Effect of the COVID-19 pandemic on asthma exacerbations in New Zealand: An interrupted time series analysis

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Background: New Zealand (NZ) implemented some of the strictest restrictions during the novel coronavirus pandemic (coronavirus disease 2019 [COVID-19]), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). How this impacted asthma exacerbation rates in NZ is unknown.
Objective: We sought to explore the effects of the COVID-19 restrictions on asthma exacerbations in NZ during 2020.
Methods: We used a population-based, interrupted time series to examine the impact of the first COVID-19 lockdown in NZ on asthma exacerbation rate. The primary outcome measure was change in the monthly exacerbation rate, defined as hospitalization and/or course of corticosteroids, before and after the first lockdown. In a secondary analysis, we quantified the number of patients with asthma, the actual asthma exacerbation rate from March to December 2019 versus March to December 2020, and the number of asthma hospitalizations.
Results: There was a significant drop in the exacerbation rate immediately after lockdown (−3.02; $P < .0001$) followed by a significant and sustained increasing trend; the rate postlockdown increased relative to that prelockdown (0.27; $P < .0001$). Similar patterns were observed in all sociodemographic groups. In our secondary analysis, we identified 507,622 people with asthma; this reduced to 458,023 in 2020 postlockdown. The overall asthma exacerbation rate was 33.3% less in 2020 than in 2019 (reduction from 48.6/1000 patients to 32.4/1000 patients). The rate of asthma hospitalizations decreased from 9.5 per 1000 patients in 2019 to 6.2 per 1000 patients in 2020; this decrease was observed across all demographic groups.
Conclusions: The first COVID-19 lockdown in 2020 in NZ significantly reduced asthma exacerbation rates across all sociodemographic groups. Whether these reductions are sustained requires further investigation. (J Allergy Clin Immunol Global 2023;2:100157.)

Key words: *Asthma, COVID-19, public health, interrupted time series, exacerbations, hospitalizations, pandemic*

The appearance of the novel coronavirus, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), responsible for causing coronavirus disease 2019 (COVID-19), and the associated public health efforts put in place to limit the spread and impact of the disease, has had varying impacts on people's health globally.[1] The effect of the pandemic on respiratory health has been highlighted as a particular area of concern. At the start of the pandemic, extra recommendations were made for people living with chronic lung conditions due to concerns about a higher morbidity and mortality rate from COVID-19.[2] In the United States, asthma was a top 3 comorbidity in younger patients who were hospitalized for COVID-19.[3] Individuals with asthma are recognized to be more susceptible to respiratory viral infections, which are a trigger for asthma exacerbations in many individuals. To manage this, public health recommendations were issued for people with asthma with recommendations to stay home and "shield" and limit interactions with the community.[4,5] There were concerns that individuals with long-term conditions may have increased symptoms and less well-controlled disease due to reduced access to usual care, fears about contracting COVID-19 from health care utilization, and changes in health care routines.

Despite these concerns, there have been studies that report a significant decrease in asthma exacerbations[6,7] at the height of the pandemic during periods of COVID-19 lockdown,[8] with potential effects up to a 41% relative reduction in asthma exacerbations reported in adults in one study, and up to 75% in children.[9] A Dutch study in a cohort of 94 patients with moderate to severe asthma reported a significant reduction in mean exacerbation frequency. Survey data from this cohort found that patients were more likely to avoid (39%) or delay (25%) medical visits because of fear of COVID-19 infection at medical facilities, which could suggest a shift toward more self-management of exacerbations during the COVID-19 pandemic. However, findings from a study by Salciccioli et al[8] in 1178 patients showed that exacerbations reduced even when asthma control was measured using self-reported data, rather than measures based on health care utilization. The authors concluded that because their data included exacerbations that did not require health care facility interaction and were reported entirely remotely, the reduction was likely due to a true reduction in exacerbations.

In 2020, Shah et al[10] conducted an interrupted time series (ITS) analysis in an asthma cohort in the United Kingdom comparing exacerbation rates in 2020 to those in pre-COVID periods in 2016-2019. This study provided data on 100,165 patients with asthma who experienced at least 1 exacerbation during the period

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Abbreviations used

COVID-19:	Coronavirus disease 2019
ICD-10-AM:	*International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification*
ITS:	Interrupted time series
NZ:	New Zealand
OCS:	Oral corticosteroid
SARS-CoV-2:	Severe acute respiratory syndrome coronavirus 2

2016 to 2020. The authors reported a significant reduction in exacerbations across all age groups.[10] However, these data were limited to only primary care data and the effect on hospital admissions was unknown. A recent study reported that asthma may increase the risk of hospitalization,[2] yet global epidemiology studies show conflicting data, with a lower prevalence of asthma in patients hospitalized with COVID-19 in certain countries such as Italy, Spain, China, and Brazil, but a higher prevalence in studies in the United Kingdom, the United States, and Australia.[11] There have however been no data reported for New Zealand (NZ).

