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Original article

Pertussis notifications decline in Australia during COVID-19 non-pharmaceutical interventions, 2020–2021

Saskia van der Kooi, Frank Beard, Aditi Dey, Peter McIntyre, Chrissy Imai, Janaki Amin

Abstract

Background

Following implementation of coronavirus diseases 2019 (COVID-19) non-pharmaceutical interventions (NPIs) in early 2020, declines in the incidence of other respiratory pathogens have been reported. This study aimed to assess the impact of these interventions on pertussis notifications in Australia.

Methods

We compared monthly national notification rates for pertussis during the first two years of the COVID-19 pandemic (2020 and 2021) to those during the three pre-pandemic years (2017 to 2019). Incidence rate ratios (IRR) by age group and jurisdiction were calculated for 2020 and 2021 compared to the mean pre-pandemic annual notification rate.

Results

A substantial progressive decline in pertussis notifications was seen across all age groups, with all-age notification rates more than 40% lower than the pre-pandemic period in all jurisdictions in 2020, and more than 80% lower in 2021. Notification rates decreased more slowly from a lower baseline in Victoria than in other states and territories, despite the stricter, more sustained NPIs implemented in Victoria.

Conclusion

The significant decrease in pertussis notifications across all jurisdictions and age groups has likely resulted in reduced infection-acquired immunity, making maintenance of high vaccine uptake, particularly among pregnant women and young infants, of key importance.

Keywords: pertussis; VPD; COVID-19; nonpharmaceutical interventions; Australia

Introduction

Pertussis is a highly contagious, acute respiratory disease caused by droplet transmission of the *Bordetella pertussis* bacterium.[1] In Australia, where pertussis infection remains endemic, notifications display multiannual cycles, with epidemic peaks every three to four years.[2] Between 2013 and 2018, pertussis was the second most frequently notified vaccine-preventable disease (VPD) in Australia, after influenza, with the highest national notification rates among children aged 9–11 years, followed by those aged 3 years.[1] The highest morbidity and mortality from pertussis infection occurs in infants under 3 months of age, who are too young to receive more than one vaccine dose, with protection relying on maternal immunisation.[3,4] Between 2013 and 2017, infants under 2 months of age and those aged 2–3 months had the highest mean annual pertussis hospitalisation rates (143 and 138 per 100,000 population respectively) of any age group.[1]

In March 2020, after the World Health Organization (WHO) declared coronavirus disease 2019 (COVID-19) a pandemic,[5] Australia adopted a range of non-pharmaceutical interventions (NPIs) to control disease transmission, including national and jurisdictional border closures, stay at home orders, and mask mandates.[6] In addition to the near elimination of COVID-19 in 2020, COVID-19-targeted public health measures dramatically reduced the transmission of other infectious diseases.[7,8] This was most notable for viral infections transmitted by the respiratory route, such as respiratory syncytial virus (RSV) and influenza.[9–13] Declines in pertussis notifications following implementation of COVID-19 NPIs have been reported in early national and regional data,[7,13,14] but longer-term data analyses by jurisdiction and age group are lacking. We compared notification data in 2020 and 2021 with three pre-pandemic years by jurisdiction and age group.

Methods

Study design

In this descriptive study, we examined trends in pertussis notifications during 2020 and 2021 against the three years 2017 to 2019. We did not include the years 2015 and 2016 in the comparator period because both were pertussis epidemic years.[1]

Data

Pertussis is a notifiable disease under public health legislation in all states and territories. Registered medical practitioners and pathology laboratories are required to report cases to state and territory health departments, which supply de-identified data to the National Notifiable Diseases Surveillance System (NNDSS).[15] For surveillance purposes, a confirmed pertussis case requires laboratory evidence such as isolation of *B. pertussis* by culture or detection by nucleic acid testing, and a probable case requires both clinical and epidemiological evidence.[16] Monthly pertussis notification data stratified into five-year age groups between January 2015 and December 2021 were obtained from the NNDSS.

