

HPV vaccination coverage: slightly improved two-dose schedule completion estimates and historical estimates lower on AIR than HPV Register

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In November 2020, the World Health Organization (WHO) released a global strategy calling for all countries to take action to achieve the elimination of cervical cancer as a public health problem within the next century (defined as an incidence rate < 4 per 100,000).¹ Whilst the most lives will be saved in the near term through improvements in access to, and uptake of, cervical screening and cancer treatment globally, reaching and maintaining high coverage of human papillomavirus (HPV) vaccination will be critical in the longer term to the achievement of global elimination.² For girls-only vaccination programs, the WHO strategy calls for coverage of 90% by age 15 years. The COVID-19 pandemic and HPV vaccine supply issues overlay additional challenges to these scale-up plans.³

Australia has been a world leader in HPV vaccination and was the first country to implement a fully funded national HPV vaccination program for girls (aged 12–13 years) via schools in 2007 using three doses of the quadrivalent HPV (4vHPV) vaccine Gardasil[®], which provides protection against four HPV types (6, 11, 16 and 18).^{4,5} A community-based catch-up program for women up to the age of 26 years ran from 2007 to 2009 and the program was extended to include boys in 2013.^{4,5} The nine-valent HPV (9vHPV) vaccine Gardasil[®]9, in a two-dose course, replaced the 4vHPV vaccine in the National Immunisation Program (NIP) from February 2018,⁶ extending protection to cover five additional oncogenic HPV types

Abstract

Objective: To compare Australian Immunisation Register (AIR) human papillomavirus (HPV) vaccination coverage against historical data from the former National HPV Vaccination Program Register and estimate two-dose vaccination coverage.

Methods: Cross-sectional analysis of registry data for adolescent birth cohorts (1998–2007). Denominator populations were Medicare enrolments (AIR) and ABS estimated resident populations (HPV register).

Results: For adolescents aged <17 years, AIR coverage estimates were several percentage points lower than HPV register estimates due to a larger Medicare enrolment denominator. Completed course coverage (two or three valid doses) for 15-year-old females in 2020 was 81.5% and for males 78.6%, higher than completed course coverage in 15-year-olds in 2019 (79.7 and 76.8% respectively). First dose coverage was similar for Indigenous adolescents but course completion was lower, although improving over time. Course completion was slightly lower (3.5–5.7%) in areas of lowest socioeconomic status and greatest remoteness.

Conclusions: Coverage is slightly lower using AIR than HPV register estimates. Moving from three to two doses has slightly improved completion, likely due to the wider dose spacing, but equity gaps remain.

Implications for public health: An ongoing focus on equity in vaccine delivery is needed. Systems, reminders and catch-up opportunities to ensure course completion remain important.

Key words: HPV vaccination, equity, cervical cancer elimination, immunisation coverage, registry

(31, 33, 45, 52 and 58), which are the next most frequently detected in cervical cancers globally after 16 and 18. The second dose of 9vHPV vaccine is recommended 6–12 months after the first dose.⁷ Catch-up is available under the NIP in primary care up to the age of 19 years.

On the basis of Australia's success to date in the delivery of its national HPV vaccination and cervical screening programs, with the

move to the more effective HPV-based screening program in December 2017, Australia is predicted to be among the first countries to eliminate cervical cancer as a public health problem, potentially as early as 2028.⁸ Monitoring of HPV vaccination coverage was previously undertaken using the National HPV Vaccination Program Register (HPV Register), with the data and functions migrated to the Australian Immunisation Register (AIR) in late 2018.

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Previous 4vHPV vaccine coverage data from the HPV Register showed high dose one coverage (>80% in the target age cohort) from the start of the program,⁹ but with dose three coverage up to 10% lower, gradually improving coverage over time,¹⁰ higher coverage in females than males,¹¹ and a small gradient in coverage by socioeconomic status and remoteness of area of residence¹² (although notably less than that seen with cervical screening participation¹³). For the four jurisdictions (New South Wales, Queensland, Northern Territory and Australian Capital Territory) with adequate Aboriginal and Torres Strait Islander (hereafter respectfully referred to as Indigenous) status completeness, Indigenous adolescents were shown to have similar dose one coverage but lower course completion rates.¹⁴

Comparison of HPV vaccination coverage estimates derived from AIR and the HPV Register is important to assess accuracy and consistency of trend data following the transition to use of AIR. Assessment of coverage achieved under the two-dose 9vHPV vaccination program is important to determine what impact the schedule change has had on uptake, identify any remaining program gaps with particular focus on equity of uptake, and assess whether current predictions of elimination timelines are accurate. In this paper, we compare overall population HPV vaccination coverage estimates in eligible birth cohorts between the two registers. Using AIR data, we also assess coverage trends by gender and Indigenous status and estimate coverage for 15-year-olds in 2019 and 2020 by socioeconomic status and remoteness.