NZ was reported during the height of the global pandemic in 2020 to be the country with the strictest public health restrictions and the most restrictive of all lockdowns internationally, restricting both international entry to NZ but also interregional and intraregional travel at various times between March 2020 and September 2022, when restrictions were lifted. These restrictions limited the movement of people including the temporary closure of nonessential health services.[12] How this impacted asthma control—in particular, asthma exacerbation rates—during this time is unknown.

This study aimed to explore using an ITS methodology the effects of the COVID-19 pandemic and lockdown on asthma exacerbations in NZ during 2020. We hypothesized that a significant effect would include both a significant level change (ie, immediate change in magnitude of asthma exacerbation after lockdown) and a significant change in the trend of asthma exacerbation rate before lockdown as compared with after the lockdown.

METHODS

Study design and setting

We used a population-based ITS design to examine the impact of the first nationwide COVID-19 lockdown in NZ on asthma exacerbation rate. ITS study designs are quasi-experimental designs that account for secular trends. These are widely used to evaluate and track the impact of population-level interventions or policy changes and can help provide evidence for decision making.

Data sources and study population

We obtained national data on hospital admission, medication use, primary care enrollment, and sociodemographic characteristics from 4 data sets maintained by the Ministry of Health. The National Minimum Dataset contains information on public and privately funded hospital admissions in NZ[13] and includes all patient hospitalization episodes and discharge diagnoses, which are coded using the *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification* (*ICD-10-AM*).[14] This coding was used to identify asthma-related hospital admissions. The Pharmaceutical Collection contains information about all dispensings of subsidized medications in community pharmacies across NZ.[15] Data include the date of dispensing, the name of the medication, formulation, the quantity dispensed, and the duration of supply if this is recorded. A "Chemical ID" and a "Formulation ID" are available to identify the name of the drug and formulation dispensed. Patient sociodemographic data and information on primary care enrollment were obtained from the Primary Health Organisation Enrolment Collection and the National Health Index database.[16,17]

The NZ government announced the first restrictions on health care on March 23, 2020 (allowing only virtual, noncontact consultations), with a full COVID-19 lockdown on March 25, 2020 (reprioritization of health services to the most essential ones). To ensure a sufficient number of observations for the ITS model, we used monthly data of 72-month intervals: 62 months before the lockdown and 10 months after the lockdown, from January 2015 to December 2020. All patients in the study were enrolled with a primary care clinic during these study years. Patients with a recorded clinical diagnosis of asthma (*ICD-10-AM* codes J45-J46) or who had at least 1 outpatient prescription dispensed for asthma medications (such as inhaled or oral asthma medication including inhaled corticosteroids, long-acting β-agonists, short-acting β-agonists, leukotriene receptor antagonists, and biologics) during a calendar year over this period were included, and they were followed over time to assess asthma exacerbation rates. Patients were excluded from follow-up following any hospital diagnosis of other chronic lung diseases (*ICD-10-AM* codes J40-J44) or dispensing of an inhaled beta-adrenoceptor agonist with an anticholinergic agent or a long-acting muscarinic antagonist to exclude patients with chronic obstructive pulmonary disease diagnosis.

Outcome measure

The primary outcome measure was the change in the monthly rate of asthma exacerbation before and after the first COVID-19 lockdown. An asthma exacerbation was defined as the presence of either an acute asthma-related hospital admission (*ICD-10-AM* code J45 or J46) or an acute course of oral corticosteroids (OCSs) in a given assessment period. OCSs included were prednisone tablets, prednisolone liquid, methylprednisolone tablets, and dexamethasone tablets because these were identified as OCSs used for managing asthma; other OCSs such as oral budesonide were excluded. OCS courses were counted as an asthma exacerbation only if dispensed to a patient with asthma at least 8 days following a previous OCS dispensing. An exacerbation was considered to be a unique exacerbation only if a gap greater than 7 days existed between OCS courses. Asthma-related mortality data were available only until 2017; thus, we did not include mortality in our definition of asthma exacerbation.

Variables

Data collected included the number of acute asthma-related hospital admissions and the number of OCSs dispensed in each month during the study period. To evaluate differing impacts of the COVID-19 lockdown across sociodemographic groups, data were aggregated by patient demographic group: sex (male, female), age (<5, 6-18, 19-64, ≥65 years), ethnicity (Māori,

Pacific peoples, Asian [including Southeast Asian, Chinese, Indian and other Asian], European, and Other; note that for the ITS analysis, this was grouped into Māori vs non-Māori for comparison of trends), and the NZ Deprivation Index quintile.[1-5] The NZ Deprivation Index is created by ranking small areas units known as mesh-blocks using 10 domains (scores). These ranks were grouped into quintiles, where lower quintiles represented less socioeconomically deprived areas and the higher quintiles represented more deprived areas.