Timeline of state and territory public health measures

Chronologies of COVID-19 public health measures for each state and territory (stay at home orders [lockdowns] and associated mandatory wearing of face masks outside the home) were sourced from reports published by the Parliament of Australia,[6] from the Australian Bureau of Statistics (ABS),[17] and from state and territory Government media releases.

Analysis

For each jurisdiction, we compared mean monthly pertussis notifications for the pre-pandemic period (2017–2019) to notifications for each month in 2020 and 2021. Annual notification rates per 100,000 population were calculated by dividing the total annual pertussis notifications by the mid-year estimated population of each jurisdiction and multiplying by 100,000. Population data were sourced from the ABS Quarterly Population Estimates.[18] Incidence rate ratios and 95% confidence intervals (IRR, 95% CI) were calculated for the annual notification rate for 2020 and 2021 compared to the mean annual notification rate for 2017 to 2019.

Age-stratified notification rates and IRRs were calculated for the age groups 0–4, 5–14, 15–24, 25–69, and ≥ 70 years for each jurisdiction and nationally.

Data were analysed using Stata 17.0.

Ethics

Institutional ethics approval was provided by the Macquarie University Human Research Ethics Committee (HREC520221151037299).

Results

Pertussis notifications

Australia

Between 2017 and 2021, a total of 40,850 pertussis notifications were recorded in the NNDSS. Annual notification rates were between 47.5 and 50.4 per 100,000 population between 2017 and 2019, before falling steeply to 13.5 per 100,000 in 2020 and to 2.1 per 100,000 in 2021. Compared to the 2017 to 2019 mean of 49.2 per 100,000 population, notification rates were 72.6% lower in 2020 (IRR: 0.27; 95% CI: 0.26–0.28) and 95.6% lower in 2021 (IRR: 0.04; 95% CI: 0.04–0.05) (Table 1).

By jurisdiction

In the pre-pandemic period, between 2017 and 2019, the highest mean annual notification rates per 100,000 population were in New South Wales (74.9), followed by Tasmania (64.3) and the Australian Capital Territory (63.5). The lowest were in the Northern Territory (28.9) and Victoria (30.0).

During 2020 and 2021, all jurisdictions saw a substantial and sustained decline in pertussis notifications (Appendix A, Table A.1). In 2020, five states and territories had declines greater than the national average of 72.6%: Western Australia (89.1%; IRR: 0.11 [95% CI: 0.09–0.13]), Tasmania (81.4%; IRR: 0.19 [95% CI: 0.14–0.24]), Australian Capital Territory (80.8%; IRR 0.19 [95% CI: 0.14–0.26]), the Northern Territory (78.8%; IRR: 0.21 [95% CI: 0.11–0.37]), and New South Wales (78.4%; IRR: 0.22 [95% CI: 0.20–0.23]). Victoria had the smallest reduction (45.8%; IRR: 0.54 [95% CI: 0.50–0.58]).

In 2021, all-age pertussis notifications were lower by more than 90% compared to the pre-pandemic period in all jurisdictions other than Victoria (84.6%).

By age group

Between 2017 and 2019, the highest age-specific mean annual notification rates per 100,000 population in Australia were in children aged 5–9 years (165.7) and 10–14 years (137.7), followed by children aged 0–4 years (98.3). Annual notification rates in 2020 and 2021 were substantially lower across all age groups compared to the 2017 to 2019 mean (Appendix A, Figure A.1).

Compared to the pre-pandemic period, the largest decrease in national notifications was observed in the 5–14 years age group: 79.7% (IRR: 0.20 [95% CI: 0.18–0.22]) in 2020 and 98.8% (IRR: 0.01 [95% CI: 0.01–0.01]) in 2021, followed by the 0–4 years age group: 75.2% (IRR: 0.25 [95% CI: 0.22–0.28]) in 2020 and 97.0% (IRR: 0.03 [95% CI: 0.02–0.04]) in 2021. Trends by age group were broadly similar in all jurisdictions (Appendix A, Table A.1).