Methods

Background to the HPV Register and Australian Immunisation Register

The HPV Register was a purpose-built vaccine register designed to support the national HPV vaccination program at a time when the Australian Childhood Immunisation Register (ACIR)¹⁵ only collected vaccination data for children aged less than seven years. As authorised by national legislation, the HPV Register collected identified information about HPV vaccine doses administered in Australia through notification by immunisation providers, predominantly from consent form data uploaded in bulk electronically through the register portal by State and Territory school immunisation

programs, but also in batch electronic or individual hard or soft copy notification forms from primary care providers.¹⁶ The HPV Register estimated coverage by using notified doses as the numerator and the eligible population (by age, sex and relevant geographical area), as per Australia's official population estimates (Australian Bureau of Statistics Estimated Resident Population (ABS ERP)) as the denominator for each relevant cohort.^{9,16} In 2018, the Australian Immunisation Register (AIR)¹⁷⁻¹⁹, an expansion of the ACIR to a whole of life register which began in late 2016, took over the functions of the HPV Register. Immunisation providers, including the school-based programs, notify identified HPV vaccine dose information to the AIR in a manner identical to other vaccines received across the lifespan in Australia. Some fields previously collected by the HPV Register, such as school details, are not collected by AIR and Indigenous status is now primarily derived from Medicare enrolment information (Medicare is Australia's government run universal health insurance scheme), which forms the population denominator of the AIR. Consistent with longstanding ACIR practice, the AIR estimates coverage for all vaccines by using notified doses as the numerator and the age/sex/area matched Medicare enrolled population as held by the AIR as the denominator.^{19,20} Other than during the initial catch up program for women aged 18-26 years in 2007-2009, immunisation providers have not received incentive payments for notification of HPV doses to either register. Notification to the HPV Register was not mandatory and notification of NIP vaccines including HPV only became mandatory from 1 July 2021.²¹

Comparison of HPV Register and AIR HPV vaccination coverage estimates

The last published vaccination coverage estimates from the HPV Register were for the cohort of adolescents aged 12 to 19 years as at 30 June 2017.²² For our analysis, we obtained the summary historical HPV Register data as at close of the Register (Dec 2018) and calculated coverage for female and male adolescents by year of age, using the number of adolescents in each age group with a record on the HPV Register of a vaccine received by 30 June 2018 as the numerator, and the Australian Bureau of Statistics (ABS) Estimated Resident Population (ERP) by Single Year of Age²³ as at 30 June 2017 as the denominator. These

estimates were compared to AIR coverage estimates calculated for female and male adolescents by year of age using the number of adolescents in each age group with an AIR record of a HPV vaccination received by 30 June 2018 as the numerator, and the number of Medicare-registered adolescents in each age group in AIR as at 30 June 2017 as the denominator. All people registered with Medicare are automatically added to AIR, with an 'opt-out' provision; people without Medicare enrolment can also be added, but were excluded in our analysis.

Assessing HPV vaccination coverage as at end-2020

AIR data, as at 31 March 2021, were provided by Services Australia. Vaccination encounters up to 31 December 2020 were included in analyses. Eligible year-wide birth cohorts for female and male adolescents aged 12-<20 years as at 31 December 2020 were used to assess HPV vaccination coverage. The proportion of adolescents vaccinated was calculated using the number of adolescents in each cohort with a record of an HPV vaccination encounter between 1 January 2007 and 31 December 2020 as the numerator, and the number of Medicare-registered adolescents in each cohort as the denominator. Coverage was assessed separately for each dose of HPV vaccine by gender and Indigenous status. The 2.6% of adolescents whose Indigenous status was not specified were classified as non-Indigenous for the purposes of this analysis.

