

# Consequences of COVID-19 protection measures on children's respiratory health in Aotearoa New Zealand

Claire O'Loughlin, Tali Uia, Cameron Grant, Kirsten Smiler, Marianna Churchward, Catherine Tu'akalau, Rochelle Ellison-Lupena, Mona Jeffreys

## ABSTRACT

**AIM:** To explore the impact of COVID-19 protection measures on children's respiratory health in Aotearoa New Zealand.

**METHOD:** Annual hospitalisation rates (2017/2018 to 2022/2023) for specific respiratory illnesses in children under age 15 years were calculated. Comparisons were made across time and age/sex/ethnicity groups.

**RESULTS:** Hospitalisation rates for respiratory illnesses were lower for all children in the years when COVID-19 protection measures were strictly enforced, followed by an increase in rates in subsequent years. There was an excess of hospitalisations for tamariki Māori and for Pacific children compared with non-Māori, non-Pacific children. Inequities in influenza that were present before the pandemic re-emerged rapidly following the relaxation of COVID-19 protection measures.

**CONCLUSION:** Reducing the burden of respiratory illness in children is a key challenge for health delivery in Aotearoa New Zealand. The re-appearance of inequities across outcomes and age groups following the relaxation or removal of COVID-19 protection measures indicates the need for an effective strategy that embeds learnings from our pandemic response.

Various non-pharmaceutical interventions (NPIs) were used to manage the risk of COVID-19 in Aotearoa New Zealand. These included international border controls; social distancing and national and regional “lockdowns”; test, trace and isolate procedures; mask wearing and enhanced hygiene measures; and a comprehensive public information campaign. Their effects were heralded in the literature as resoundingly successful during the early phases of the pandemic.<sup>1-3</sup>

In addition to keeping rates of COVID-19 at among the lowest levels of any country in 2020 and 2021, these measures resulted in lower rates of other respiratory viral infections and associated respiratory illnesses, as well as disruptions to the seasonal patterns of these virus-associated illnesses.<sup>4-8</sup> It has been proposed that one consequence of these disrupted patterns is the so-called “immunity debt”, where a larger proportion of the population becomes susceptible to a disease following an extended period of reduced exposure.<sup>9,10</sup> For young children, who have not been exposed to maternal antibodies or viral infection in infancy, this immunity gap raises concerns of future and potentially more severe respiratory illnesses as NPIs are relaxed or discontinued worldwide.

Aotearoa New Zealand's own COVID-19 protection

measures began on 3 February 2020 with a ban on foreigners arriving from mainland China, and on 19 March the border was closed to everyone except citizens and permanent residents. A four-tiered Alert Level system was introduced to eliminate COVID-19 on 21 March, and on 25 March the country moved to Alert Level 4—full lockdown—until 27 April 2020. During this period, the public was advised to stay at home in their “bubble” with no travel except for necessities. Gatherings were banned and public and education facilities were closed, along with all businesses except for essential services.<sup>2</sup> A timeline infographic of key events for COVID-19 in Aotearoa New Zealand that covers the period January 2020 to October 2022 plots the subsequent shifts in national and regional alert levels alongside “All-of-Government” and other public sector activities that characterised the ongoing response to the pandemic.<sup>11</sup> On 2 December 2021 the Alert Level system ended, and there was a shift to the COVID-19 Protection Framework (with three “traffic light” settings of red, orange and green). This framework ran from 2 December 2021 to 12 September 2022 and set rules around face masks, capacity limits, local protections and lockdowns for different settings to firstly suppress the Delta variant wave of infection, and subsequently manage the impact of Omicron in

Aotearoa New Zealand.<sup>11</sup>

Following the implementation of a COVID-19 elimination strategy in March 2020, there was a dramatic reduction in the circulation of seasonal respiratory viruses, with a 99.9% reduction in influenza virus detections and a 98.0% reduction in respiratory syncytial virus (RSV) detections during winter 2020 compared with the 2015–2019 reference period.<sup>12</sup> At Kidz First Children's Hospital in South Auckland, a marked reduction in hospitalisations for lower respiratory tract infection (LRTI) among children <2 years of age was observed following the national lockdown, and cases of RSV and influenza plummeted.<sup>13</sup> Hatter et al. highlighted the absence of a seasonal epidemic of national hospital admissions for bronchiolitis in 2020 for children aged 0–4 years.<sup>14</sup> Further, analysis of national rates of children treated in hospital for a range of acute respiratory conditions revealed that hospital admissions halved in 2020.<sup>15</sup>

In 2021, however, a very different pattern emerged. Following the border with Australia reopening in late April 2021, the Institute of Environmental Science and Research's weekly data reports showed a return of RSV, with a rapid increase in cases documented in June 2021.<sup>16</sup> Provisional national data for children aged 0–4 years revealed a peak in hospital discharges for bronchiolitis that was three times higher than average peaks during 2015–2019.<sup>14</sup> Resurgences of RSV infections, including out-of-season peaks, have also been documented across several Northern and Southern hemisphere countries following the removal of COVID-related NPIs.<sup>8,17–19</sup>

In Aotearoa New Zealand, the hospitalisation of young children due to LRTI is both high relative to other developed countries and unequal, with a disproportionate burden of respiratory illness being borne by tamariki Māori, Pacific children and those living in the most deprived households.<sup>15,20,21</sup> In 2020, hospitalisation rates of children and adolescents for respiratory conditions decreased for all ethnic groups and across levels of socio-economic deprivation; however, rates then increased in 2021.<sup>15</sup>

To explore the impact of the introduction, then later removal, of NPIs on the inequitable burden of respiratory illness, we describe trends from 2017/2018 to 2022/2023 in hospitalisation rates for respiratory infections among children in Aotearoa New Zealand.

## Method

Data on numbers of hospitalisations by age, sex

and ethnicity were obtained from the Ministry of Health – Manatū Hauora (MOH) for specific respiratory illnesses, based on the International Classification of Diseases, 10th version (ICD-10). These were extracted from the National Minimum Dataset (NMDS), a national collection of public hospital discharge data, on 10 November 2023. The NMDS records a new entry for each admission–discharge event for encounters including emergency department visits lasting ≥3 hours in duration. The data supplied covered the years 2017/2018 to 2022/2023, with each 12-month period pertaining to a July to June year.

Data in the NMDS are recorded by each individual person's unique National Health Index (NHI) number. Ethnic group was classified using the prioritisation system,<sup>22</sup> in which individuals are allocated to a single ethnic group in an order of priority if they have identified with more than one ethnic group. The first two prioritised groups are Māori then Pacific peoples. All others were included in the non-Māori, non-Pacific group. Thus, if someone identifies as Māori and Samoan, they are reported as Māori only. Discussion of the limitations of this approach is included below.

Population data were obtained from the MOH and were based on annual population projections estimated by Statistics New Zealand using 2018 as the base. These projections are based on post-enumeration surveys to produce population estimates. The same prioritisation of ethnic group was applied to the population data.

Annual hospitalisation rates by age group (0–4 years, 5–9 years and 10–14 years), sex (male and female) and ethnic group (Māori, Pacific, non-Māori/non-Pacific) were calculated by dividing the number of hospitalisations by the population estimates. Eleven events of people with unrecorded sex were excluded from all analyses. Rate ratios with associated 95% confidence intervals (CIs) were calculated over time, using 2017/2018 as the reference year. These were stratified by age group (0–4 years, 5–9 years and 10–14 years) and sex. Further analyses were conducted by ethnic group, using non-Māori, non-Pacific children as the reference group, similarly stratified by age group and sex.