Time trends by jurisdiction

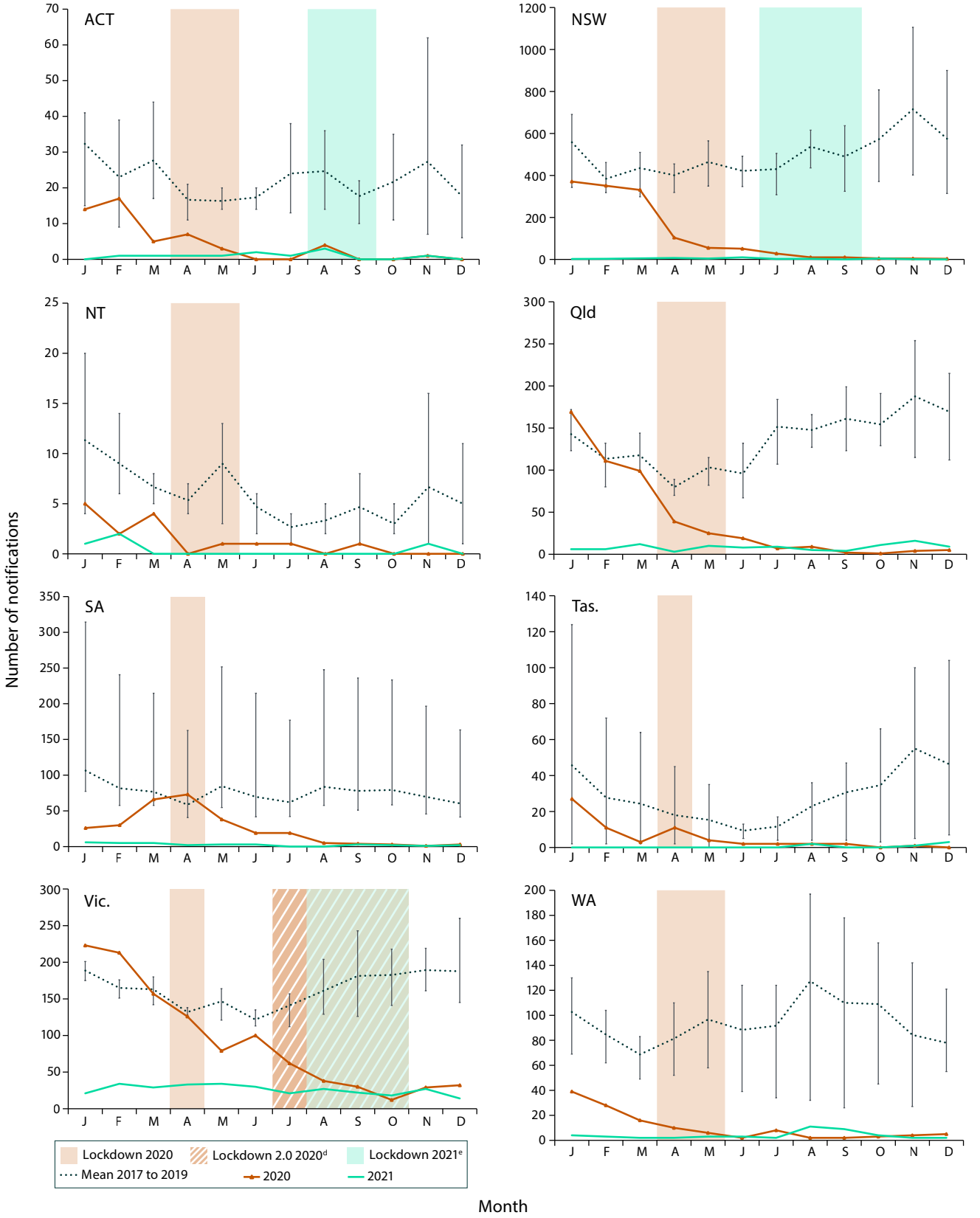
Figure 1 shows jurisdictional trends in all-age monthly pertussis notifications in relation to state and territory public health measures comprising lockdown periods and mask mandates. In 2020, pertussis notifications decreased following the national lockdown, which commenced in late March, with a marked immediate fall in New South Wales, the Northern Territory, and Queensland, and more gradual decline in other jurisdictions. Throughout 2021, pertussis notifications remained well below the 2017 to 2019 mean in all states and territories, although Victoria had consistently higher notifications.

