthma treated in the CHOC network from 2017 to 2020. Nearly half of these patients were of Hispanic origin (49.7%) as detailed in Table 2. The average age at first encounter was 9.6 years (SD = 4.6) with 16.9% of patients within 2 to 4 years old, 46.4% 5 to 11 years old, and 36.6% 12 to 18 years of age. Most were boys (57.9%) and 66.3% were on public health insurance. More than two-thirds of patients were diagnosed with asthma before 2017 (76.8%) with the remaining 23.2% diagnosed newly between 2017 and 2020.

Video/Telehealth Care Utilization Before vs During Coronavirus Disease 2019

Video telehealth was not used preceding the March 2020 stay-at-home orders in the primary care setting. Telehealth visits were

Table 2
Characteristics of Patient Population

Characteristic	N = 18,912
Age at baseline, mean (SD)	9.6 y (SD = 4.6)
2-4 y	16.9% (n = 3204)
5-11 y	46.4% (n = 8779)
≥12 y	36.6% (n = 6929)
Sex, male	57.9% (n = 10,951)
Race or ethnicity	
American Indian or Alaskan Native	0.1% (n = 13)
Asian	3.3% (n = 616)
Black or African American	1.7% (n = 318)
Hispanic	49.8% (n = 9415)
Native Hawaiian or Other Pacific Islander	0.3% (n = 59)
White	16.9% (n = 3204)
Other or unknown	28.0% (n = 5287)
Insurance	
Public	66.3% (n = 12,546)
Private	32.1% (n = 6071)
Unknown	1.6% (n = 295)
Asthma diagnosed before January 1st[a]:	
2017	76.8% (n = 14,533)
2018	7.9% (n = 1489)
2019	11.0% (n = 2087)
2020	4.2% (n = 803)

[a]Patients were included in analyses starting the month/year of asthma diagnosis.

documented at CHOC for the 2 primary care groups referred to as CHOC Medical Group (100% publicly funded) and Primacy Care Network (51% publicly-funded). After the stay-at-home order, telehealth visits were initiated in March 2020, increased dramatically in April 2020, and remained well above the initial rate in May and June (telehealth visit rate per 1000 visits across 4 months: 20, 208, 148, 136, respectively). The trend across months differed by primary care group ($P < .001$). In the 100% publicly-funded CHOC Medical Group (CMG), the telehealth visit rate per 1000 visits started lower than the 51% publicly-funded Primary Care Network (PCN) group in March (11 vs 37, $P < .001$), then increased to a similar rate in April (201 vs 214, $P = .18$), and to a significantly higher rate in May (178 vs 123, $P < .001$) and June (208 vs 89, $P < .001$). Although CMG and PCN data were not abstracted at the patient level as part of the current study, further investigation of our demographic data revealed public health insurance status was significantly associated with race ($P < .001$). Public health insurance in our population overall was noted more often in Hispanic, African American, and American Indian/Native Hawaiian patients (91.0%, 82.9%, and 71.4%, respectively) compared with Asian and White patients (49.2% and 53.4%, respectively).

Asthma-Associated Health Care Utilization and Medication use Rates Before vs During Coronavirus Disease 2019

Overall, there was a 78% decrease in the hospitalization rate, a 90% decrease in ED visit rate, and a 68% decrease in OCS use rate per 1000 patients per month at CHOC during the approximately 90-day period that encompassed the COVID-19 shutdown (April-June of 2020) compared with January to March of the same year ($P < .05$) (Fig 1). Asthma-associated morbidity rates were lower in April to June compared with January to March in previous years, but not to the extent observed in 2020 (2-way interaction effect significant in each model, $P < .05$). The range of decreased morbidity rates comparing April to June with January to March across years 2017 to 2019 before COVID-19 were the following: (1) hospitalization rate decreased from 56% to 22 %, (2) ED visit rate 42% to 26%, and (3) OCS use 36% to 25%.

In 2020, a 61% reduction in the albuterol prescription rate per 1000 patients per month occurred in the approximately 90 days after COVID-19 compared with before (IRR, 0.39; 95% confidence interval [CI], 0.37-0.42, $P < .05$) (Fig 2). This reduction was significantly greater than observed in previous years, which ranged from 13% to 32% (2-way interaction effect, $P < .05$). The pattern was similar for ICS in terms of lower prescription rates in April to June compared with January to March with rate reductions that ranged from 13% to 37% in years before COVID-19, compared with 48% in 2020 (IRR, 0.52; 95% CI 0.49-0.56, $P < .05$). Interestingly, the 48% drop in ICS prescription rate before vs during COVID-19 in 2020 was less than the 61% drop in the albuterol prescription rate.