Discharges were grouped by the ICD code on discharge using the following illness categories: acute upper respiratory infections (URTIs; J00–J06); influenza (J09–J11); selected pneumonia, bronchitis and bronchiolitis (J12–J16, J18, J20–J21), referred to as LRTIs; asthma and wheeze (J45–J46, R06.2). Selection of ICD codes for inclusion was based on Cure Kids' *State of Child Health in Aotearoa New Zealand 2022* report.<sup>15</sup>

## Results

The total number and crude rate of hospitalisations in each of the four illness categories across all years of the study are shown in Table 1. In all years other than 2020/2021, the most frequent hospitalisation illness category was LRTIs. The 2020/2021 years were when NPIs were enforced most strictly; during that period, URTIs and asthma/wheeze accounted for a greater number of hospitalisations than LRTIs, and there were virtually no instances of hospitalisation for influenza in 2020/2021. In the latter 2 years the most noticeable increase was for LRTIs and influenza, although in 2022/2023 hospitalisation rates were higher for each outcome than in any of the previous years studied.

The relative hospitalisation rates across time for the four illness categories, by age and sex group, are shown in Table 2. For all children, there was a marked absence of influenza, and significantly lower rates of LRTIs in 2020/2021. For LRTIs, these low rates persisted among children aged 5–14 into 2021/2022. For influenza, the rates increased in all age/sex groups in

2021/2022 to very high rates in 2022/2023. For URTIs, there was an overall pattern of lower rates in 2019/2020 to 2021/2022, with an increase in 2022/2023 to rates that were higher than 2017/2018 in children aged 0–9 years, but not older children. Overall, hospitalisations for asthma/wheeze showed less variation over time, although compared with 2017/2018, rates from 2019/2020 to 2020/2021 were lower, and these remained low for children aged 10–14 years into 2021/2022. In 2022/2023, the rates for children aged 0–9 years were the highest they had been over the 6-year period.

Patterns of hospitalisation rates for the four illness categories, by ethnic group and sex for children aged 0–4 years, 5–9 years and 10–14 years, are shown in Figures 1–4. In virtually all age groups and periods, the rates among Pacific children were higher than among non-Māori, non-Pacific children, other than for influenza in 2020/2021 when there was a near-total absence of the illness in all age and ethnic groups. Among tamariki Māori, the rates were generally higher than in non-Māori, non-Pacific children for asthma/wheeze across all age groups, and for influenza and LRTIs in children aged 0–4 years.

**Table 1:** Hospital discharges among children aged 0–14 years in Aotearoa New Zealand, 2017/2018–2022/2023.

	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023
<b>Acute upper respiratory infections</b>						
Number	7,238	7,734	5,426	6,852	6,050	8,500
Rate per 10,000	76.5	80.9	55.9	70.7	62.7	88.5
<b>Influenza</b>						
Number	384	1,638	686	14	1,089	2,091
Rate per 10,000	4.1	17.1	7.1	0.1	11.3	21.8
<b>Selected pneumonia, bronchitis, bronchiolitis</b>						
Number	9,970	9,147	7,573	4,080	7,887	11,612
Rate per 10,000	105.4	95.7	78.0	42.1	81.8	120.9
<b>Asthma/wheeze</b>						
Number	6,788	6,598	5,556	5,135	6,597	8,572
Rate per 10,000	71.7	69.0	57.2	53.0	68.4	89.3

Due to random rounding at the most detailed level, from which the totals have been calculated, the figures in this table may contain small errors.

**Table 2:** Relative rates of hospital discharges among children aged 0–14 years in Aotearoa New Zealand, 2017–2023.

		0–4 years (F)	0–4 years (M)	5–9 years (F)	5–9 years (M)	10–14 years (F)	10–14 years (M)
		RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
<b>Influenza</b>	<b>2017/2018</b>	1	1	1	1	1	1
	<b>2018/2019</b>	4.47 (3.60–5.55)	4.29 (3.54–5.20)	4.94 (3.51–6.97)	4.39 (3.33–5.80)	2.56 (1.65–3.95)	3.62 (2.39–5.50)
	<b>2019/2020</b>	2.14 (1.69–2.71)	1.63 (1.31–2.03)	1.83 (1.24–2.70)	1.75 (1.28–2.40)	1.28 (0.79–2.09)	1.41 (0.88–2.28)
	<b>2020/2021</b>	0.01 (0.00–0.07)	0.04 (0.02–0.10)	*	0.08 (0.03–0.20)	0.07 (0.02–0.28)	0.03 (0.00–0.24)
	<b>2021/2022</b>	3.10 (2.47–3.88)	2.58 (2.11–3.17)	3.26 (2.27–4.67)	2.54 (1.89–3.42)	3.08 (2.02–4.70)	2.70 (1.76–4.15)
	<b>2022/2023</b>	5.29 (4.27–6.55)	4.82 (3.98–5.83)	8.42 (6.04–11.74)	6.50 (4.96–8.52)	3.04 (1.99–4.64)	5.21 (3.49–7.79)
<b>URTI</b>	<b>2017/2018</b>	1	1	1	1	1	1
	<b>2018/2019</b>	1.04 (0.98–1.09)	1.05 (1.00–1.10)	1.22 (1.06–1.40)	1.26 (1.12–1.41)	0.94 (0.76–1.15)	1.09 (0.89–1.35)
	<b>2019/2020</b>	0.72 (0.68–0.77)	0.77 (0.73–0.81)	0.66 (0.56–0.78)	0.73 (0.64–0.84)	0.63 (0.50–0.79)	0.73 (0.58–0.92)
	<b>2020/2021</b>	0.93 (0.88–0.98)	1.08 (1.03–1.13)	0.56 (0.47–0.66)	0.69 (0.61–0.79)	0.51 (0.40–0.65)	0.55 (0.43–0.71)
	<b>2021/2022</b>	0.86 (0.81–0.91)	0.90 (0.86–0.94)	0.59 (0.50–0.70)	0.69 (0.60–0.78)	0.63 (0.50–0.79)	0.59 (0.46–0.75)
	<b>2022/2023</b>	1.16 (1.10–1.22)	1.22 (1.16–1.27)	1.20 (1.05–1.39)	1.21 (1.08–1.36)	0.98 (0.80–1.20)	0.93 (0.75–1.15)
<b>LRTI</b>	<b>2017/2018</b>	1	1	1	1	1	1
	<b>2018/2019</b>	0.90 (0.86–0.94)	0.92 (0.89–0.96)	1.02 (0.86–1.21)	0.84 (0.71–0.99)	0.91 (0.70–1.19)	1.07 (0.83–1.39)
	<b>2019/2020</b>	0.73 (0.70–0.77)	0.77 (0.74–0.80)	0.76 (0.64–0.91)	0.78 (0.66–0.92)	0.71 (0.53–0.94)	0.62 (0.46–0.84)
	<b>2020/2021</b>	0.37 (0.35–0.40)	0.44 (0.42–0.46)	0.31 (0.24–0.40)	0.35 (0.28–0.44)	0.39 (0.27–0.55)	0.40 (0.28–0.56)
	<b>2021/2022</b>	0.83 (0.79–0.87)	0.82 (0.79–0.85)	0.48 (0.39–0.59)	0.45 (0.37–0.55)	0.41 (0.29–0.57)	0.46 (0.33–0.63)
	<b>2022/2023</b>	1.20 (1.15–1.25)	1.19 (1.14–1.23)	1.15 (0.97–1.35)	0.90 (0.77–1.06)	0.89 (0.68–1.16)	0.89 (0.68–1.16)

**Table 2 (continued):** Relative rates of hospital discharges among children aged 0–14 years in Aotearoa New Zealand, 2017–2023.