Table 1: Pertussis notification rates for 2020 and 2021 compared to the 2017 to 2019 mean annual rate, by age group, Australia

Age group (years)	Notification rate per 100,000 population per year			2020 vs. 2017–2019[a]		2021 vs. 2017–2019[a]	
	2017 to 2019 mean	2020	2021	IRR	95% CI	IRR	95% CI
0–4	98.3	24.5	3.0	0.25	0.22–0.28	0.03	0.02–0.04
5–14	152.1	30.9	1.7	0.20	0.18–0.22	0.01	0.01–0.01
15–24	38.4	13.0	1.7	0.37	0.33–0.42	0.05	0.04–0.07
25–69	29.3	9.8	2.3	0.34	0.32–0.36	0.08	0.07–0.09
≥ 70	24.9	7.6	1.9	0.31	0.26–0.36	0.08	0.06–0.10
Overall	**49.2**	**13.5**	**2.1**	**0.27**	**0.26–0.28**	**0.04**	**0.04–0.05**

a IRR: incidence rate ratio. 95% CI: 95% confidence interval.

Figure 1: Monthly notifications by jurisdiction, Australia, for 2020 and 2021 compared to the 2017–2019 monthly mean[a,b,c]



a Maxima and minima for the 2017–2019 monthly mean are displayed as error bars.

b ACT: Australian Capital Territory; NSW: New South Wales; NT: Northern Territory; Qld: Queensland; SA: South Australia; Tas.: Tasmania; Vic.: Victoria; WA: Western Australia.

c Lockdowns of one month or greater duration are displayed, as per legend; lockdown periods of less than one month are not shown.

d Victoria only; mandatory masks.

e Australian Capital Territory, New South Wales and Victoria only; mandatory masks.

Sensitivity analysis

A sensitivity analysis using a five-year (2015–2019) rather than three-year (2017–2019) pre-pandemic comparison period showed a greater decrease in annual notification rate relative to this longer pre-pandemic mean in all jurisdictions except Tasmania, in both 2020 (range 0.1% to 24.1%) and 2021 (0.2% to 6.9%) (Appendix A, Table A.2). In Tasmania, the decrease in pertussis notifications was less pronounced in 2020 and 2021 using a five-year pre-pandemic analysis than in the primary three-year analysis.

Discussion

Our study showed a substantial, progressive decrease in pertussis notifications following the implementation of COVID-19-targeted NPI public health measures in Australia. Compared to the pre-pandemic period (2017 to 2019), pertussis notification rates decreased in all jurisdictions and across all age groups.

From May 2020 onwards, following the initial COVID-19 national lockdown, all-age monthly pertussis notifications remained well below the previous three-year mean in all jurisdictions.

Monthly pertussis notifications in Victoria fell more slowly in 2020 compared to other states and territories. While still substantial, Victoria had the smallest decrease in notification rates compared to the pre-pandemic period, though decreases in Victoria came off a lower baseline. This is despite the additional strict internal containment measures implemented in Victoria (a second lockdown with associated mask mandates for 111 days in 2020)[19] and, although genotype data are not available, could suggest ongoing transmission of *B. pertussis* strains relatively newly introduced from interstate or overseas (i.e. prior to the lockdowns) in Victoria during this period. In 2021, all-age notification rates were more than 80% lower than the pre-pandemic period in all jurisdictions, with absolute rates in Victoria being higher than other states and territories, although it is unclear whether this reflects truly higher incidence or different testing and/or public health follow-up practices.