Demographic Differentials in Asthma-Associated Emergency Department Visit and Oral Corticosteroid Prescription Rates Before vs During Coronavirus Disease 2019

The ED visit rates before COVID-19 were highest in those on public health insurance and in the youngest age group ($P < .05$) (Table 3). Rates also seemed higher in African American children compared with other race groups, although not significant at the .05 level. Reduced ED visit rates in April to June compared with January to March were observed across all demographic characteristics with exception of African American children, who were the only group to exhibit a nonsignificant ED visit rate reduction before vs during COVID-19 in 2020.

The OCS prescription rates per 1000 patients per month exhibited significant differentials in the COVID-19 impact by age and race (3-way interaction effect, $P < .05$) (Table 4). Rate reductions in April to June compared with January to March across the 3 age groups were similar in years before COVID-19, ranging from 26% to 32%. However, in the year of COVID-19, the rate differential before vs during COVID-19 by age was striking, in which an 80% reduction was observed in patients 2 to 4 years old compared with 69% in patients 5 to 11 years and 59% in patients 12 to 18 years ($P < .05$). Race differentials in OCS requirement also seemed more pronounced in 2020, in which the minority children of African American and Hispanic descents had a larger rate reduction during COVID-19 than White children (77% and 72% compared with 48%, respectively) ($P = .002$).

Uncontrolled Asthma Before vs During Coronavirus Disease 2019

An ACT survey was completed by 166 patients in the 3-month period of April to June in both 2019 and 2020. In April to June of 2020 (during COVID-19), the odds of uncontrolled disease were reduced by 70% compared with the concurrent period in 2019 from 27.0% to 10.0% (odds ratio, 0.30; 95% CI, 0.16-0.55, $P < .05$). Corroborating evidence was indicated by the 76% reduced odds of an OCS requirement (odds ratio, 0.24; 95% CI, 0.09-0.66, $P < .001$), and the 45% reduced odds of 3 or more albuterol prescriptions during the corresponding 6-month period of January to June in 2020 compared with 2019 ($P < .05$) (Table 5).

Pollution (Particulate Matter) and Influenza Rates

The average number of days per month that daily average $PM_{2.5}$ exceeded the WHO standard threshold of 10.0 ug/m^3 decreased by 37% between January to March period and April to June in 2020 (13.7 days vs 8.6 days per month) ($P = .06$). This is in contrast with the significant 30% increase in comparing rates in the concurrent monthly periods during years before COVID-19 ($P = .04$) (2-way interaction effect between year[s] and month periods, $P = .012$) (Fig 3). The daily average $PM_{2.5}$ evaluated on a continuous scale correspondingly found significant reduction of 2.41 points between January to March and April to June in 2020 ($P = .003$) that was not observed in 2017 to 2019 ($P = .62$) (2020: 10.4 [95% CI, 9.3-11.5] vs 8.0 [95% CI, 6.9-9.2] compared with 2017 to 2019: 10.0 [95% CI, 9.4-10.7] vs 9.8 [95% CI, 9.2-10.4]) (data not provided, 2-way interaction effect between year[s] and month periods, $P = .02$).

The rate of influenza per 1000 pediatric and adult patients in reporting California practices decreased by 77% between January to March and April to June in 2020 (197.2 vs 45.8 per 1000 patients per month) ($P < .001$). This reduction was significantly greater than the 49% reduction when comparing the rates in the concurrent monthly periods during years before COVID-19 ($P = .04$) (2-way interaction effect between year[s] and month periods, $P = .01$) (Fig 3).