Statistical analyses

Descriptive statistics were used to summarize the data. ITS models were used to compare monthly asthma exacerbation rates before and after the first COVID-19 lockdown. The equation for the ITS is as follows:

$y = \beta_0 + \beta_1 \times \text{Time} + \beta_2 \times \text{Intervention} + \beta_3 \times (\text{Time} \times \text{Intervention}) + \text{error term}$; where:

y = average monthly asthma exacerbations

β_0 = intercept (estimates the baseline level of asthma exacerbation, ie, at January 2015)

β_1 = slope of the trend of asthma exacerbation before lockdown (from January 2015 to March 2020). This parameter is useful to control for secular trends before the introduction of the lockdown

β_2 = change in the level of asthma exacerbations immediately after the lockdown is implemented (March 2020)

β_3 = slope of the trend of asthma exacerbation after the lockdown (from March to December 2020).

A 1-month time unit was used to provide optimal precision to the ITS model. For every assessment period (defined as a month), we determined the total number of asthma exacerbations. Then, asthma exacerbation rates were derived for every month from January 2015 to December 2020 by dividing the total number of exacerbations in each month by the total number of patients registered in general practice in each study year. The rates were stratified by sex, age group, ethnicity (Māori vs non-Māori), and deprivation index quintile.[1-5] The single-point intervention was defined as the month corresponding to the start of lockdown in March 2020.

We used the prelockdown asthma exacerbation trends to model the counterfactual of postlockdown trends (if the lockdown was not implemented). The impact of the lockdown was assessed by comparing actual utilization to the postlockdown counterfactual. We hypothesized the potential impact of the lockdown as an immediate change because it was a legal requirement affixed at one time point. The ITS analysis involved several steps. First, ordinary least squares regression analysis was applied, with 4 coefficients to be determined including an intercept term, preintervention trend, postintervention level, and trend. The ordinary least squares model was then tested for the 2 types of autocorrelation relationships in data points over time, "autoregression" and "moving average" with autocorrelation and partial autocorrelation plots. The patterns observed from the plots were used to determine the order of the moving average and/or autoregression relationship.

Autocorrelation-type relationships were expected because our data showed a seasonality pattern. Subsequently, a generalized least squares model was fitted to the data incorporating the autoregression relationship presented in our data. The final fitted model was then used to extract the absolute and relative changes in the outcomes of interest: overall exacerbation rate, and exacerbation rate stratified by sex, age, Māori versus non-Māori ethnicities, and socioeconomic deprivation index quintile. The ITS analysis is a method that allows comparison of 2 potential changes as a result of an intervention: a change in level and a change in trend. Change in level describes the change in the exacerbation rate immediately after the intervention (in this case, the COVID-19 lockdown). A change in trend corresponds to the difference in the trend (slow change in exacerbation rate over time) between preintervention and postintervention periods. A similar approach has been used in other studies.[10] Statistical significance was defined as P less than .05. All analyses were undertaken using R Studio (V.1.4.1717, Posit PBC, Boston Mass) and R (V4.1.0, University of Auckland, New Zealand).

In a secondary analysis, we quantified the number of patients with asthma, the number of acute asthma hospital admissions and OCS courses, and the actual asthma exacerbation rate within each sociodemographic group in two 10-month periods from March-December 2019 and March-December 2020 to provide further comparative information on the impact of the COVID-19 lockdown across different patient groups. Asthma exacerbation rates were derived for each of the 2 years 2019 and 2020 by dividing the total number of exacerbations in each year by the total number of patients registered in general practice in each study year. Adjusted incidence rate ratios for asthma exacerbations before and after the advent of COVID-19 were then estimated for each sociodemographic group using multivariable Poisson regression, adjusting for age, sex, ethnicity, and deprivation quintile as appropriate. Chi-square tests were used for differences in proportions of patients.

Ethics

The study was approved by the Auckland Health Research Ethics Committee (ethics no. AH23069).

RESULTS

Study population and characteristics

Over the study time frame, the total number of patients registered in primary care (general practice [GP]) from 2015 to 2020 was used for the ITS analysis. This GP population increased from 4,483,436 in 2015 to 4,882,659 in 2020. These patients provided the patient denominators for the calculation of asthma exacerbation rates in each year of the study. Second, an identified asthma patient cohort from 2015 to 2020 was used. This comprised a total of 1,149,690 patients with asthma, which were followed for between 1 and 6 years between 2015 and 2020 to identify all asthma-related exacerbations (Table I).

Exacerbation pattern (during follow-up)

Fig 1 shows the asthma exacerbation rate of the asthma patient cohort for every month during the follow-up period (January 2015 to December 2020) using an ITS model. The figure illustrates the seasonality pattern seen in the exacerbation rate, with the rate gradually increasing from January onward until NZ winter (July), and then gradually decreasing again from August/September until December/January. Fig 2 shows the asthma exacerbation rate by month and year which highlights the reduction in rate for 2020.