Assessing HPV vaccination coverage at 15 years of age

The World Health Organization recommends assessing coverage at 15 years of age for the purpose of comparison internationally and over time. As HPV vaccination in Australia is delivered routinely in early high school, usually around the age of 12-13 years, all adolescents have had the opportunity to complete the vaccination course by age 15 years. The outcome of interest is completion of a clinically valid course (either two or three doses). HPV vaccination coverage was calculated using the number of 15-year-olds in 2020 (2005 birth cohort) and in 2019 (2004 birth cohort) recorded on the AIR to have received dose one, dose two and dose three of HPV vaccine by 31 December 2019 (assessed using AIR data as at 29 February 2020) and by 31 December 2020 (assessed using AIR data as at 31 March 2021)

respectively as the numerator, and the total number of Medicare-registered adolescents in the cohorts aged 15 years in 2019 and 2020 in AIR as the denominators. The 2019 15-year-old cohort (2004 birth cohort) was the first to include some students eligible for the two-dose schedule, with NSW adopting the schedule in 2017 and all other states in 2018. Due to the later age/year level of routine vaccination in South Australia and Western Australia, some students in the 2004 birth cohort from those States were also on the two-dose schedule. As all individuals in these cohorts were under 15 years of age at dose one, anyone with dose two spaced further than the minimum interval of five months after dose one was considered clinically complete (and not requiring a third dose). HPV vaccination completion status at 15 years of age was calculated by gender and Indigenous status and dose one and two coverage calculated by remoteness of area of residence (assigned using Accessibility/Remoteness Index of Australia [ARIA++]²⁴ classification by postcode) and socioeconomic status of area of residence (assigned using ABS Socio-Economic Indexes for Areas [SEIFA] Index of Education and

Occupation²⁵ in quintiles by postcode). These are standard methods used to monitor population level access and use of health services by geography and monitor health and other outcomes by socioeconomic status in Australia, including immunisation coverage.^{9,19,20}

Ethics statement

This work was undertaken as part of a national evaluation of the HPV vaccination program with ethics approvals from the Human Research Ethics Committees of Sydney Children's Hospitals Network, Aboriginal Health and Medical Research Council of NSW, the Northern Territory Department of Health and Menzies School of Health Research and the Aboriginal Health Research Ethics Committee of South Australia.

Results

Vaccination coverage estimates using HPV Register data were higher than AIR estimates for all doses for females aged 13–18 years (range 0.3–3.4%) and males aged 13–17 years (range 0.8–3.2%) (Tables 1 and 2). This

is due to the ABS ERP being smaller than the Medicare enrolment population denominator in each of these birth cohorts (for example, ABS ERP data estimated that there were 137,984 females aged 15 years in Australia in June 2017, whereas Medicare enrolment data enumerated 142,570, a difference of 4,586. With a similar numerator of first HPV vaccine doses in each register (~122,000), the estimated coverage in AIR, due to the extra individuals in the denominator, is about 3% lower). Coverage estimates for each dose for 19-year-old females and 18–19-year-old males were lower using HPV Register than AIR data, as the ABS ERP was larger than the Medicare enrolment population denominator for these cohorts. There were also minor differences in numerator data between the registers across age groups (range 67–2,719 doses per sex/birth cohort/dose number group).

HPV vaccine coverage as at end-2020

Using AIR data, HPV vaccine coverage as at 31 December 2020 was several percentage points higher in females than males across all age cohorts (range 1.7–5.0%) (Table 3). First

Table 1: HPV Register dose 1–3 HPV vaccine coverage estimates versus AIR dose 1–3 HPV vaccine coverage estimates, females.