Discussion

We have found that asthma status at our medical center has substantially improved since the onset of COVID-19 in conjunction with associated school closure in mid-March. This has been exhibited by considerably better asthma control defined by the ACT[15] and albuterol use,[16] reduced severe asthma exacerbations requiring OCS, and fewer ED visits and hospitalizations during COVID-19 April to June 2020 period compared with the pre−COVID-19 January to March 2020 period, with significantly greater reductions than observed for similar comparison periods in previous years (2017-2019) ($P < .05$). Among the possible explanations for this improvement in asthma status, we explored the following 4 indicators: (1) air pollution $PM_{2.5}$ levels; (2) influenza infection rates; (3) adherence by ICS prescriptions; and (4) change in video TM visits. Both $PM_{2.5}$ levels and influenza infection rates exhibited the greatest decrease during the COVID-19 period of April to June compared with the pre−COVID-19 January to March period in 2020, which was significantly greater ($P < .05$) than these
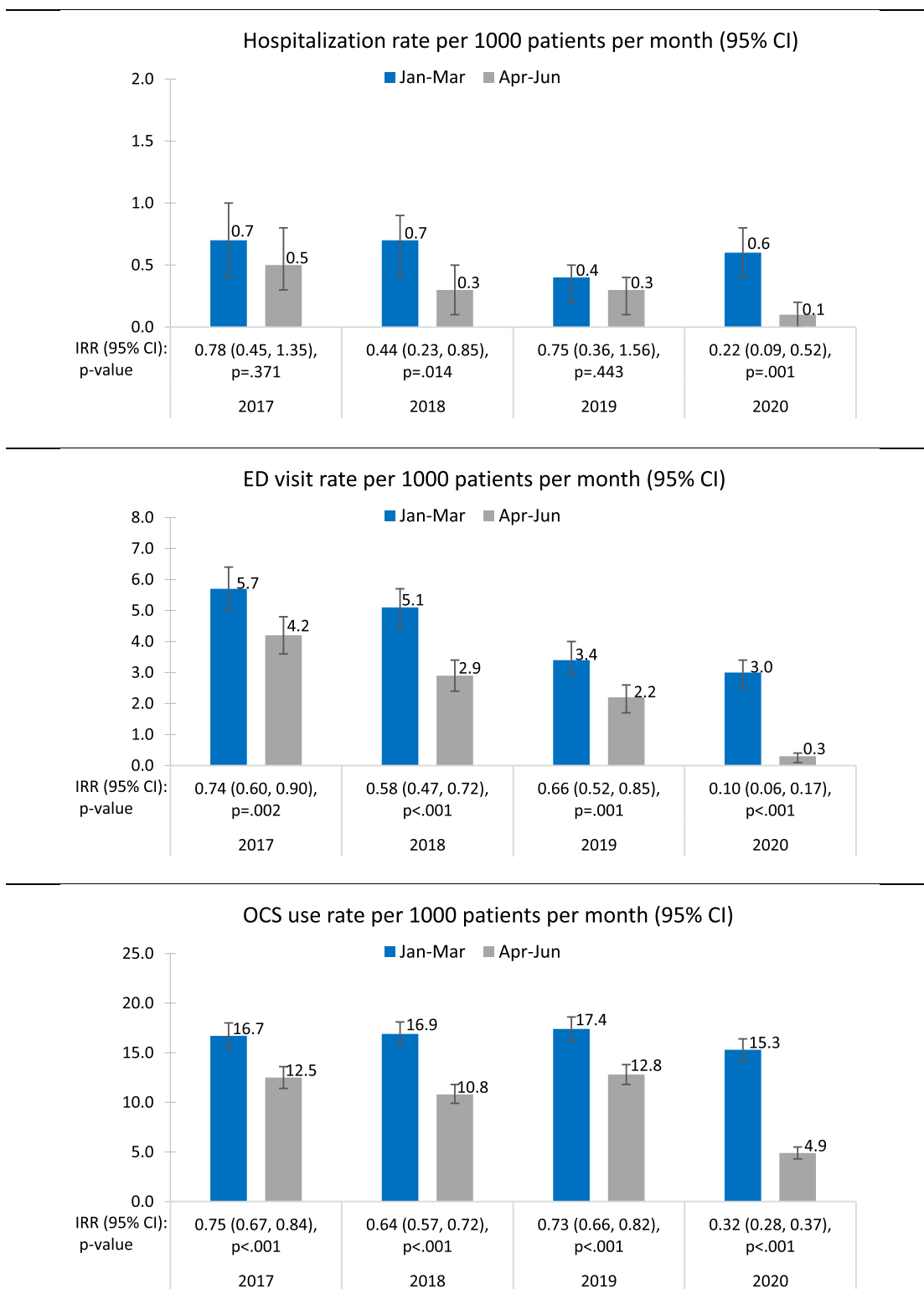
Figure 1. Monthly morbidity rates per 1000 patients with asthma. Rates were significantly lower in April to June compared with January to March across years and, to an even greater extent, in 2020 compared with previous years ($P < .05$). Poisson regression using GEE analyses with the specification of repeat measures. CI, confidence interval; ED, emergency department; GEE, generalized estimating equations; IRR, incidence rate ratios; OCS, oral corticosteroid.

comparable periods in 2017 to 2019. There was no evidence of enhanced medication adherence as assessed by the number of ICS controller prescriptions. In contrast, Kaye et al[17] found increased adherence to daily controller medication during the first 3 months of 2020. It should be noted that the study of Kaye et al[17] was conducted only in adults from January through March 2020, and did not include data after

stay-at-home orders were imposed. In addition, the study included data collected by means of electronic inhaler monitoring, which includes reminders for missed doses.[17]