TABLE I. ITS analyses—Change in mean monthly exacerbation rates per 1000 patients after March 2020 lockdown

Demographic	Total no. of patients with asthma, N (%)	Intercept (baseline mean exacerbation rate*)	Change in level after lockdown	Change in trend after lockdown	Residual SE
All patients	1,149,690 (100)	4.885	−3.015 ($P < .0001$)	0.268 ($P < .0001$)	1.12
Sex					
Male	517,996 (45.1)	4.412	−2.637 ($P < .0001$)	0.232 ($P < .0001$)	0.97
Female	631,694 (54.9)	5.330	−3.398 ($P < .0001$)	0.307 ($P < .0001$)	1.28
Age group (y)					
<6	205,048 (17.8)	11.520	−8.979 ($P < .0001$)	0.867 ($P < .0001$)	3.14
6-18	196,848 (17.1)	3.682	−3.466 ($P < .0001$)	0.336 ($P < .0001$)	1.11
19-64	603,100 (52.5)	3.868	−2.475 ($P < .0001$)	0.228 ($P < .0001$)	0.95
≥65	144,694 (12.6)	6.176	−2.323 ($P < .0001$)	0.166 ($P < .0001$)	1.13
Ethnic group					
Māori	225,823 (19.6)	6.948	−4.517 ($P < .0001$)	0.499 ($P < .0001$)	1.77
Non-Māori	923,867 (80.4)	4.507	−2.728 ($P < .0001$)	0.223 ($P < .0001$)	1.01
Socioeconomic Deprivation Index†					
1	221,762 (19.3)	3.933	−2.880 ($P < .0001$)	0.244 ($P < .0001$)	0.96
2	209,846 (18.3)	4.098	−2.735 ($P < .0001$)	0.224 ($P < .0001$)	0.98
3	209,092 (18.2)	4.346	−3.044 ($P < .0001$)	0.277 ($P < .0001$)	1.07
4	217,533 (18.9)	4.876	−3.286 ($P < .0001$)	0.310 ($P < .0001$)	1.18
5	242,688 (21.1)	5.635	−4.042 ($P < .0001$)	0.420 ($P < .0001$)	1.38
Unknown‡	48,769 (4.2)	—	—	—	—

*Note that the baseline mean exacerbation rate is based on the entire NZ GP population (shown as monthly rate per 1000 NZ patients enrolled in primary care) at January 2015.
†Higher deprivation index indicates areas with higher socioeconomic deprivation.
‡Some people may not have a permanent residence; hence, their deprivation index cannot be determined.

Table I provides the overall results of the ITS analyses (the exacerbation rates in this table are expressed as the mean monthly exacerbations per 1000 patients). The change in level in the table represents immediate change in exacerbation rate due to lockdown in March 2020. Overall, there was a significant drop in the exacerbation rate immediately after lockdown (−3.02; $P < .0001$) followed by a significant and sustained increase in trend (relative to the prelockdown trend in exacerbation rates). The trend in exacerbation rate postlockdown increased relatively to that of prelockdown (0.27; $P < .0001$).

Table I also presents the results of the ITS analyses when the cohort was stratified by sex, age, ethnicity (Māori vs non-Māori), and deprivation index. Similar postlockdown patterns were observed in all groups. Stratified by sex, there was a significant reduction in the exacerbation rate immediately and an additional increase per month after lockdown for both males and females. Stratified by age, there was a significant drop in exacerbation rates in all age groups, with a notable decrease among the adolescents (<6 years old, −8.98, $P < .0001$, and those aged 6-18 years, −3.47, $P < .0001$) and an additional increase in postlockdown trend compared with prelockdown. When stratified by Māori ethnicity and deprivation index, respectively, there was a significant drop in exacerbations during the lockdown period, with an increasing trend postlockdown across both ethnicity and deprivation groups.

Secondary analysis—Number of individuals with asthma and exacerbations 10 months before and after the first COVID-19 lockdown

In total, there were 507,622 patients identified as having asthma, based on having either acute hospital admissions for asthma or dispensing of asthma medications in 2019 before the advent of the COVID-19 lockdown period. This number reduced to 458,023 patients in 2020 postlockdown (Table II). Of these, 304,977 patients were included in the asthma cohorts of both years. The proportion of patients younger than 6 years identified as having asthma was significantly less following the COVID-19 lockdown in 2020 (8.5%) than in 2019 (11.7%; $P < .001$). The rate of acute hospital admissions for asthma decreased from 9.5 per 1000 patients in 2019 to 6.2 per 1000 patients in 2020, and a decrease in acute asthma admission rates was observed in all patient demographic groups.

The overall asthma exacerbation rate based on all acute asthma admissions and courses of OCSs dispensed to patients with asthma was 33.3% less in 2020 than in 2019 (reduction from 48.6/1000 patients to 32.4/1000 patients), and a significant decrease in asthma exacerbations was evident in all patient demographic groups (Table II).