To date, there are very few Australian studies exploring the relationship between COVID-19 NPIs and pertussis notifications. Studies in the region of Central Queensland and in Victoria, using the same NNDSS data, found similar all-age pertussis notification rates to our study.[13,14] In Europe, studies in England and France also demonstrated a decrease in pertussis cases of comparable magnitude temporally associated with the introduction of COVID-19 NPIs among all age groups, including young children.[20,21]

Decreased community circulation of respiratory pathogens, such as *B. pertussis*, associated with COVID-19 NPIs has likely resulted in reduced natural immunity. This, coupled with a decrease in routine vaccine administration in many countries during the pandemic, could contribute to immunity gaps,[22] and increased vulnerability of populations to future disease outbreaks. In New Zealand, long-standing low maternal and delayed infant vaccination in the wake of strict COVID-19 measures may have contributed to a cluster of three infant pertussis deaths in early 2023.[23] In Australia, maternal pertussis vaccination coverage has been relatively high,[24] and the impact of the pandemic on childhood vaccination coverage rates, including pertussis-containing vaccines, has been limited.[25,26] More recent maternal data are required to ensure coverage has not reduced in more recent years. It is important to maximise routine vaccination coverage across all ages and high-risk groups to mitigate this possible transmission risk due to reduced natural immunity.[27]

Although large scale NPIs have generally not been used in Australia since mid-2022, and have focused more on healthcare settings, surveillance data as of early September 2023 suggest no resurgence of pertussis.[28,29] In contrast, influenza notifications, which were well below usual levels in 2020 and 2021,[30,31] resurged in 2022 and 2023.[32,33] This suggests different patterns of immunity, carriage, and transmission between *B. pertussis* and influenza.

This study has some limitations. As it is an ecological study, it cannot demonstrate a direct causal relationship between the implementation of COVID-19 NPIs and a decrease in pertussis notifications. Further, as with most notifiable conditions, pertussis notifications are not a complete enumeration of all infections. Infection ascertainment is affected by disease severity and testing and public health follow-up practices, which are also affected by age at infection.[34] Pertussis could also have been under-reported during the pandemic due to changes in healthcare-seeking behaviour, and alterations to testing practices,[35] which could have varied between age groups and jurisdictions. Based on our sensitivity analysis, it is likely that our findings are generally conservative estimates, though less so for Tasmania.

Conclusion

The implementation of COVID-19-targeted NPIs in Australia appears to have been associated with a significant decrease in pertussis notifications in all jurisdictions and across all age groups, when compared to the pre-pandemic period. Although these NPIs are no longer in place, pertussis notifications have not yet rebounded. However, it is important to ensure high vaccination rates, particularly among high-risk groups such as pregnant women and young children, to mitigate the potential resurgence of pertussis infections and significant associated health outcomes, especially in the context of potentially increased transmission risk due to reduced natural immunity.

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Appendix A

Table A.1: Pertussis notification rates for 2020 and 2021 compared to the 2017 to 2019 mean annual rate, by age group, Australia