Age at 30 June 2017	National HPV Register & Estimated Resident Population Method ^a				Australian Immunisation Register Method ^b				Difference between NHPVR & AIR
	Population (ABS ERP as at June 2017)	Number of doses recorded on NHPVR (% coverage)			Population (Medicare enrolment as at June 2017)	Number of doses recorded on AIR (% coverage)			
13yrs	138,602	Dose 1:	121,862	(87.9%)	143,879	Dose 1:	122,881	(85.4%)	2.5
		Dose 2:	116,038	(83.7%)		Dose 2:	117,182	(81.4%)	2.3
		Dose 3:	101,325	(73.1%)		Dose 3:	103,577	(72.0%)	1.1
14yrs	137,916	Dose 1:	122,943	(89.1%)	142,973	Dose 1:	122,542	(85.7%)	3.4
		Dose 2:	118,707	(86.1%)		Dose 2:	118,891	(83.2%)	2.9
		Dose 3:	110,671	(80.2%)		Dose 3:	112,022	(78.4%)	1.8
15yrs	137,984	Dose 1:	122,666	(88.9%)	142,570	Dose 1:	121,991	(85.6%)	3.3
		Dose 2:	118,679	(86.0%)		Dose 2:	118,494	(83.1%)	2.9
		Dose 3:	110,690	(80.2%)		Dose 3:	111,216	(78.0%)	2.0
16yrs	141,215	Dose 1:	122,430	(86.7%)	143,965	Dose 1:	121,285	(84.3%)	2.4
		Dose 2:	118,280	(83.8%)		Dose 2:	117,645	(81.7%)	2.1
		Dose 3:	110,882	(78.5%)		Dose 3:	110,739	(76.9%)	1.6
17yrs	144,001	Dose 1:	122,110	(84.8%)	146,194	Dose 1:	120,642	(82.5%)	2.3
		Dose 2:	117,892	(81.9%)		Dose 2:	116,996	(80.0%)	1.9
		Dose 3:	109,747	(76.2%)		Dose 3:	109,367	(74.8%)	1.4
18yrs	146,652	Dose 1:	117,311	(80.0%)	146,658	Dose 1:	115,754	(78.9%)	1.1
		Dose 2:	112,212	(76.5%)		Dose 2:	111,287	(75.9%)	0.6
		Dose 3:	103,367	(70.5%)		Dose 3:	102,905	(70.2%)	0.3
19yrs	152,571	Dose 1:	113,799	(74.6%)	147,742	Dose 1:	111,080	(75.2%)	-0.6
		Dose 2:	108,325	(71.0%)		Dose 2:	106,234	(71.9%)	-0.9
		Dose 3:	98,898	(64.8%)		Dose 3:	97,396	(65.9%)	-1.1

Notes:

a: HPV Register estimates calculated using the number of adolescents in each age group with a record on the HPV Register of a vaccine received by 30 June 2018 as the numerator, and the Australian Bureau of Statistics Estimated Resident Population by Single Year of Age as at 30 June 2017 as the denominator.

b: AIR data estimates calculated using the number of adolescents in each age group with an AIR record of a HPV vaccine received by 30 June 2018 as the numerator, and the number of Medicare-enrolled adolescents in each age group as at 30 June 2017 as the denominator.

Table 2: HPV Register dose 1–3 HPV vaccine coverage estimates versus AIR dose 1–3 HPV vaccine coverage estimates, males.

Age at 30 June 2017	National HPV Register & Estimated Resident Population Method ^a			Australian Immunisation Register Method ^b			Difference between NHPVR & AIR
	Population (ABS ERP as at June 2017)	Number of doses recorded on NHPVR (% coverage)		Population (Medicare enrolment as at June 2017)	Number of doses recorded on AIR (% coverage)		
13yrs	147,500	Dose 1:	125,318 (85.0%)	152,839	Dose 1:	126,889 (83.0%)	2.0
		Dose 2:	118,513 (80.3%)		Dose 2:	119,817 (78.4%)	1.9
		Dose 3:	99,875 (67.7%)		Dose 3:	102,170 (66.9%)	0.8
14yrs	144,913	Dose 1:	124,811 (86.1%)	150,379	Dose 1:	124,621 (82.9%)	3.2
		Dose 2:	120,094 (82.9%)		Dose 2:	120,404 (80.1%)	2.8
		Dose 3:	111,122 (76.7%)		Dose 3:	112,454 (74.8%)	1.9
15yrs	145,161	Dose 1:	123,458 (85.0%)	150,114	Dose 1:	123,063 (82.0%)	3.0
		Dose 2:	118,931 (81.9%)		Dose 2:	119,002 (79.3%)	2.6
		Dose 3:	110,197 (75.9%)		Dose 3:	110,936 (73.9%)	2.0
16yrs	149,155	Dose 1:	120,750 (81.0%)	152,042	Dose 1:	119,868 (78.8%)	2.2
		Dose 2:	116,489 (78.1%)		Dose 2:	115,972 (76.3%)	1.8
		Dose 3:	108,424 (72.7%)		Dose 3:	108,336 (71.3%)	1.4
17yrs	150,325	Dose 1:	114,608 (76.2%)	153,254	Dose 1:	113,601 (74.1%)	2.1
		Dose 2:	110,000 (73.2%)		Dose 2:	109,313 (71.3%)	1.9
		Dose 3:	98,941 (65.8%)		Dose 3:	98,705 (64.4%)	1.4
18yrs	154,655	Dose 1:	107,299 (69.4%)	153,925	Dose 1:	106,843 (69.4%)	0.0
		Dose 2:	102,441 (66.2%)		Dose 2:	102,225 (66.4%)	-0.2
		Dose 3:	90,703 (58.6%)		Dose 3:	90,881 (59.0%)	-0.4
19yrs	160,650	Dose 1:	52,229 (32.5%)	154,979	Dose 1:	51,959 (33.5%)	-1.0
		Dose 2:	49,110 (30.6%)		Dose 2:	48,963 (31.6%)	-1.0
		Dose 3:	42,826 (26.7%)		Dose 3:	42,893 (27.7%)	-1.0