DISCUSSION

This is the first study in NZ to investigate the effect of the COVID-19 pandemic and associated public health restrictions on asthma exacerbation rates. This is particularly novel because NZ had the strictest lockdown restrictions relative to the rest of the world[12] yet has one of the highest rates of asthma.[18] In NZ, studies have shown the effect of the COVID-19 lockdown on reduced health care utilization in conditions such as acute coronary syndrome hospitalizations[1] and cancer.[19] How the lockdown affected asthma exacerbations is however not yet known. An observational study in NZ reported a reduction in the absolute number of weekly ambulance attendances, particularly attendance to respiratory conditions, by more than 20%.[20] Another study compared hospital admissions data for cardiorespiratory conditions for each week of 2020 with those from 2015 to 2019 and found a reduction in asthma hospital admissions but fell short of conducting statistical testing of differences and did not explore asthma exacerbations that did not require hospitalization.[21] Our study found a

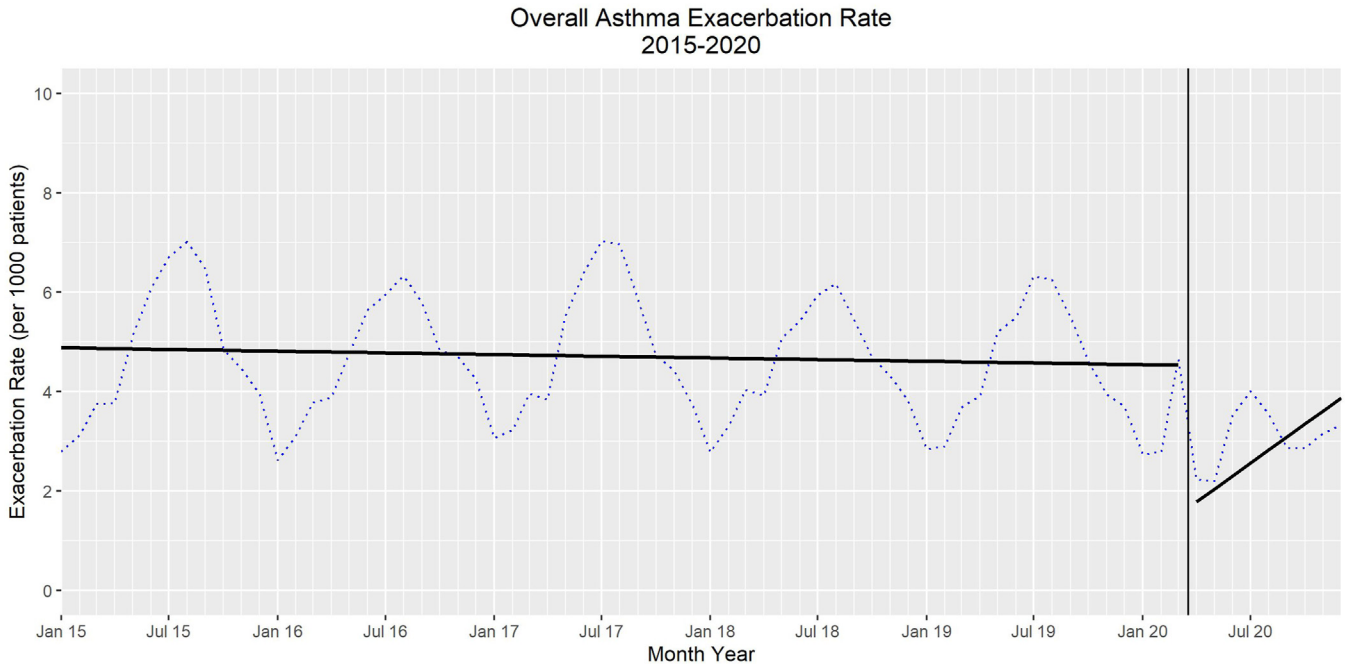

FIG 1. Asthma exacerbation rate time series analysis by month (2015-2020).

significant reduction in asthma exacerbations during the COVID-19 lockdown, a finding that corroborates results from previous studies. This phenomenon was observed in other countries such as the United States, the United Kingdom,[10] Scotland and Wales,[22] the Netherlands,[7] Japan,[23] and Singapore.[24] These studies showed similar trends using a range of methodologies to measure the impact of the lockdown on exacerbations. Several studies also focused only on hospitalizations rather than exacerbations. Our study has the strength of using both the ITS methodology and a traditional pre-post analysis to explore the effect of the COVID-19 lockdown on exacerbations as well as asthma rates and hospital admissions. The ITS analysis allows detection of changes that may be delayed or intermittent following an intervention and because the design compares participants to themselves, the design is likely to be more sensitive to differences in the effects of the intervention. The ITS design is particularly useful to assess the impact of COVID-related lockdown on exacerbation because this approach includes 3 measures of time: (1) study year (to control for secular trends), (2) lockdown period (to test for immediate effects of the lockdown), and (3) several months postlockdown (to test for continuing change in level and trend postlockdown). Traditional regression or pre-post analysis approaches are not able to provide this level of detailed information.