		0–4 years (F)	0–4 years (M)	5–9 years (F)	5–9 years (M)	10–14 years (F)	10–14 years (M)
		RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
<b>Asthma/ wheeze</b>	<b>2017/2018</b>	1	1	1	1	1	1
	<b>2018/2019</b>	0.95 (0.88–1.01)	1.01 (0.96–1.06)	0.98 (0.88–1.09)	0.96 (0.88–1.05)	0.74 (0.62–0.87)	0.92 (0.78–1.09)
	<b>2019/2020</b>	0.77 (0.72–0.83)	0.83 (0.78–0.87)	0.86 (0.77–0.97)	0.82 (0.75–0.90)	0.62 (0.52–0.73)	0.89 (0.75–1.05)
	<b>2020/2021</b>	0.73 (0.68–0.78)	0.84 (0.79–0.88)	0.68 (0.60–0.77)	0.69 (0.62–0.76)	0.47 (0.39–0.56)	0.75 (0.63–0.89)
	<b>2021/2022</b>	1.02 (0.96–1.09)	1.09 (1.03–1.14)	0.85 (0.76–0.96)	0.91 (0.83–1.00)	0.45 (0.37–0.54)	0.66 (0.55–0.79)
	<b>2022/2023</b>	1.36 (1.28–1.44)	1.34 (1.28–1.41)	1.20 (1.08–1.33)	1.25 (1.15–1.37)	0.72 (0.61–0.85)	0.90 (0.76–1.06)

RR = rate ratio; 95% CI = 95% confidence interval; URTI = upper respiratory tract infection; LRTI = lower respiratory tract infection.

\*No cases of influenza among females aged 5–9 years were reported in 2020/2021.

For other illness categories and age groups the patterns were mixed.

The hospitalisation rates for influenza were generally greater for children  $\leq 5$  years old compared with older children (Figure 1). Among all age groups, influenza hospitalisation rates, which had peaked in 2018/2019, were virtually zero in 2020/2021. In 2021/2022, these rates rose again, and reached a higher rate in 2022/2023 in most groups than in previous outbreaks—particularly noticeable among Pacific children. Notably, the rise was steeper for Māori and Pacific children aged 0–4 years compared with non-Māori, non-Pacific children, meaning inequities in influenza that were present prior to the pandemic re-emerged rapidly when COVID-19 protection measures were relaxed or discontinued.

Broadly, for children aged 0–9 years similar patterns were seen for hospitalisations for LRTIs (Figure 2). Although the 2020/2021 figures show a narrowing of inequities as the rates decreased in these younger children, the rates increased again subsequently, and for Pacific children were higher than the pre-pandemic rates. For older children (aged 10–14 years), the increase in 2022/2023 of LRTI rates was only evident for Pacific children.

For URTIs, males in each ethnic group aged 0–9 years tended to have higher hospitalisation rates than females. In 2019/2020, hospitalisation rates fell. In the youngest age group, these increased in 2020/2021 and between 2021/2022 and 2022/2023; in Pacific males, rates reached a level not seen in the previous 5 years. In children aged 5–9 years, rates plateaued from 2019/2020 to 2021/2022, and then increased in 2022/2023. In older children, there was a downwards trend from a peak in 2017/2018 and 2018/2019, until 2022/2023 when rates showed a modest increase (Figure 3).

Hospitalisations for asthma or wheeze showed a rather different pattern to influenza and LRTIs (Figure 4). For most age/ethnic groups, there were modest reductions in hospitalisation rates from 2017/2018 to 2020/2021, with these being more marked for older children (aged 10–14 years) and proportionally smaller for younger children. Data on Māori males aged 10–14 years contradicted this pattern. In 2021/2022 and 2022/2023, hospitalisation rates for asthma or wheeze increased for children aged 0–4 and 5–9 years but showed little change for 10–14-year-olds. Pacific children and tamariki Māori had higher hospitalisation rates for these conditions than non-Māori, non-Pacific children.

Hospitalisation rates for tamariki Māori

compared to non-Māori, non-Pacific children are shown in Table 3. For all illness categories, there is an excess of hospitalisations for tamariki Māori under 5 years. These inequities are most marked for LRTIs in this youngest group of children, and extend across all age/sex groups for influenza rates in 2021/2022 and across all age/sex groups and time periods for asthma/wheeze.

Hospitalisation rates for Pacific children compared to non-Māori, non-Pacific children are shown in Table 4. The inequities shown are particularly striking for pre-school-aged children, with relative rates for Pacific children over twice that of non-Māori, non-Pacific children in each year for influenza, LRTIs and asthma/wheeze. Inequities in URTIs are also evident in this age group, but to a lesser degree. Of note is the high relative rate of hospitalisation for influenza in older Pacific children compared to non-Māori, non-Pacific children in 2019/2020, which reduced to virtually none in 2020/2021, but reappeared the following year. Inequities in LRTI rates for older Pacific children have increased over time, being particularly stark in the most recent years (2021/2022 to 2022/2023).

## Discussion

The data presented show changing patterns of hospitalisations for respiratory conditions over a 6-year period, including the years during which COVID-related NPIs were enforced. The dip in rates in 2019/2020 and/or 2020/2021 was seen for each of the four illness categories but was most marked for influenza and least marked for asthma/wheeze and URTIs. For each of influenza, LRTIs and URTIs, the changing trends were most marked for younger children.

This study includes all public hospital discharges across the country for a 6-year period. In Aotearoa New Zealand, all acute infectious disease-related admissions are to public hospitals. A significant limitation of the data for Pacific children arises from the use of prioritised ethnicity.<sup>22</sup> Although this has been used as a mechanism to allow comparison between groups without overlapping categories and causes no issues for the interpretation of Māori data, it results in significant under-counting of Pacific children. We have calculated that in the 2018 Census, of the 125,967 Pacific children aged under 15 years, 30% also reported Māori ethnicity (calculated from <https://explore.data.stats.govt.nz/>). Thus, the data presented here will be an under-estimate of the

Figure 1: Rates of hospital discharges for influenza.