Jurisdiction	Age group (years)	Notification rate per 100,000 population per year			2020 vs. 2017–2019[a]		2021 vs. 2017–2019[a]	
		2017 to 2019 mean	2020	2021	IRR	95% CI	IRR	95% CI
Australian Capital Territory	0–4	76.6	14.4	0.0	0.18	0.05–0.54	< 0.001	0.00–0.19
	5–14	156.2	21.6	1.8	0.14	0.07–0.25	0.01	0.00–0.06
	15–24	58.3	19.0	0.0	0.32	0.15–0.63	< 0.001	0.00–0.11
	25–69	44.2	8.3	2.6	0.19	0.11–0.30	0.06	0.02–0.13
	≥ 70	43.9	2.5	7.1	0.06	0.00–0.36	0.16	0.03–0.56
	Overall	**63.5**	**11.8**	**2.5**	**0.19**	**0.14–0.26**	**0.04**	**0.02–0.07**
New South Wales	0–4	179.0	43.4	1.7	0.24	0.21–0.28	0.01	0.00–0.02
	5–14	265.3	47.0	0.5	0.18	0.16–0.20	< 0.001	0.00–0.00
	15–24	53.5	13.9	0.4	0.26	0.21–0.31	0.01	0.00–0.02
	25–69	37.5	9.6	0.4	0.26	0.23–0.28	0.01	0.01–0.02
	≥ 70	25.5	5.6	0.4	0.22	0.16–0.29	0.02	0.00–0.04
	Overall	**74.9**	**16.2**	**0.5**	**0.22**	**0.20–0.23**	**0.01**	**0.00–0.01**
Northern Territory	0–4	75.7	5.6	5.7	0.07	0.00–0.49	0.08	0.00–0.50
	5–14	47.9	22.9	0.0	0.47	0.17–1.14	<0.001	0.00 –0.24
	15–24	20.9	6.1	0.0	0.29	0.03–1.53	<0.001	0.00–0.72
	25–69	21.0	2.6	2.0	0.13	0.03–0.35	0.09	0.02–0.30
	≥ 70	15.9	0.0	0.0	<0.001	0.00–4.65	<0.001	0.00–4.36
	Overall	**28.9**	**6.1**	**1.6**	**0.21**	**0.11–0.37**	**0.06**	**0.02–0.15**
Queensland	0–4	59.2	6.2	5.3	0.10	0.06–0.17	0.09	0.05–0.15
	5–14	114.1	25.7	4.9	0.23	0.19–0.27	0.04	0.03–0.06
	15–24	22.8	11.1	1.7	0.49	0.36–0.65	0.07	0.04–0.14
	25–69	16.4	6.4	1.1	0.39	0.33–0.46	0.07	0.04–0.09
	≥ 70	11.8	5.9	1.0	0.51	0.32–0.78	0.09	0.03–0.20
	Overall	**32.4**	**9.5**	**1.9**	**0.29**	**0.26–0.32**	**0.06**	**0.05–0.07**
South Australia	0–4	100.1	18.3	5.1	0.18	0.10–0.30	0.05	0.02–0.12
	5–14	159.9	21.1	0.5	0.13	0.10–0.18	< 0.001	0.00–0.02
	15–24	40.5	21.6	0.5	0.53	0.37–0.77	0.01	0.00–0.07

Jurisdiction	Age group (years)	Notification rate per 100,000 population per year			2020 vs. 2017–2019[a]		2021 vs. 2017–2019[a]	
		2017 to 2019 mean	2020	2021	IRR	95% CI	IRR	95% CI
	25–69	33.4	15.8	1.7	0.47	0.39–0.57	0.05	0.03–0.08
	≥ 70	27.2	6.6	3.2	0.25	0.13–0.43	0.12	0.05–0.25
	Overall	**52.6**	**16.2**	**1.8**	**0.31**	**0.27–0.35**	**0.03**	**0.02–0.05**
Tasmania	0–4	118.0	40.5	0.0	0.34	0.16–0.68	< 0.001	0.00–0.11
	5–14	255.0	28.6	0.0	0.11	0.07–0.18	< 0.001	0.00–0.02
	15–24	51.9	1.6	0.0	0.03	0.00–0.18	< 0.001	0.00–0.12
	25–69	30.7	9.5	1.5	0.31	0.20–0.46	0.05	0.02–0.12
	≥ 70	14.4	2.6	1.2	0.18	0.02–0.86	0.09	0.00–0.63
	Overall	**64.3**	**12.0**	**1.1**	**0.19**	**0.14–0.24**	**0.02**	**0.01–0.04**
Victoria	0–4	35.3	25.6	3.9	0.72	0.56–0.94	0.11	0.06–0.19
	5–14	64.2	29.2	1.7	0.45	0.39–0.53	0.03	0.01–0.05
	15–24	19.2	15.1	4.6	0.79	0.62–1.00	0.24	0.16–0.34
	25–69	25.9	13.9	5.7	0.54	0.48–0.60	0.22	0.19–0.25
	≥ 70	28.5	14.1	3.7	0.50	0.39–0.64	0.13	0.08–0.19
	Overall	**30.3**	**16.4**	**4.7**	**0.54**	**0.50 –0.58**	**0.15**	**0.14–0.17**
Western Australia	0–4	86.4	5.8	0.0	0.07	0.03–0.13	< 0.001	0.00–0.03
	5–14	84.4	7.6	0.3	0.09	0.06–0.14	< 0.001	0.00–0.02
	15–24	31.3	4.3	0.6	0.14	0.07–0.24	0.02	0.00–0.07
	25–69	32.0	3.9	2.3	0.12	0.09–0.16	0.07	0.05–0.10
	≥ 70	38.9	4.2	2.3	0.11	0.05–0.20	0.06	0.02–0.13
	Overall	**43.3**	**4.7**	**1.8**	**0.11**	**0.09–0.13**	**0.04**	**0.03–0.05**
Australia	0–4	98.3	24.5	3.0	0.25	0.22–0.28	0.03	0.02–0.04
	5–14	152.1	30.9	1.7	0.20	0.18–0.22	0.01	0.01–0.01
	15–24	38.4	13.0	1.7	0.37	0.33–0.42	0.05	0.04–0.07
	25–69	29.3	9.8	2.3	0.34	0.32–0.36	0.08	0.07–0.09
	≥ 70	24.9	7.6	1.9	0.31	0.26–0.36	0.08	0.06–0.10
	Overall	**49.2**	**13.5**	**2.1**	**0.27**	**0.26–0.28**	**0.04**	**0.04–0.05**