Our study found an overall reduction in asthma exacerbation rate by 33% across all demographic groups. This reduction is similar to the 36% pooled reduction in emergency admissions for asthma observed by Davies et al[22] in Scotland and Wales following lockdown. Our study however captured exacerbations by measuring changes in hospitalizations for asthma and in dispensings of OCSs. We saw a reduction in overall hospital admissions for asthma by 41.6% and in OCS dispensings by 32.6%. This suggests that the reduction in severe exacerbations requiring hospitalization may have been greater than the exacerbations managed in primary care by OCSs. This contrasts with the findings reported by Shah et al, which found a significant reduction in severe asthma exacerbations following lockdown for those managed in primary care with OCSs,[10] but no significant reduction in exacerbations requiring hospital care. This difference may be due to the way exacerbations data are captured in the 2 studies. In the United Kingdom, national primary care data are available, whereas in NZ, there are no national primary care data sets; thus, we were only able to measure exacerbations managed in primary care via OCS dispensings as a proxy marker. We found that most of the exacerbation data were related to OCS use. There is a possibility that this may have overestimated exacerbation rates because OCSs can be used for indications other than for asthma; however, because we only had patients with asthma in the study, the risk is likely to be low. We tried to improve the accuracy of this by including only those OCSs that are used for asthma exacerbations. In contrast, these data may have underestimated asthma hospitalizations because NZ data sets capture hospitalizations only if the patient is admitted but do not capture attendance at emergency departments nor presentation at accident and emergency clinics in the community. However, emergency department or accident and emergency clinic presentation without OCS dispensing is unlikely to be a true exacerbation and our inclusion of OCS dispensing data is likely to capture most outpatient presentations of exacerbations. This is true also for our identification of the asthma cohort because patients were identified with asthma on the basis of their dispensing records of asthma medication and/or presentation to hospital with asthma. It may be that patients are using asthma medication for other reasons (eg, for general shortness of breath or respiratory tract infections, or in the case of inhaled budesonide, for management of COVID-19). Conversely, there are likely patients with asthma who are not captured in this cohort if they do not use regular asthma medication and have not had a hospitalization for asthma. Because this is a database study, the accuracy of the data included also relies on the accuracy of coding captured by the Ministry of Health data sets.

There are several plausible explanations for the reduction in asthma exacerbations observed in NZ. Overall, a reduction in