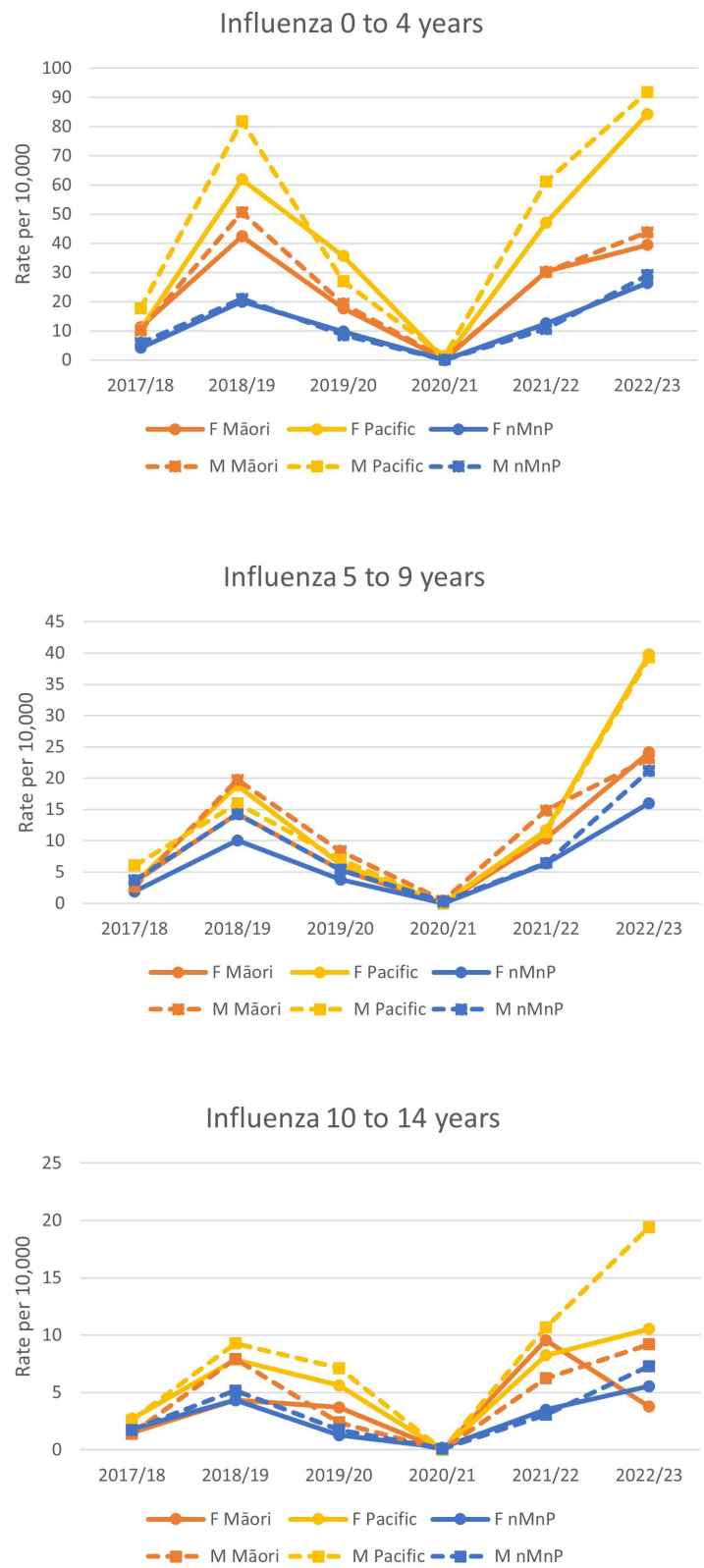
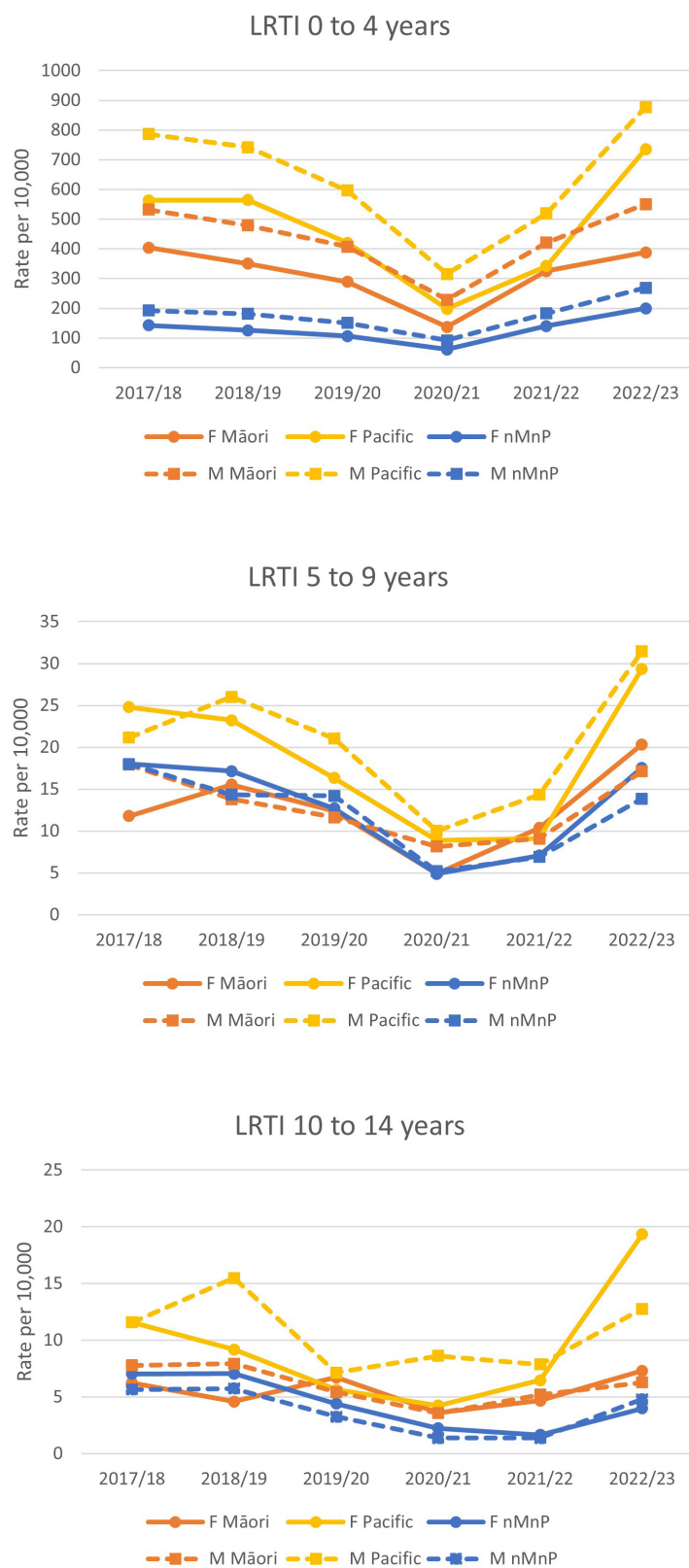


Figure 2: Rates of hospital discharges for lower respiratory tract infections.