Finally, we experienced tremendous increases in the use of video TM at our institution since the onset of COVID-19. Our data suggest that socioeconomic status did not limit access to TM as indicated by
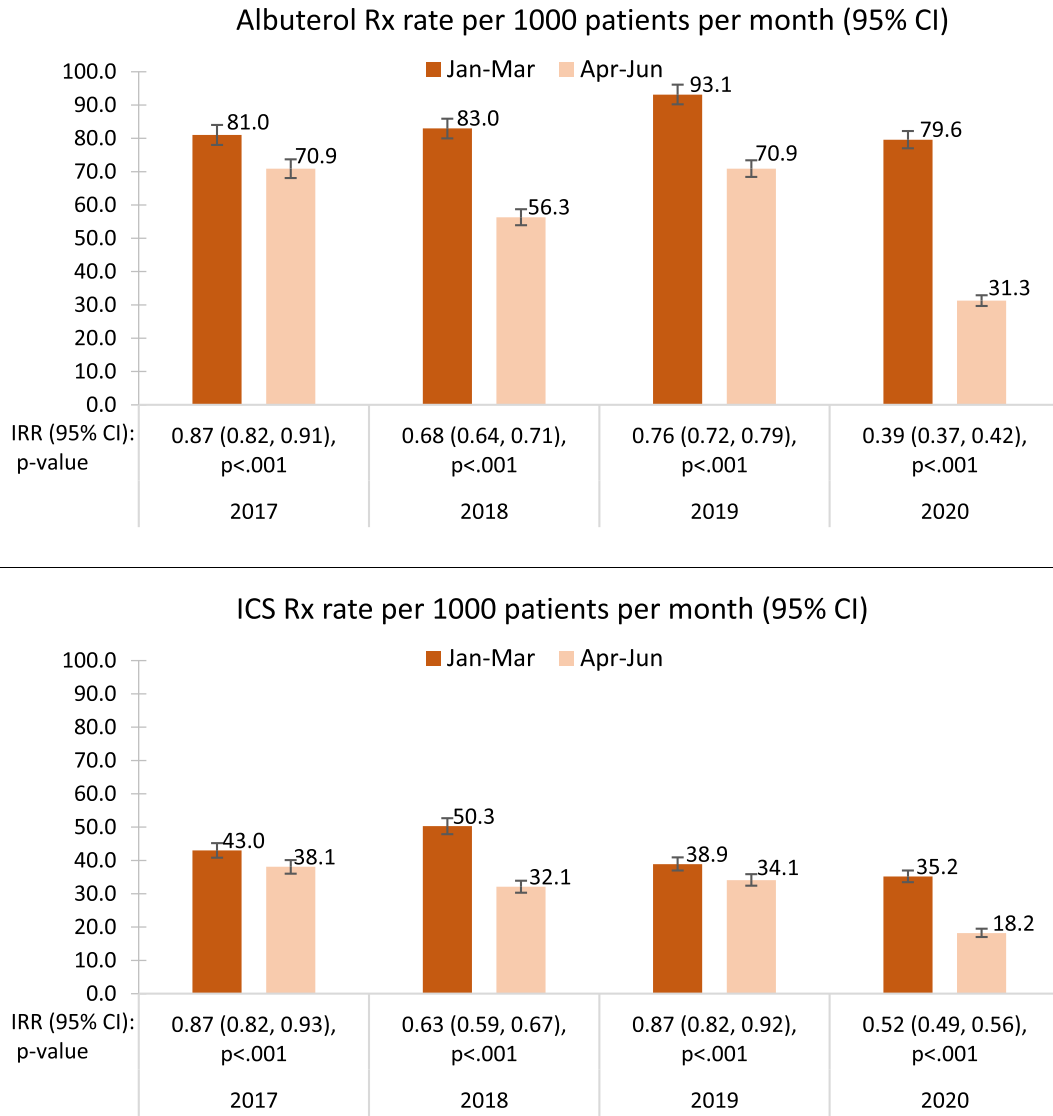
Albuterol Rx rate per 1000 patients per month (95% CI)

IRR (95% CI): p-value	0.87 (0.82, 0.91), p<.001	0.68 (0.64, 0.71), p<.001	0.76 (0.72, 0.79), p<.001	0.39 (0.37, 0.42), p<.001
	2017	2018	2019	2020

ICS Rx rate per 1000 patients per month (95% CI)

IRR (95% CI): p-value	0.87 (0.82, 0.93), p<.001	0.63 (0.59, 0.67), p<.001	0.87 (0.82, 0.92), p<.001	0.52 (0.49, 0.56), p<.001
	2017	2018	2019	2020

Figure 2. Monthly medication prescription rates per 1000 patients with asthma. Rates were significantly lower in April to June compared with January to March across years and, to an even greater extent, in 2020 compared with previous years ($P < .05$). Poisson regression using GEE analyses with the specification of repeat measures. CI, confidence interval; ED, emergency department; GEE, generalized estimating equations; IRR, incidence rate ratios; OCS, oral corticosteroid; Rx, prescription.

the higher rate of telehealth visits in the 100% publicly insured cohort compared with approximately half of visits in the cohort 51% funded from public insurance. Although race and ethnicity for the telehealth visits were not available, it is known that those on public health insurance are mostly minority populations,[18] suggesting that race and ethnicity did not limit access to telehealth in our population as in the study by Taquechel et al.[14]