Notes:

a: HPV Register estimates calculated using the number of adolescents in each age group with a record on the HPV Register of a vaccine received by 30 June 2018 as the numerator, and the Australian Bureau of Statistics Estimated Resident Population by Single Year of Age as at 30 June 2017 as the denominator.

b: AIR data estimates calculated using the number of adolescents in each age group with an AIR record of a HPV vaccine received by 30 June 2018 as the numerator, and the number of Medicare-enrolled adolescents in each age group as at 30 June 2017 as the denominator.

Table 3: HPV vaccine coverage (%) by first and final dose number,^a gender, Indigenous status and birth cohort/age^b for vaccination encounters recorded up to 31 December 2020.^c

	FEMALES																		
	13yrs ^d (1 Jan – 31 Dec 2007)		14yrs (1 Jan – 31 Dec 2006)		15yrs ^e (1 Jan – 31 Dec 2005)			16yrs (1 Jan – 31 Dec 2004)			17yrs (1 Jan – 31 Dec 2003)			18yrs (1 Jan – 31 Dec 2002)			19yrs (1 Jan – 31 Dec 2001)		
	Dose 1	Dose 2	Dose 1	Dose 2	Dose 1	Dose 2	Dose 3	Dose 1	Dose 2	Dose 3	Dose 1	Dose 2	Dose 3	Dose 1	Dose 2	Dose 3	Dose 1	Dose 2	Dose 3
All	77.1	63.3	85.3	79.2	87.1	82.2	13.2	87.0	83.7	53.7	87.4	84.8	79.0	87.3	84.6	79.2	85.7	83.0	77.7
Indigenous	73.5	54.3	84.9	72.4	88.6	78.1	16.2	90.1	82.1	47.7	90.6	84.3	72.1	89.0	82.8	72.3	86.8	80.3	70.2
Non-Indigenous	77.3	63.8	85.3	79.6	87.0	82.4	13.0	86.8	83.8	54.0	87.2	84.8	79.4	87.2	84.7	79.5	85.6	83.2	78.1
	MALES																		
	13yrs ^d (1 Jan – 31 Dec 2007)		14yrs (1 Jan – 31 Dec 2006)		15yrs ^e (1 Jan – 31 Dec 2005)			16yrs (1 Jan – 31 Dec 2004)			17yrs (1 Jan – 31 Dec 2003)			18yrs (1 Jan – 31 Dec 2002)			19yrs (1 Jan – 31 Dec 2001)		
	Dose 1	Dose 2	Dose 1	Dose 2	Dose 1	Dose 2	Dose 3	Dose 1	Dose 2	Dose 3	Dose 1	Dose 2	Dose 3	Dose 1	Dose 2	Dose 3	Dose 1	Dose 2	Dose 3
All	73.4	58.4	83.2	75.9	85.4	79.4	11.0	84.8	81.0	48.7	84.9	81.7	75.2	84.3	81.1	75.4	81.2	78.2	72.7
Indigenous	67.6	47.2	79.5	65.2	84.1	71.4	13.1	85.1	75.9	39.9	86.0	78.7	65.0	84.3	76.9	66.2	80.5	73.2	62.7
Non-Indigenous	73.7	59.1	83.4	76.5	85.4	79.8	10.9	84.8	81.3	49.2	84.8	81.8	75.7	84.3	81.3	75.8	81.2	78.5	73.1

Notes:

a: Coverage for dose 1 and dose 2 reported for adolescents aged 13-14 years following the HPV vaccination program changing from a 3-dose schedule to a 2-dose schedule in 2018 (2017 in NSW). Coverage for dose 1, dose 2 and dose 3 reported for adolescents aged 15-19 years, however dose 3 coverage is low in the 2005 and 2004 cohorts due to the transition from the 3-dose to the 2-dose HPV vaccination schedule.

b: Age assessed at 31 December 2020. Birth cohort for adolescents aged 12 years not included as 12-year-olds are not eligible for HPV vaccination in some states/territories.

c: All HPV vaccinations administered up to and on 31st December 2020 included in coverage calculation irrespective of age at dose.

d: Not all 13-year olds in 2020 will have been offered HPV vaccine in their 2020 year level, notably those in SA and WA

e: 15-year-old coverage is the recommended time point for coverage reporting between jurisdictions and over time

Source: Australian Immunisation Register, data as at 31 March 2021

dose coverage for Indigenous adolescents was broadly similar to that in non-Indigenous adolescents, except in 13-year-old females and males and 14-year-old males where it was 4–5% lower. Coverage of the second and third doses was lower (i.e. lower course completion) for Indigenous adolescents across all age cohorts.