a IRR: incidence rate ratio. 95% CI: 95% confidence interval.

Table A.2: Pertussis notification rates for 2020 and 2021 compared to the 2015 to 2019 mean annual rate, by age group, Australia

Jurisdiction	Age group (years)	Notification rate per 100,000 population per year			2020 vs. 2015–2019[a]		2021 vs. 2015–2019[a]	
		2015 to 2019 mean	2020	2021	IRR	95% CI	IRR	95% CI
Australian Capital Territory	0–4	92.7	14.4	0.0	0.16	0.04–0.45	0.00	0.00–0.16
	5–14	226.7	21.6	1.8	0.10	0.05–0.18	0.01	0.00–0.05
	15–24	66.7	19.0	0.0	0.29	0.14–0.56	0.00	0.00–0.10
	25–69	65.1	8.3	2.6	0.13	0.08–0.20	0.04	0.02–0.09
	≥ 70	70.2	2.5	7.1	0.04	0.00–0.23	0.11	0.02–0.35
	Overall	**87.8**	**11.8**	**2.5**	**0.14**	**0.10–0.18**	**0.03**	**0.01–0.05**
New South Wales	0–4	261.9	43.4	1.7	0.17	0.14–0.19	0.01	0.00–0.01
	5–14	379.4	47.0	0.5	0.12	0.11–0.14	0.00	0.00–0.00
	15–24	70.4	13.9	0.4	0.20	0.16–0.24	0.01	0.00–0.02
	25–69	50.7	9.6	0.4	0.19	0.17–0.21	0.01	0.01–0.01
	≥ 70	32.3	5.6	0.4	0.17	0.13–0.23	0.01	0.00–0.03
	Overall	**105.1**	**16.2**	**0.5**	**0.16**	**0.15–0.16**	**0.00**	**0.00–0.01**
Northern Territory	0–4	73.4	5.6	5.7	0.08	0.00–0.50	0.08	0.00–0.50
	5–14	103.0	22.9	0.0	0.22	0.09–0.48	0.00	0.00–0.11
	15–24	28.5	6.1	0.0	0.20	0.02–0.96	0.00	0.00–0.46
	25–69	25.5	2.6	2.0	0.10	0.03–0.29	0.08	0.25–0.25
	≥ 70	22.6	0.0	0.0	0.00	0.00–0.25	0.00	0.00–4.12
	Overall	**40.4**	**6.1**	**1.6**	**0.15**	**0.08–0.26**	**0.04**	**0.01–0.11**
Queensland	0–4	71.4	6.2	5.3	0.09	0.05–0.14	0.07	0.04–0.12
	5–14	125.6	25.7	4.9	0.20	0.17–0.24	0.04	0.03–0.06
	15–24	24.1	11.1	1.7	0.46	0.34–0.61	0.07	0.03–0.13
	25–69	18.6	6.4	1.1	0.34	0.29–0.41	0.06	0.04–0.08
	≥ 70	12.0	5.9	1.0	0.49	0.31–0.76	0.08	0.03–0.19
	Overall	**36.1**	**9.5**	**1.9**	**0.26**	**0.24–0.29**	**0.05**	**0.04–0.06**
South Australia	0–4	122.5	18.3	5.1	0.15	0.09–0.24	0.04	0.01–0.10
	5–14	228.4	21.1	0.5	0.09	0.07–0.13	0.00	0.00–0.01
	15–24	51.4	21.6	0.5	0.42	0.29–0.59	0.01	0.00–0.05