There have been several important epidemiologic studies to both assess asthma status during COVID-19 and explore possible explanations for similar findings. In Table 1, we compare 5 of these studies with our own study and found that only the study of Taquechel et. al[14] compares favorably with our study in terms of length of the observation period in weeks, the number of key observations of both asthma status, and factors which could affect these outcomes. As we have discussed, Taquechel et al[14] found substantially decreased ED visits and hospitalizations and less need for OCS in the 60-day window from April to May compared from January to March. Demographic differences found a higher proportion of asthma encounters such as outpatient visits, hospitalizations, and phone calls in the

African American population and those on Medicaid vs commercial insurances. In our cohort, racial differences were also found indicating that African Americans had poorer outcomes in terms of ED visits during COVID-19 months compared with pre−COVID-19, but not for severe exacerbations requiring OCS. The differences noted between our outcomes and those reported by Taquechel et al[14] probably reflect differences in demographics, with African American children representing only 1.7% of our population (in contrast with 42% in the study of Taquechel et al[14]), and Hispanic children comprising 49.8% in our population (compared with 9% in the study of Taquechel et al[14]). Unlike the study of Taquechel et al,[14] we did not find considerable differences between public and commercial insurance in these beforeor during COVID-19 outcomes, although ED visit and OCS use rates were consistently higher for patients on public vs private health insurance. In terms of the relationship of air pollution and viral infection changes to improved asthma outcomes during the COVID 19 pandemic, Taquelchel et al[14] found that improvement in asthma status was seen to strongly be associated with decreased HRV infections, but not influenza A or B, nor respiratory syncytial virus diagnosis by

Table 3

Influence of Demographic Characteristics on Monthly Average Emergency Department Visits Per 1000 Patients Comparing January to March and April to June During Years 2017 to 2019 and 2020

Monthly ED visit rate per 1000 patients	Years 2017-2019			Year 2020			Months effect depends on year and demographic[a] P value
	January-March Rate (95% CI)	April-June Rate (95% CI)	IRR (95% CI), P value	January-March Rate (95% CI)	April-June Rate (95% CI)	IRR (95% CI), P value	
Overall	4.4 (4.0-4.8)	2.9 (2.6-3.3)	0.67 (0.59-0.76), P < .001	3.0 (2.5-3.5)	0.2 (0.1-0.4)	0.08 (0.05-0.15), P < .001	—
Age at baseline, y							P = .42
2-4	8.0 (6.4-9.6)	7.1 (5.6-8.6)	0.88 (0.68-1.15), P = .36	9.3 (5.9-12.6)	0.6 (0.0-1.4)	0.06 (0.02-0.26), P < .001	
5-11	5.4 (4.8-6.0)	3.1 (2.7-3.6)	0.56 (0.47-0.67), P < .001	3.6 (2.8-4.4)	0.2 (0.0-0.4)	0.07 (0.03-0.17), P < .001	
≥12	2.4 (1.9-2.8)	1.6 (1.2-1.9)	0.68 (0.52-0.88), P = .003	1.6 (1.1-2.1)	0.2 (0.0-0.4)	0.18 (0.08-0.41), P < .001	
Sex							P = .69
Male	4.8 (4.3-5.4)	3.4 (3.0-3.9)	0.69 (0.59-0.80), P < .001	3.2 (2.6-3.9)	0.3 (0.1-0.5)	0.08 (0.04-0.17), P < .001	
Female	3.8 (3.2-4.3)	2.2 (1.8-2.7)	0.59 (0.47-0.73), P < .001	2.6 (1.9-3.3)	0.2 (0.0-0.4)	0.10 (0.04-0.22), P < .001	
Race							P = .08
Black	8.3 (4.4-12.1)	4.5 (1.7-7.3)	0.55 (0.25-1.18), P = .13	1.1 (0.0-3.4)	2.3 (0.0-5.4)	1.97 (0.18-21.76), P = .58	
Hispanic	5.6 (5.0-6.1)	4.0 (3.5-4.5)	0.72 (0.62-0.83), P < .001	4.0 (3.2-4.8)	0.4 (0.1-0.6)	0.09 (0.05-0.18), P < .001	
White	5.1 (4.1-6.1)	2.5 (1.8-3.2)	0.49 (0.35-0.69), P < .001	3.5 (2.3-4.8)	0.3 (0.0-0.7)	0.10 (0.03-0.32), P < .001	
Other or unknown	2.1 (1.6-2.6)	1.1 (0.8-1.5)	0.55 (0.37-0.82), P = .003	1.1 (0.6-1.7)	0.1 (0.0-0.2)	0.05 (0.01-0.40), P = .004	
Insurance							P = .55
Public	5.4 (4.9-5.8)	3.5 (3.2-3.9)	0.66 (0.58-0.75), P < .001	3.9 (3.2-4.6)	0.4 (0.2-0.6)	0.11 (0.06-0.19), P < .001	
Private	1.8 (1.2-2.3)	1.1 (0.7-1.6)	0.33 (0.24-0.46), P < .001	1.1 (0.6-1.6)	0.1 (0.0-0.2)	0.05 (0.01-0.40), P = .004	

Abbreviations: CI, confidence interval; ED, emergency department; GEE, generalized estimating equations; IRR, incidence rate ratio.