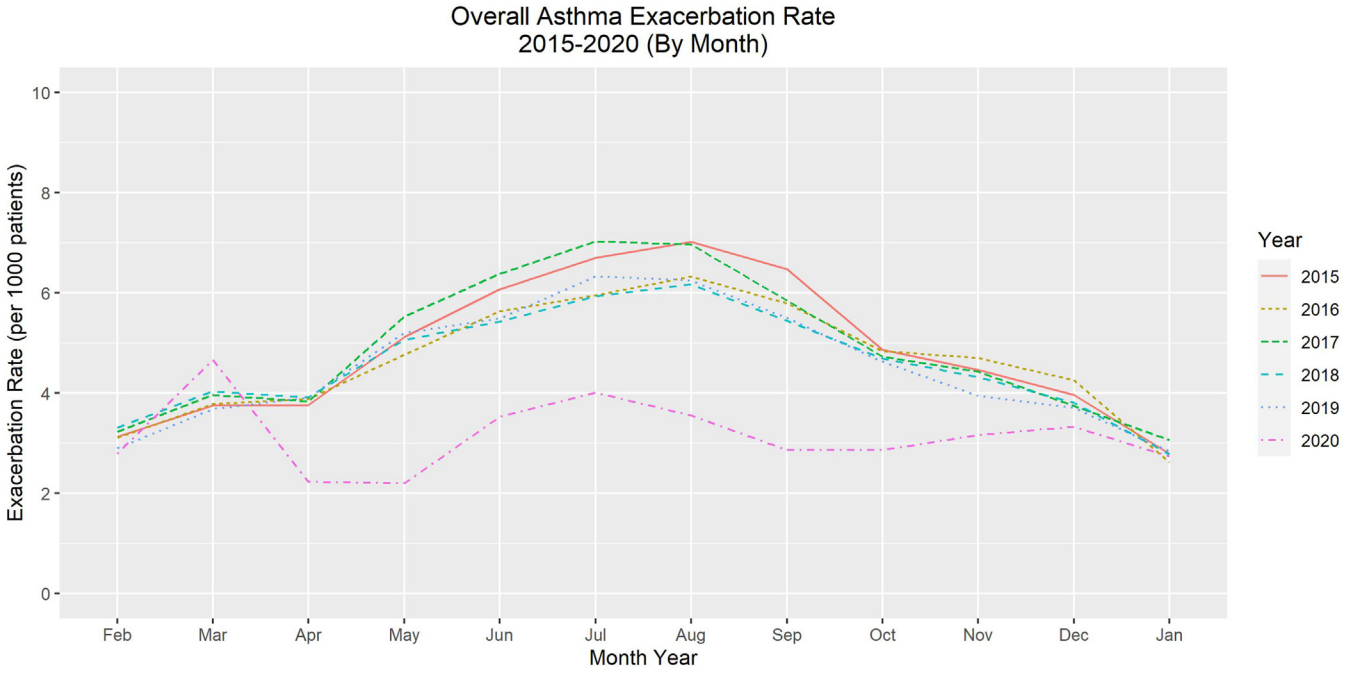

FIG 2. Asthma exacerbation rate by month and year (2015-2020).

health care utilization was observed in general as supported by data showing a reduction in ambulance attendances in NZ, particularly for respiratory presentations.[20] This reduction was likely driven by fear of contracting COVID-19, and concerns about pressures on the health care system.[25] The reduced presentations for respiratory conditions may have reflected reduced transmission of respiratory viruses in general through public health measures such as social distancing and mask wearing. This in turn may have contributed to a reduction in exacerbations because respiratory tract infections are common triggers of asthma symptoms.[26] Other studies have reported an improvement in asthma inhaler adherence and self-management associated with lockdowns.[26-28] There may also have been a shift in the way exacerbations were managed, with less severe exacerbations being managed in primary care rather than in hospitals, which may be why the reduction in OCS dispensing was not as large as the reduction in asthma hospitalizations.

Our data show that although there was a reduction in exacerbation in the immediate period of postlockdown, this increased after lockdown although the postlockdown increase for the entire 2020 is still less than the prelockdown levels. The reasons why exacerbations increased immediately after lockdown is uncertain. It is possible that as the population returned to "normality" as restrictions were reduced, so too did their usual asthma self-management behaviors, such as medication adherence and trigger avoidance. It is unknown whether the decreases seen during the first lockdown in 2020 are observed with other similar lockdowns and whether the changes in behavior associated with public health restrictions such as mask wearing can lead to a sustained improvement in asthma control and reduction in exacerbations. Further research into the behaviors around lockdowns is warranted to explore this. Our study also found clear seasonal patterns in exacerbations, with a sharp decrease in mean hospital-based exacerbation rate in December. This reduction may be due to several factors: the onset of summer, the carryover effects of fewer influenza cases in winter 2020[29] due to COVID-19 public health restrictions, and the closure of the NZ borders to international visitors, which may have reduced the size of public and family gatherings over Christmas in 2020.

Several important points were found in terms of the impact of COVID-19 restrictions on the magnitude of reduction in exacerbations in different sociodemographic groups. Although the restrictions saw a reduction in exacerbation rates across all patients with asthma as seen in our ITS analysis, the changes in exacerbation rates were greatest for Māori, those younger than 6 years, females, and more deprived areas. These findings are important to consider because it may have significant implications for ensuring accessibility of health care services during future pandemics or lockdowns. It appears that public health restrictions affect different sociodemographic groups differently, which may be mediated through differences in health care–seeking behavior during a pandemic. Indeed, ethnicity has been reported to be an important factor to consider for pandemic planning due to differences in cultural, behavioral, and societal differences affecting health-seeking behavior.[30]

This study has some limitations. The Ministry of Health databases contain data registered by health care providers during routine clinical or pharmacy practice, and the data are not specifically collected for research. As such, our study is at risk of well-known biases, such a misclassification bias, differential recording, or missing data. However, medication dispensing data in NZ are of the highest quality, because the data are used for claiming purposes. The registration of subsidized medications in any community pharmacy in a traceable way for each patient and each pharmaceutical product is a legal requirement for reimbursement. Although the ITS method is considered one of the strongest nonexperimental study designs for evaluating the impact of interventions (lockdown in our case) over time, the observed changes in trend and level of asthma exacerbations might have been due to other events that occurred simultaneously

TABLE II. Patients with asthma and asthma exacerbations 10 mo before and after the first COVID-19 lockdown*