Jurisdiction	Age group (years)	Notification rate per 100,000 population per year			2020 vs. 2015–2019[a]		2021 vs. 2015–2019[a]	
		2015 to 2019 mean	2020	2021	IRR	95% CI	IRR	95% CI
	25–69	43.3	15.8	1.7	0.37	0.30–0.44	0.04	0.02–0.06
	≥ 70	36.2	6.6	3.2	0.19	0.10–0.32	0.09	0.04–0.19
	Overall	**70.1**	**16.2**	**1.8**	**0.23**	**0.20–0.26**	**0.03**	**0.02–0.04**
Tasmania	0–4	79.4	40.5	0.0	0.51	0.23–1.05	0.00	0.00–0.17
	5–14	157.8	28.6	0.0	0.18	0.10–0.29	0.00	0.00–0.04
	15–24	33.6	1.6	0.0	0.05	0.00–0.28	0.00	0.00–0.19
	25–69	19.6	9.5	1.5	0.47	0.30–0.74	0.08	0.02–0.19
	≥ 70	10.8	2.6	1.2	0.22	0.02–1.10	0.11	0.00–0.79
	Overall	**40.9**	**12.0**	**1.1**	**0.29**	**0.22–0.38**	**0.03**	**0.01–0.06**
Victoria	0–4	53.3	25.6	3.9	0.48	0.38–0.62	0.07	0.04–0.12
	5–14	80.4	29.2	1.7	0.37	0.31–0.43	0.02	0.01–0.04
	15–24	25.7	15.1	4.6	0.59	0.47–0.74	0.18	0.12–0.26
	25–69	38.3	13.9	5.7	0.37	0.33–0.41	0.15	0.13–0.17
	≥ 70	43.6	14.1	3.7	0.33	0.26–0.42	0.09	0.06–0.13
	Overall	**43.1**	**16.4**	**4.7**	**0.39**	**0.36–0.41**	**0.11**	**0.10–0.12**
Western Australia	0–4	90.7	5.8	0.0	0.06	0.03–0.12	0.00	0.00–0.02
	5–14	102.1	7.6	0.3	0.08	0.05–0.11	0.00	0.00–0.02
	15–24	35.3	4.3	0.6	0.12	0.06–0.21	0.02	0.00–0.06
	25–69	39.7	3.9	2.3	0.10	0.08–0.13	0.06	0.04–0.08
	≥ 70	51.1	4.2	2.3	0.08	0.04–0.15	0.05	0.02–0.10
	Overall	**52.6**	**4.7**	**1.8**	**0.09**	**0.07–0.11**	**0.03**	**0.02–0.04**
Australia	0–4	133.4	24.5	3.0	0.18	0.16–0.20	0.02	0.02–0.03
	5–14	201.2	30.9	1.7	0.15	0.14–0.16	0.01	0.01–0.01
	15–24	43.1	13.0	1.7	0.31	0.28–0.35	0.04	0.03–0.06
	25–69	38.7	9.8	2.3	0.26	0.25–0.28	0.06	0.05–0.07
	≥ 70	33.3	7.6	2.3	0.66	0.56–0.76	0.16	0.12–0.21
	Overall	**64.9**	**13.5**	**2.1**	**0.21**	**0.20–0.22**	**0.03**	**0.03–0.04**

a IRR: incidence rate ratio. 95% CI: 95% confidence interval.

Figure A.1: Australian national pertussis notification rates by 5-year age group showing annual rates for 2020 and 2021 compared to the 2017 to 2019 mean annual notification rate