[a]Test of 3-way interaction effect (years x months x demographic) in GEE Poisson regression model; years (2017-2019 vs 2020) and months (January-March vs April-June).

Table 4

Influence of Demographic Characteristics on Monthly Average Oral Corticosteroid Rx Rate Per 1000 Patients Comparing January to March and April to June During Years 2017 to 2019 and 2020

Monthly OCS Rx rate per 1000 patients	Years 2017-2019			Year 2020			3-way interaction effect[a] P value
	January-March Rate (95% CI)	April-June Rate (95% CI)	IRR (95% CI), P value	January-March Rate (95% CI)	April-June Rate (95% CI)	IRR (95% CI), P value	
Overall	17.5 (16.6-18.4)	12.4 (11.7-13.1)	0.71 (0.67-0.76), P < .001	15.1 (14.0-16.3)	4.9 (4.2-5.5)	0.31 (0.27-0.36), P < .001	—
Age at baseline, y							P = .008
2-4	35.7 (32.4-38.9)	25.3 (22.6-27.9)	0.70 (0.60-0.80), P < .001	48.6 (41.1-56.1)	9.2 (6.0-12.4)	0.20 (0.13-0.30), P < .001	
5-11	18.2 (17.1-19.2)	12.3 (11.5-13.2)	0.68 (0.62-0.75), P < .001	17.4 (15.6-19.1)	5.3 (4.3-6.3)	0.31 (0.25-0.38), P < .001	
≥12	11.1 (10.2-12.0)	8.4 (7.6-9.1)	0.74 (0.67-0.84), P < .001	9.0 (7.8-10.2)	3.9 (3.1-4.7)	0.41 (0.33-0.51), P < .001	
Sex							P = .34
Male	18.9 (17.9-19.9)	13.1 (12.3-13.9)	0.69 (0.64-0.75), P < .001	16.5 (15.1-18.0)	4.8 (4.1-5.6)	0.28 (0.24-0.34), P < .001	
Female	14.3 (13.3-15.3)	10.5 (9.7-11.4)	0.74 (0.66-0.82), P < .001	13.5 (11.9-15.1)	4.9 (4.0-5.9)	0.38 (0.30-0.47), P < .001	
Race							P = .002
Black	22.0 (15.8-28.3)	12.2 (7.6-16.8)	0.55 (0.35-0.89), P = .01	29.9 (18.4-41.4)	6.8 (1.4-12.2)	0.23 (0.09-0.55), P = .001	
Hispanic	18.8 (17.8-19.8)	13.6 (12.8-14.5)	0.73 (0.68-0.79), P < .001	16.7 (15.1-18.3)	4.7 (3.9-5.6)	0.28 (0.23-0.35), P < .001	
White	22.0 (19.9-24.0)	14.4 (12.8-16.1)	0.66 (0.57-0.76), P < .001	17.1 (14.3-19.9)	8.8 (6.9-10.8)	0.52 (0.39-0.68), P < .001	
Other or unknown	9.7 (8.6-10.7)	7.1 (6.2-8.0)	0.73 (0.62-0.87), P < .001	11.3 (9.6-12.9)	2.9 (2.1-3.8)	0.27 (0.19-0.37), P < .001	
Insurance							P = .87
Public	18.2 (17.4-19.0)	12.8 (12.1-13.5)	0.70 (0.66-0.75), P < .001	17.6 (16.2-19.1)	5.5 (4.7-6.3)	0.31 (0.27-0.37), P < .001	
Private	12.9 (11.4-14.4)	9.7 (8.4-11.0)	0.75 (0.63-0.90), P = .002	10.9 (9.3-12.6)	3.8 (2.8-4.7)	0.36 (0.27-0.48), P < .001	

Abbreviations: CI, confidence interval; GEE, generalized estimating equations; IRR, Incidence rate ratio; OCS, Oral Corticosteroid; Rx, prescription.

[a]Test of 3-way interaction effect (years x months x demographic) in GEE Poisson regression model; years (2017-2019 vs 2020) and months (January-March vs April-June).