**Figure 3:** Rates of hospital discharges for acute upper respiratory tract infections.

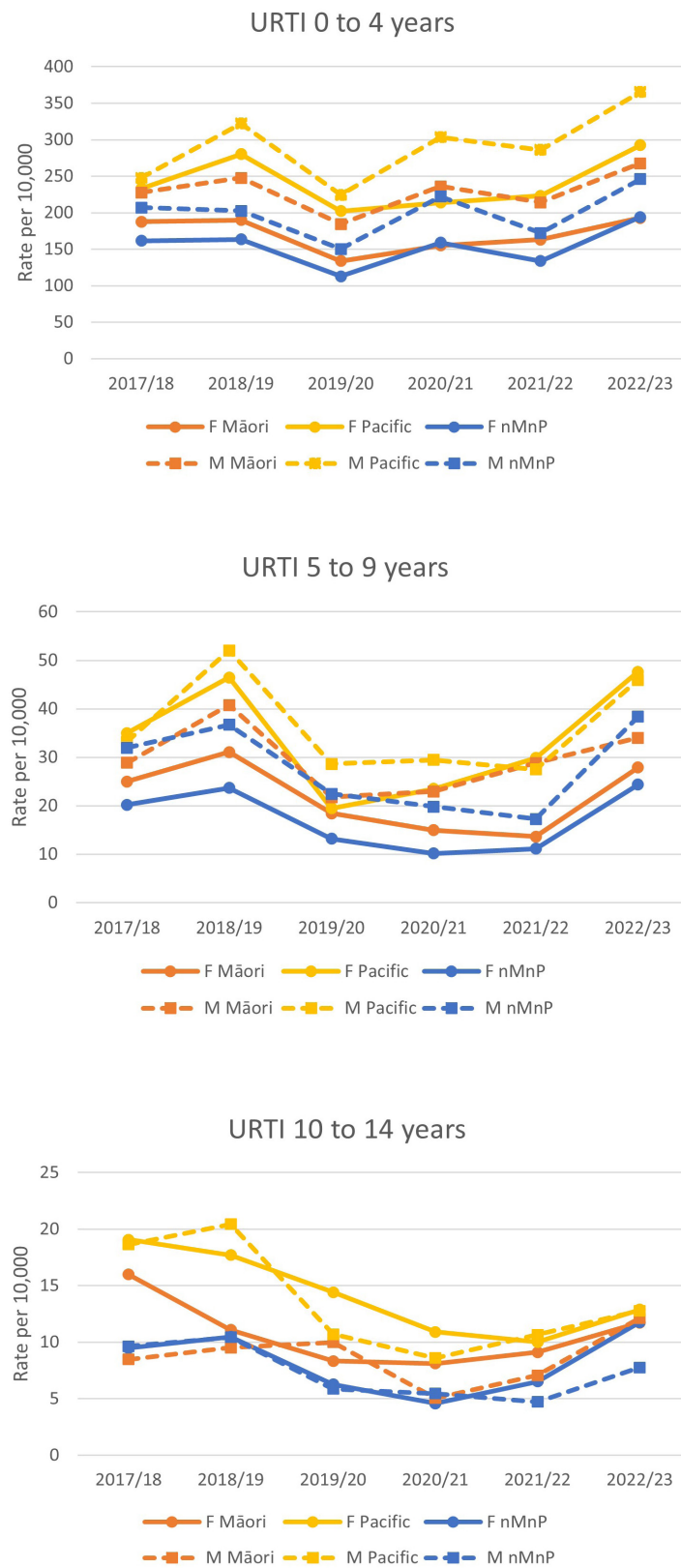
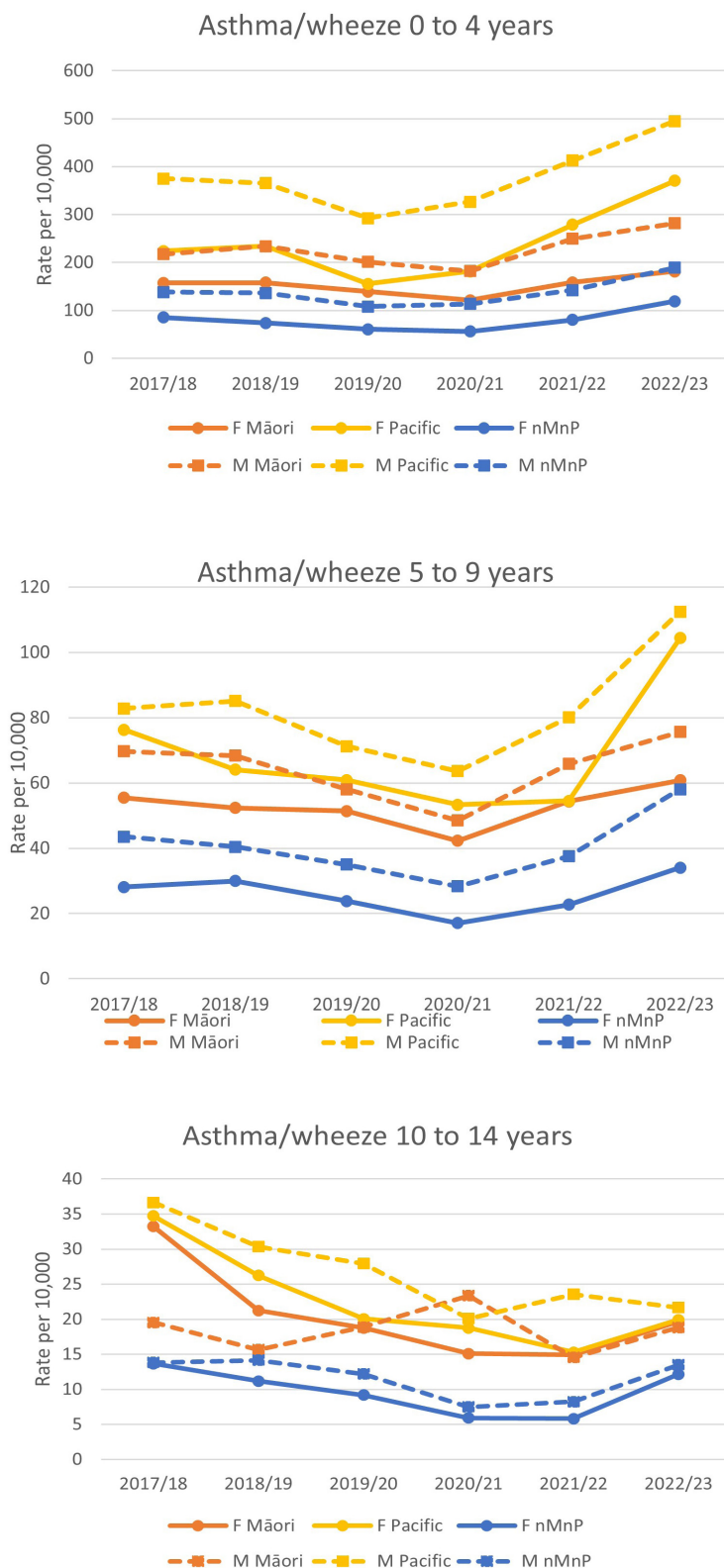


Figure 4: Rates of hospital discharges for asthma/wheeze.



**Table 3:** Relative rates of hospital discharges for Māori compared to non-Māori, non-Pacific children aged 0–14 years in Aotearoa New Zealand, 2017/2018–2022/2023.