	Primary care registered patient population		Patients with asthma† (%)		Acute admissions for asthma		Courses of OCSs		Exacerbations/1000 GP patients‡			
Demographic	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	% change in exacerbations	Adjusted incidence rate ratio (95% CI)§
All patients	4,838,187	4,882,659	507,622	458,023	4,827	2,819	230,351	155,215	48.6	32.4	−33.3%	0.67 (0.66-0.67)
Age (y)												
<6	430,343	425,282	59,473 (11.7)	39,051 (8.5)	1,469	683	38,059	17,061	91.9	43.0	−53.2%	0.47 (0.46-0.48)
6-18	819,992	828,209	90,681 (17.9)	77,695 (17.0)	1,295	767	28,970	16,170	36.9	20.5	−44.4%	0.56 (0.55-0.57)
19-64	2,847,832	2,867,502	280,120 (55.2)	268,168 (58.5)	1,796	1,235	116,640	85,523	41.6	30.3	−27.2%	0.73 (0.73-0.74)
≥65	740,020	761,666	77,348 (15.2)	73,109 (16.0)	267	134	46,682	35,921	63.4	47.3	−25.4%	0.74 (0.73-0.75)
Sex												
Male	2,360,250	2,379,766	226,393 (44.6)	202,475 (44.2)	2,100	1,247	98,392	64,134	42.6	27.5	−35.4%	0.65 (0.64-0.65)
Female	2,477,937	2,502,893	281,229 (55.4)	255,548 (55.8)	2,727	1,572	131,959	91,081	54.4	37.0	−32.0%	0.68 (0.68-0.69)
Ethnicity												
Māori	743,726	749,074	98,177 (19.3)	89,053 (19.4)	1,885	1,119	47,090	33,474	65.9	46.2	−29.9%	0.71 (0.70-0.72)
European	2,973,557	2,972,488	310,380 (61.1)	285,356 (62.3)	1,646	942	135,513	93,627	46.1	31.8	−31.0%	0.69 (0.68-0.69)
Pacific	353,785	356,702	39,681 (7.8)	33,030 (7.2)	740	438	21,670	13,300	63.3	38.5	−39.2%	0.61 (0.60-0.62)
Asian	671,941	703,146	51,139 (10.1)	42,956 (9.4)	469	252	22,211	12,310	33.8	17.9	−47.0%	0.53 (0.52-0.54)
Other	95,178	101,249	8,245 (1.6)	7,628 (1.7)	87	68	3,867	2,504	41.5	25.4	−38.8%	0.61 (0.58-0.64)
Deprivation quintile‖												
1—least deprived	1,012,678	1,015,324	101,475 (20.0)	92,223 (20.1)	546	313	43,077	28,410	43.1	28.3	−34.3%	0.65 (0.64-0.65)
2	934,967	936,761	95,172 (18.7)	85,608 (18.7)	590	376	41,136	26,907	44.6	29.1	−34.8%	0.64 (0.63-0.65)
3	895,965	897,975	94,919 (18.7)	85,841 (18.7)	764	430	41,844	28,384	47.6	32.1	−32.6%	0.66 (0.65-0.67)
4	883,521	885,651	98,496 (19.4)	89,196 (19.5)	1,009	623	45,526	31,420	52.7	36.2	−31.3%	0.67 (0.66-0.68)
5—most deprived	912,428	909,054	109,989 (21.7)	98,191 (21.4)	1,806	1,058	52,869	37,745	59.9	42.7	−28.7%	0.69 (0.68-0.70)

*Before: March-December 2019. After: March-December 2020.

†Based on data showing hospitalization with asthma or dispensing of asthma medication.

‡Exacerbations calculated on the basis of the whole NZ population enrolled in primary care.

§Adjusted incidence rate ratio (IRR) for all exacerbations after vs before COVID-19. Age groups adjusted for sex, ethnicity, and deprivation; sex adjusted for age, ethnicity, and deprivation; ethnicity adjusted for age, sex, and deprivation; deprivation adjusted for age, sex, and ethnicity. $P < .001$ for all adjusted IRRs.

||Deprivation quintile unknown for 7571 patients with asthma in 2019 and 6964 patients in 2020.

with the lockdown. However, we are not aware of any national or regional policies over the study period that could have a major impact on our findings, and the effect of national lockdowns on exacerbations is similar to that reported in other countries. In terms of data completeness, we did not have access to outpatient and emergency visits data, although OCS dispensing was used as a proxy measure for exacerbations managed in these settings. It is possible that exacerbation rates are higher than reported in our study. Lastly, our study did not investigate whether the interventions had an impact on asthma-related mortality or other relevant clinical and economic outcomes. However, only a very small proportion of patients die from asthma in NZ and exacerbations are the key marker of asthma morbidity. Finally, our findings may not be generalizable to other settings outside NZ because contextual factors may play an important role in asthma-related hospital admission and OCS prescription patterns. Nevertheless, our results are useful for informing policies and research on health care presentations during large-scale, unexpected public health events, such as pandemics, natural disasters, or other events that may lead to restrictions on health care provisions.

Conclusions

This study is the first to explore the effect of the COVID-19 pandemic and associated public health restrictions on asthma exacerbation rates in NZ. Our study used a novel methodology combining ITS and a traditional pre-post incidence rate ratio analysis to investigate the impact of the pandemic and lockdown on asthma exacerbation. Our findings showed that the COVID-19 lockdown significantly reduced asthma exacerbation rates across all sociodemographic groups in NZ, and that although rates increased postlockdown, these were still less than prelockdown levels. These results may reflect an overall reduction in health care utilization during this period, as well as improved asthma management during this time. Whether these reductions are sustained into the future remains the subject of future research.

DISCLOSURE STATEMENT

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