Table 5
Uncontrolled Asthma

N = 166	2019	2020	OR (95% CI)[a]	P value
Asthma Uncontrolled	April-June	April-June		
ACT <20	27.0%	10.0%	0.30 (0.16-0.55)	P < .001
OCS requirement	11.4%	3.0%	0.24 (0.09-0.66)	P < .001
	January-June	January-June		
Albuterol Rx ≥3	23.5%	14.5%	0.55 (0.31-0.97)	P = .04

Abbreviations: ACT, asthma control test; CI, confidence interval; GEE, generalized estimating equations; OCS, oral corticosteroid; OR, odds ratio; Rx, prescription.
NOTE: Demographics of 166 patients include the following: (1) sex: 56.0% male; (2) race: 1.2% African American, 6.6% Asian, 58.4% Hispanic, 16.9% White, and 18.1% other or unknown; (3) age at January 1, 2019: 11.4% (2-4 years), 63.9% (5-11 years), 24.7% (≥12 years), and (4) 80.7% public insurance.
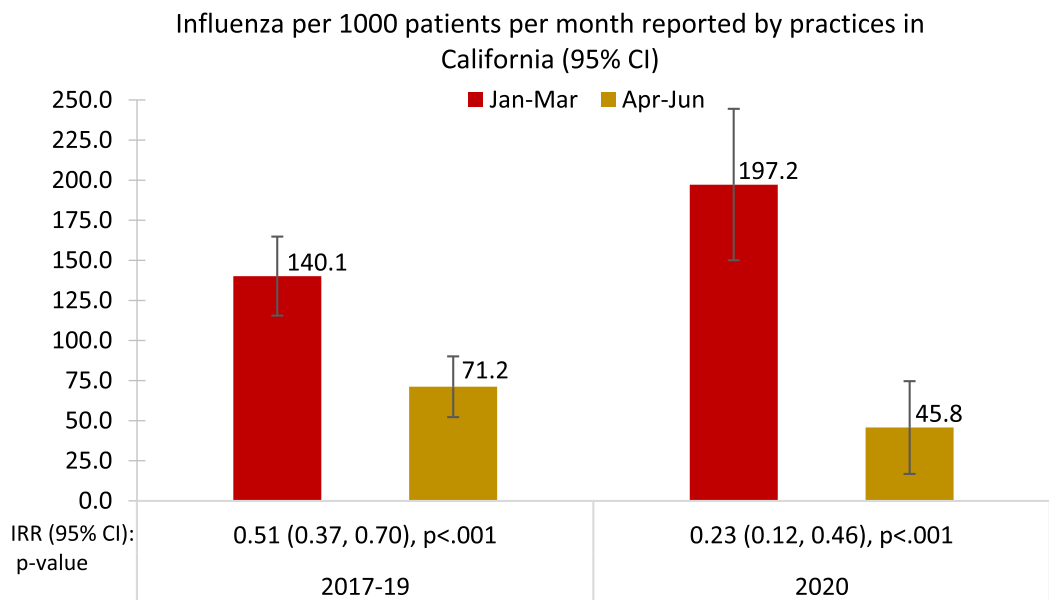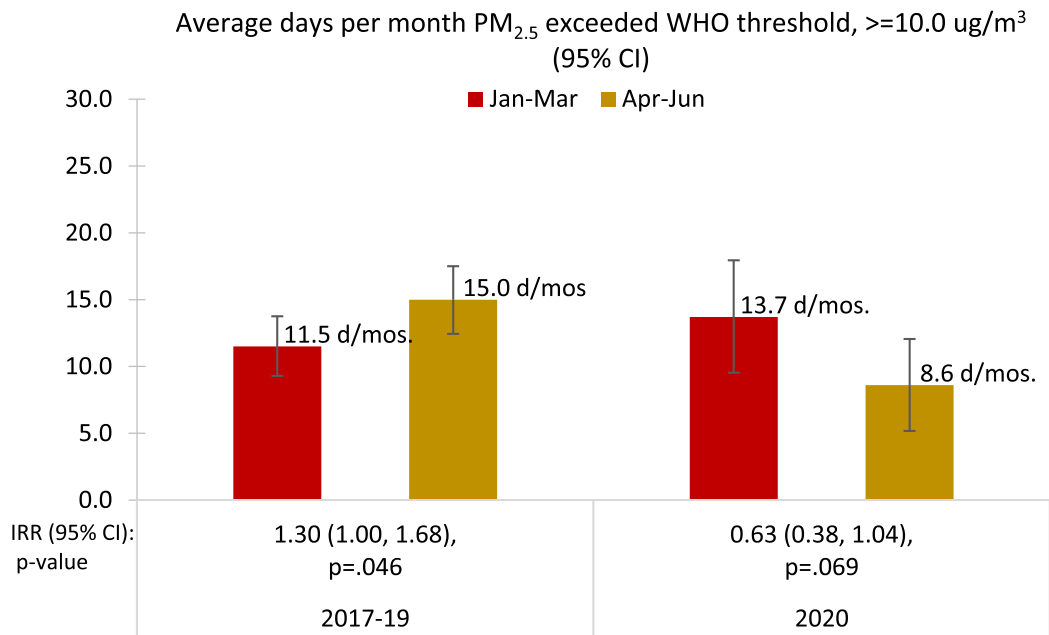[a]GEE analyses using binomial distribution adjusting for repeated measures.