		0–4 years (F)	0–4 years (M)	5–9 years (F)	5–9 years (M)	10–14 years (F)	10–14 years (M)
		RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
<b>Influenza</b>	<b>2017/2018</b>	2.70 (1.76–4.13)	1.75 (1.18–2.59)	1.84 (0.93–3.61)	0.71 (0.37–1.36)	0.82 (0.32–2.06)	0.81 (0.32–2.03)
	<b>2018/2019</b>	2.12 (1.72–2.60)	2.41 (2.00–2.92)	1.43 (1.04–1.96)	1.38 (1.07–1.79)	1.00 (0.58–1.74)	1.54 (1.00–2.35)
	<b>2019/2020</b>	1.81 (1.33–2.46)	2.26 (1.67–3.05)	1.41 (0.84–2.36)	1.55 (1.03–2.34)	2.91 (1.40–6.05)	1.35 (0.64–2.84)
	<b>2020/2021*</b>						
	<b>2021/2022</b>	2.42 (1.88–3.12)	2.83 (2.19–3.66)	1.63 (1.11–2.39)	2.31 (1.65–3.25)	2.73 (1.75–4.25)	2.04 (1.25–3.35)
	<b>2022/2023</b>	1.49 (1.23–1.82)	1.51 (1.25–1.81)	1.51 (1.17–1.93)	1.09 (0.86–1.38)	0.68 (0.39–1.17)	1.26 (0.87–1.82)
<b>URTI</b>	<b>2017/2018</b>	1.16 (1.07–1.27)	1.10 (1.02–1.19)	1.24 (0.98–1.56)	0.90 (0.74–1.10)	1.68 (1.23–2.32)	0.88 (0.60–1.29)
	<b>2018/2019</b>	1.16 (1.07–1.26)	1.22 (1.14–1.31)	1.31 (1.06–1.62)	1.11 (0.93–1.32)	1.06 (0.75–1.50)	0.91 (0.64–1.30)
	<b>2019/2020</b>	1.19 (1.07–1.31)	1.23 (1.13–1.34)	1.40 (1.06–1.85)	0.97 (0.77–1.22)	1.33 (0.88–2.00)	1.70 (1.17–2.49)
	<b>2020/2021</b>	0.98 (0.89–1.07)	1.06 (0.99–1.14)	1.47 (1.08–2.02)	1.16 (0.92–1.46)	1.77 (1.15–2.74)	0.93 (0.58–1.49)
	<b>2021/2022</b>	1.22 (1.11–1.34)	1.24 (1.15–1.35)	1.23 (0.89–1.69)	1.67 (1.33–2.09)	1.40 (0.95–2.06)	1.50 (0.97–2.31)
	<b>2022/2023</b>	0.99 (0.91–1.08)	1.09 (1.02–1.17)	1.15 (0.92–1.43)	0.89 (0.74–1.07)	1.00 (0.72–1.38)	1.56 (1.12–2.19)
<b>LRTI</b>	<b>2017/2018</b>	2.83 (2.63–3.04)	2.77 (2.61–2.94)	0.65 (0.48–0.89)	1.00 (0.77–1.29)	0.89 (0.56–1.40)	1.10 (0.73–1.67)
	<b>2018/2019</b>	2.79 (2.59–3.01)	2.65 (2.49–2.82)	0.90 (0.68–1.20)	0.96 (0.72–1.29)	0.65 (0.39–1.08)	1.12 (0.75–1.69)
	<b>2019/2020</b>	2.72 (2.51–2.96)	2.71 (2.53–2.90)	0.98 (0.71–1.34)	0.82 (0.60–1.12)	1.52 (0.96–2.43)	1.23 (0.76–2.01)
	<b>2020/2021</b>	2.24 (1.99–2.51)	2.48 (2.27–2.71)	1.01 (0.60–1.68)	1.57 (1.04–2.39)	1.61 (0.85–3.05)	1.60 (0.85–2.99)
	<b>2021/2022</b>	2.33 (2.16–2.51)	2.31 (2.16–2.46)	1.46 (1.00–2.13)	1.32 (0.90–1.93)	2.82 (1.49–5.35)	3.14 (1.70–5.82)
	<b>2022/2023</b>	1.94 (1.82–2.07)	2.05 (1.94–2.16)	1.16 (0.89–1.50)	1.24 (0.94–1.63)	1.83 (1.16–2.90)	1.57 (0.98–2.52)

**Table 3 (continued):** Relative rates of hospital discharges for Māori compared to non-Māori, non-Pacific children aged 0–14 years in Aotearoa New Zealand, 2017/2018–2022/2023.

		0–4 years (F)	0–4 years (M)	5–9 years (F)	5–9 years (M)	10–14 years (F)	10–14 years (M)
		RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
<b>Asthma/ wheeze</b>	<b>2017/2018</b>	1.85 (1.67–2.05)	1.57 (1.45–1.71)	1.97 (1.66–2.34)	1.60 (1.39–1.85)	2.43 (1.91–3.09)	1.41 (1.08–1.85)
	<b>2018/2019</b>	2.15 (1.93–2.39)	1.72 (1.59–1.87)	1.75 (1.47–2.07)	1.69 (1.46–1.96)	1.90 (1.43–2.51)	1.10 (0.83–1.47)
	<b>2019/2020</b>	2.30 (2.05–2.58)	1.86 (1.70–2.03)	2.16 (1.80–2.59)	1.66 (1.42–1.94)	2.04 (1.51–2.74)	1.55 (1.18–2.03)
	<b>2020/2021</b>	2.16 (1.92–2.45)	1.60 (1.46–1.75)	2.47 (2.01–3.05)	1.71 (1.44–2.03)	2.54 (1.80–3.59)	3.12 (2.35–4.16)
	<b>2021/2022</b>	1.98 (1.78–2.19)	1.76 (1.62–1.90)	2.39 (1.99–2.87)	1.75 (1.51–2.04)	2.55 (1.80–3.62)	1.77 (1.29–2.42)
	<b>2022/2023</b>	1.52 (1.39–1.67)	1.49 (1.39–1.60)	1.78 (1.52–2.10)	1.30 (1.14–1.49)	1.62 (1.24–2.13)	1.40 (1.07–1.82)

Figures displayed are rate ratios for Māori children compared with the reference category of 1.0 for non-Māori, non-Pacific children.

RR = rate ratio; 95% CI = 95% confidence interval; URTI = upper respiratory tract infection; LRTI = lower respiratory tract infection.

\*Very few cases of influenza in 2020/2021 precluded the calculation of RRs.

**Table 4:** Relative rates of hospital discharges for Pacific children compared to non-Māori, non-Pacific children aged 0–14 years in Aotearoa New Zealand, 2017/2018–2022/2023.