Figure 3. Average days per month daily average $PM_{2.5}$ pollution levels exceeded WHO standard (≥10.0 ug/m^3) and monthly influenza rates per 1000 patients in reporting practices within California during respective time periods. Poisson regression using GLM analyses. Two-way interaction effect shows significant pre/post changes in 2020 vs previous years for both PM2.5 (P = .01), and influenza infection (P = .04). CI, confidence interval; GLM, generalized linear models; IRR, incidence rate ratios; PM2.5, particulate matter with diameter less than 2.5 micrometers; WHO, World Health Organization.

polymerase chain reaction (PCR) comparing 2020 with 2015-2019. However, none of the during–COVID-19 period pollution patterns evaluated, including PM$_{2.5}$, particulate matter 10, ozone, or nitric dioxide were different in the during–COVID-19 period of March 18, 2020, to May 17, 2020, compared with the pre–COVID-19 period of January 17, 2020, to March 17, 2020. In contrast, we found that both influenza and PM$_{2.5}$ exhibit statistically lower rates during vs pre–COVID-19, which was associated with improved asthma status. In our study located in southern California with high traffic volumes reflecting relatively high average PM$_{2.5}$, the average number of days per month with daily average values exceeding the WHO threshold (≥ 10.0 ug/m^3) was reduced by 37% in April to June compared with January to March of 2020, whereas the rate increased by 30% in April to June compared with January to March in years before COVID-19.

Several other studies have also found decreased ED visits[11-13] and hospitalizations[13] in the during vs pre–COVID-19 period, but with no reported attempt to identify potential contributory factors that could explain the improvement noted, as detailed in Table 1.

In an international online survey for observations made as of April 19, 2020 sent to providers in the Pediatric Asthma in Real Life Think Tank and the World Allergy Organization Pediatric Allergy Commission, Papadolous et al[6] reported findings of a marked reduction in asthma encounters, improved asthma control (by ACT or asthma control questionnaire validated tools), and self-reported better adherence among 133,000 children with asthma sampled.[6] A substantial limitation of this study is that the clinical data are not based on direct evaluation, but based on subjective survey evaluation, which makes it subject to recall bias.

Limitations

Key potential limitations could include the reliability of the air pollution data in terms of data collection station distribution. The 3 sites for PM$_{2.5}$ measurements encompass the entire county. Furthermore, the South Coast Air Quality Management District network exceeds the minimum monitoring requirements for all criteria pollutants.[19] Another potential limitation is the reliability of clinically defined influenza infections vs other similar viruses because this is not PCR-based. However, Orange County–specific data were not available. The ILI study by Wallace et al[20] reported the rate of ILI in their study and the number of influenza A positive PCR samples correlated with the reports of ILI per 100,000 population from sentinel practices, similar to what is collected by ILINet. Furthermore, they reported that most of the ILI-reported cases tested positive for Influenza A.[20] The availability of ACT survey data were limited to a small number of patients in our cohort, with information available from April to June of 2019 and 2020. This may reflect a biased sample because the ACT cohort had a greater persistence of asthma when compared with the larger non-ACT cohort. However, the use of albuterol of 3 or more canisters per 6 months, a validated marker of uncontrolled asthma and risk of exacerbations,[16] found similar directional evidence of the decreased rate of uncontrolled asthma during COVID-19. Finally, African American children were underrepresented in our population of minority children with asthma, and thus, our findings for this small African American cohort cannot be generalizable to other populations. Telehealth data were for all primary care visits and not asthma-specific visits, so our telehealth findings need to be viewed with caution regarding asthma visit patterns.

Conclusions

We have stressed the importance of a comprehensive approach to assessing the effect of COVID-19 in terms of both asthma status, and, identification of key demographic and environmental factors that could affect asthma outcomes in a largely Hispanic, underserved, minority population in Orange County, California. Consistent with other studies,[11-14] we found improved asthma control associated with reduced asthma exacerbations and health care utilization in association with less influenza infection and reduced air pollution, such as seen with PM$_{2.5}$, by the stay-at-home mandate. In addition, we found increased, not decreased, telehealth rates in our publicly insured cohort, suggesting that in our population socioeconomic and minority status were not impediments to telehealth visit access. Better adherence, as previously suggested,[17] was not supported using our ICS claims data. To be more generalizable, these data need to be confirmed in a comprehensive manner in other geographic areas with other racial and ethnic populations.

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