		0–4 years (F)	0–4 years (M)	5–9 years (F)	5–9 years (M)	10–14 years (F)	10–14 years (M)
		RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
<b>Influenza</b>	<b>2017/2018</b>	2.51 (1.38–4.55)	3.05 (1.93–4.82)	1.68 (0.63–4.51)	1.64 (0.82–3.29)	1.48 (0.50–4.38)	1.47 (0.50–4.33)
	<b>2018/2019</b>	3.10 (2.41–3.99)	3.90 (3.12–4.87)	1.87 (1.25–2.81)	1.12 (0.74–1.69)	1.82 (0.96–3.44)	1.80 (1.01–3.18)
	<b>2019/2020</b>	3.65 (2.59–5.13)	3.16 (2.18–4.59)	1.65 (0.82–3.31)	1.30 (0.70–2.42)	4.43 (1.89–10.37)	4.04 (1.96–8.32)
	<b>2020/2021*</b>						
	<b>2021/2022</b>	3.76 (2.78–5.08)	5.73 (4.33–7.59)	1.84 (1.09–3.10)	1.77 (1.06–2.94)	2.35 (1.27–4.36)	3.49 (1.99–6.14)
	<b>2022/2023</b>	3.19 (2.56–3.97)	3.15 (2.57–3.87)	2.49 (1.85–3.34)	1.86 (1.41–2.45)	1.90 (1.12–3.23)	2.66 (1.79–3.97)
<b>URTI</b>	<b>2017/2018</b>	1.44 (1.28–1.62)	1.20 (1.07–1.33)	1.73 (1.29–2.33)	1.04 (0.78–1.38)	2.01 (1.32–3.07)	1.93 (1.28–2.92)
	<b>2018/2019</b>	1.71 (1.54–1.91)	1.59 (1.44–1.75)	1.96 (1.51–2.55)	1.42 (1.13–1.79)	1.69 (1.11–2.58)	1.96 (1.33–2.89)
	<b>2019/2020</b>	1.79 (1.57–2.04)	1.50 (1.33–1.68)	1.48 (1.00–2.18)	1.27 (0.94–1.73)	2.30 (1.43–3.70)	1.83 (1.08–3.08)
	<b>2020/2021</b>	1.35 (1.19–1.52)	1.37 (1.24–1.51)	2.31 (1.59–3.37)	1.49 (1.09–2.03)	2.38 (1.38–4.10)	1.58 (0.90–2.78)
	<b>2021/2022</b>	1.67 (1.48–1.89)	1.66 (1.50–1.85)	2.69 (1.91–3.79)	1.59 (1.15–2.20)	1.54 (0.90–2.61)	2.26 (1.34–3.83)
	<b>2022/2023</b>	1.51 (1.36–1.67)	1.48 (1.36–1.63)	1.95 (1.50–2.54)	1.20 (0.94–1.53)	1.10 (0.70–1.72)	1.65 (1.04–2.61)
<b>LRTI</b>	<b>2017/2018</b>	3.95 (3.62–4.30)	4.09 (3.81–4.39)	1.38 (0.98–1.95)	1.17 (0.82–1.68)	1.64 (0.97–2.80)	1.64 (0.98–2.76)
	<b>2018/2019</b>	4.50 (4.12–4.91)	4.10 (3.81–4.41)	1.35 (0.95–1.93)	1.81 (1.30–2.53)	1.30 (0.73–2.31)	2.19 (1.39–3.46)
	<b>2019/2020</b>	3.96 (3.58–4.37)	3.97 (3.66–4.30)	1.29 (0.85–1.96)	1.48 (1.03–2.13)	1.28 (0.63–2.62)	1.62 (0.86–3.06)
	<b>2020/2021</b>	3.23 (2.80–3.72)	3.42 (3.07–3.82)	1.82 (1.01–3.30)	1.93 (1.12–3.33)	1.89 (0.81–4.41)	3.85 (2.01–7.37)
	<b>2021/2022</b>	2.45 (2.21–2.71)	2.85 (2.62–3.09)	1.29 (0.72–2.28)	2.08 (1.31–3.30)	3.92 (1.83–8.36)	4.75 (2.34–9.64)
	<b>2022/2023</b>	3.68 (3.42–3.96)	3.26 (3.06–3.48)	1.67 (1.20–2.32)	2.27 (1.65–3.11)	4.85 (3.07–7.67)	3.20 (1.92–5.34)

**Table 4 (continued):** Relative rates of hospital discharges for Pacific children compared to non-Māori, non-Pacific children aged 0–14 years in Aotearoa New Zealand, 2017/2018–2022/2023.

		0–4 years (F)	0–4 years (M)	5–9 years (F)	5–9 years (M)	10–14 years (F)	10–14 years (M)
		RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
<b>Asthma/ wheeze</b>	<b>2017/2018</b>	2.63 (2.31–2.99)	2.71 (2.46–2.99)	2.71 (2.19–3.35)	1.90 (1.57–2.30)	2.54 (1.84–3.51)	2.65 (1.95–3.60)
	<b>2018/2019</b>	3.18 (2.79–3.62)	2.69 (2.44–2.96)	2.14 (1.71–2.67)	2.11 (1.75–2.54)	2.34 (1.63–3.36)	2.14 (1.55–2.96)
	<b>2019/2020</b>	2.57 (2.20–2.99)	2.71 (2.43–3.02)	2.56 (2.02–3.24)	2.04 (1.66–2.50)	2.18 (1.46–3.25)	2.29 (1.64–3.20)
	<b>2020/2021</b>	3.24 (2.79–3.76)	2.87 (2.59–3.19)	3.12 (2.40–4.04)	2.24 (1.80–2.79)	3.16 (2.05–4.87)	2.68 (1.81–3.99)
	<b>2021/2022</b>	3.48 (3.08–3.93)	2.91 (2.65–3.19)	2.40 (1.87–3.08)	2.13 (1.75–2.59)	2.62 (1.66–4.15)	2.86 (1.99–4.13)
	<b>2022/2023</b>	3.11 (2.81–3.45)	2.62 (2.41–2.84)	3.06 (2.54–3.70)	1.94 (1.64–2.28)	1.64 (1.12–2.39)	1.61 (1.13–2.29)

Figures displayed are rate ratios for Pacific children compared with the reference category of 1.0 for non-Māori, non-Pacific children.

RR = rate ratio; 95% CI = 95% confidence interval; URTI = upper respiratory tract infection; LRTI = lower respiratory tract infection.

\*Very few cases of influenza in 2020/2021 precluded the calculation of RRs.

true acute respiratory illness burden experienced by Pacific children. Furthermore, we based our data on the ICD codes used in the 2022 Cure Kids report.<sup>15</sup> We note that J22 (unspecified acute lower respiratory infection) was not included in the 2022 report but is included in the recently published 2023 report. This omission could affect our results if there is differential use of the code across age/sex/ethnicity groups; we are unable to assess the impact of this within the current study.

Given the nature of our study design, we were unable to ascribe hospitalisations to a causative agent (cf. Trenholme et al. 2021).<sup>13</sup> Moreover, given that the data pertain to a July to June year, winter peaks cannot be easily ascribed to one year or another, since the winter period overlaps these. An important observation in Aotearoa New Zealand is the changing pattern of RSV infections, which has been previously described.<sup>12,20</sup> In our study, most RSV infections would likely have been captured in the LRTI group, which includes pneumonia, bronchitis and bronchiolitis; this category will also include non-RSV diseases. In addition, RSV can lead to URTI or the exacerbation of asthma/wheeze, particularly viral wheeze in preschool children. Patterns of causative agents of respiratory infections (both community and hospital) in 2020/2021 in Australia and Aotearoa New Zealand have recently been described, including peaks of RSV and rhinovirus activity and an absence of influenza.<sup>23</sup>

It is important to consider non-causal reasons for the observed trends. These could include changes in the threshold for admissions based on the severity of illnesses due to health sector pressures. The changes in viral panel testing during the pandemic could also have differentially affected clinical diagnoses. Furthermore, lower access to primary healthcare, both due to concerns of accessing health services while COVID-19 was a threat<sup>24,25</sup> as well as the more recent issues of closed books<sup>26</sup> and inability to get general practitioner appointments, could have affected rates of hospital admissions for respiratory illnesses among children.

Importantly, we demonstrate the reappearance of pre-existing inequities in respiratory health in the years following the relaxation or removal of COVID-related NPIs. The inequities in respiratory disease for tamariki Māori identified in our study are consistent with previous research that illustrates the significant health inequities Māori experience across multiple health domains.<sup>27</sup> The inequities are driven by the ongoing experience

of colonisation and the harm caused by societal structures that systematically disadvantage Māori.<sup>28</sup> The causal mechanisms between colonisation and health inequities have been identified, beginning with the basic causes of racism and discrimination through to medial drivers of socio-economic opportunities and health systems.<sup>29</sup> Across this pathway Māori experience systemic racism,<sup>30</sup> barriers to accessing care<sup>31</sup> and fewer socio-economic resources<sup>32</sup> than non-Māori, non-Pacific. The re-emergence of pre-existing respiratory inequities is therefore unsurprising given COVID-related NPIs reduced the spread of infection but did little to address the underlying basic causes.

For Pacific children, who had higher rates of respiratory illnesses prior to the pandemic, the re-appearance of inequities is even more stark, with hospitalisation rates in 2022/2023 for many age/sex/illness categories being higher than in pre-COVID years. We postulate that this could be due to a combination of factors. The broader socio-economic determinants of health affect respiratory health, including living in crowded and poorly insulated houses.<sup>33</sup> Pacific children are disproportionately more likely to be living in households experiencing material hardship, food insecurity or housing issues, including household crowding,<sup>34,35</sup> all factors which may have been exacerbated by the current cost of living crisis. However, the higher rates of respiratory disease for Pacific peoples are not fully explained by area-level deprivation.<sup>36</sup> The health challenges experienced by Pacific peoples are also influenced by systemic racism, discrimination and unconscious biases within healthcare structures.<sup>37-39</sup> These biases may extend to children through their caregivers, as caregivers often engage with health services on behalf of their children.<sup>40</sup> Each of these factors, either individually or in combination, could be potential explanations for the observed patterns that we demonstrate.

The higher rates of hospitalisations in young children for illnesses due to infectious causes seen in our results are consistent with the concept of immunity debt.<sup>9,10</sup> For example, the absence of RSV circulation for one season when COVID-related NPIs were in place has been argued to have resulted in a change in population immunity, with absence of exposure to RSV resulting in a waning in immunity and hence more severe disease when re-exposure occurred. While this concept has been discussed predominantly in relation to infants and young children, a recent

paper examining temporal changes in RSV epidemiology in Aotearoa New Zealand in the post-COVID era showed that this effect was seen across the whole population.<sup>41</sup>

Results for asthma/wheeze showed persisting inequities in hospitalisations, which is consistent with previous findings.<sup>42</sup> Preschool wheeze is the most common cause of hospital admission in the preschool age group in Aotearoa New Zealand.<sup>43</sup> It is frequently a recurring problem with affected children having multiple hospital presentations. An excessive inflammatory response to a respiratory viral infection is the central underlying process leading to recurrent disease. That wheeze admissions have increased in this age group since COVID-19 is another indicator of changes in immune system function in the post-COVID era. Lower access to primary care in the post-COVID era is another potential explanation for the increase in asthma-related admissions.<sup>26</sup>

The national immunisation schedule includes vaccines for respiratory health, specifically against pertussis, pneumococcal disease and *Haemophilus influenzae* type b, along with a targeted influenza vaccine for high-risk children—although in 2022/2023 this was briefly funded for all children aged 3–12 years, and then 6 months–12 years. However, vaccine coverage has never been equitable in Aotearoa New Zealand. Coverage for tamariki Māori has been consistently lower than for all other ethnic groups; prior to the onset of the COVID-19 pandemic, Pacific children had high immunisation rates at 12 and 24 months, though not at 6 months.<sup>44</sup> However, since the 2020 lockdowns the rates for tamariki Māori and for Pacific children have fallen substantially.<sup>25,44</sup> Strengthening support for both Māori and Pacific providers to address declining levels of vaccine coverage is likely to reverse the worrying trends.

The adverse impacts of the cost of living and

health service crises in the recent years are likely to have impacted on childhood hospitalisations. Māori and Pacific providers worked hard during the pandemic to meet the needs of communities that were not being met by the national response.<sup>39,45</sup> However, the current data cannot assess the separate impact of these activities on non-COVID hospitalisations. While we have described how COVID-related NPIs reduced hospitalisations for respiratory illnesses in children across ethnic groups, we are not suggesting that the *drivers* of health inequities were affected by COVID-19 restrictions. Rather, the wider determinants of health inequities are likely to have been amplified by the pandemic, and their impacts on respiratory hospitalisations reappeared when NPIs were removed.

In summary, our results support the call by Baker and colleagues<sup>46</sup> for a continued mitigation strategy not only for COVID-19 but also for other respiratory illnesses, which builds on learnings from our pandemic response. The central tenets of this approach that integrates COVID-19 control measures with those for seasonal respiratory infections such as influenza and RSV are: i) an enhanced system for delivering vaccinations to ensure high and equitable coverage, ii) the promotion of testing and self-isolation when unwell, supported by paid sick leave, and iii) measures to minimise the transmission of respiratory pathogens in key indoor environments, including schools. In order to be successfully implemented, an evidence-based approach supported by culturally responsive partnerships with both Māori and Pacific primary care providers is necessary. This has the potential to alter the worrying patterns of the re-appearance of inequities we have demonstrated, leading to improvements in respiratory health among children in Aotearoa New Zealand.

**COMPETING INTERESTS**

Nil.

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**AUTHOR INFORMATION**

Dr Claire O'Loughlin: Research Fellow, Te Hikuwai Rangahau Hauora | Health Services Research Centre, Te Herenga Waka – Victoria University of Wellington, Aotearoa New Zealand.

Tali Uia: Research Assistant, Te Hikuwai Rangahau Hauora | Health Services Research Centre, Te Herenga Waka – Victoria University of Wellington, Aotearoa New Zealand.

Dr Cameron Grant: Head of Department – Paediatrics, Child & Youth Health, Professor in Paediatrics, The University of Auckland, Aotearoa New Zealand; Paediatrician, Starship Children's Hospital, Auckland, Aotearoa New Zealand.

Dr Kirsten Smiler: Manutaki Takirua, Te Hikuwai Rangahau Hauora | Co-director, Health Services Research Centre, Aotearoa New Zealand; Pūkenga Matua, Hauora Māori, Te Kura Tātai Hauora | Senior Lecturer, Māori Health, School of Health, Te Herenga Waka – Victoria University of Wellington, Aotearoa New Zealand.

Dr Marianna Churchward: Pacific Senior Research Fellow, Te Hikuwai Rangahau Hauora | Health Services Research Centre, Te Herenga Waka – Victoria University of Wellington, Aotearoa New Zealand.

Catherine Tu'akalau: Nurse Practitioner, Pacific Health Plus, Porirua, Aotearoa New Zealand; Pacific Health Service Hutt Valley, Naenae, Hutt Valley, Aotearoa New Zealand.

Dr Rochelle Ellison-Lupena: Pūkenga, Hauora Māori, Te Kura Tātai Hauora | Lecturer, Māori Health, School of Health, Te Herenga Waka – Victoria University of Wellington, Aotearoa New Zealand.

Dr Mona Jeffreys: Associate Professor (Research), Te Hikuwai Rangahau Hauora | Health Services Research Centre, Te Herenga Waka – Victoria University of Wellington, Aotearoa New Zealand.

**CORRESPONDING AUTHOR**

Dr Claire O'Loughlin: Te Hikuwai Rangahau Hauora | Health Services Research Centre, Te Herenga Waka – Victoria University of Wellington, PO Box 600, Wellington 6140, Aotearoa New Zealand.  
E: [claire.f.loughlin@vuw.ac.nz](mailto:claire.f.loughlin@vuw.ac.nz)

**URL**

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