Dose two coverage in the 2020 15-year-old cohort was 82.2% in females and 79.4% in males, slightly lower than in the 16-year-old cohort, which included more individuals still on a three-dose schedule (Table 3). Dose two coverage in these two younger cohorts lay between dose two and dose three coverage in the 17-year-old cohort, all of whom were on a three-dose schedule.

HPV vaccine coverage by remoteness and socioeconomic status

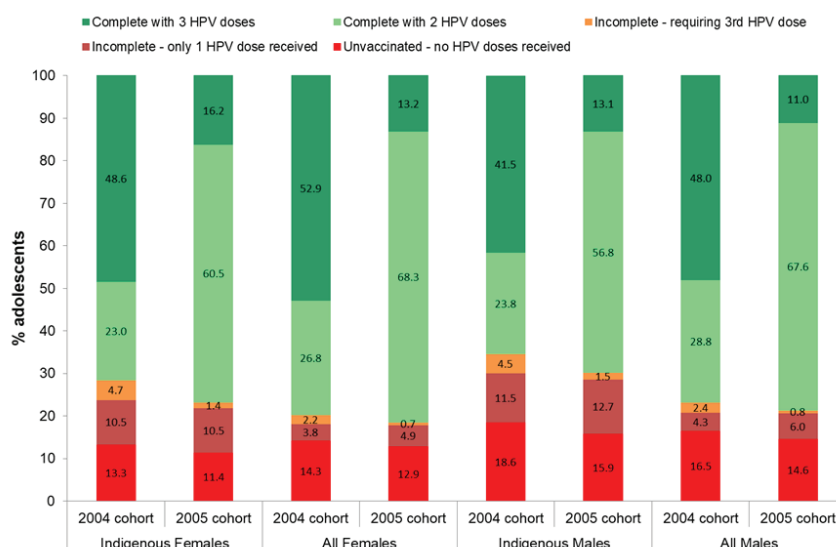
Table 4 shows coverage at age 15 years for females and males in 2020 by socioeconomic status and remoteness of area of residence. Data suggest minimal difference in dose one coverage by remoteness but lower coverage for the second dose in remote areas. Among females there was little difference for dose one coverage by socioeconomic status but second dose coverage was 3.5% lower in the most disadvantaged quintile compared to the least disadvantaged. Amongst males, dose one coverage was 2.4% lower in the most disadvantaged than least disadvantaged quintile, with second dose coverage 5.6% lower.

Overall, 80% of all adolescents aged 15 years in 2020 had completed the HPV vaccination schedule (either two- or three-dose schedule administered at correct intervals), whereas only 73.3% of Indigenous adolescents had (Figure 1). The proportions with a completed course at age 15 years in 2020 and 2019 were 81.5% and 79.7% in females and 78.6% and 76.8% for males, respectively. For female and male Indigenous adolescents aged 15 years, completed course coverage in 2020 was 76.7% and 69.9%, and in 2019, 71.6% and 65.3%, respectively. These figures are higher than the dose three coverage in earlier birth cohorts (Table 3) but lower than dose two coverage in those cohorts.

Conclusions

HPV vaccination coverage estimated using AIR data is broadly consistent with historical data from the HPV Register (higher in

Figure 1: HPV vaccination schedule completion status in the 2004 and 2005 birth cohorts (adolescents aged 15 years in 2019 and 2020 respectively) by gender and Indigenous status, for vaccination encounters recorded up to 31 December 2019 and 31 December 2020 respectively.^a



Notes:

a: All HPV vaccinations administered up to and on 31st December 2019 for the 2004 cohort and up to and on 31st December 2020 for the 2005 cohort, irrespective of whether administered before or after 15th birthday.

Source: Australian Immunisation Register, data as at 29 February 2020 for 2004 cohort and as at 31 March 2021 for 2005 cohort.

Table 4: Coverage (%) for the first and second dose of HPV vaccine by socioeconomic status and remoteness of area of residence for the 2005 birth cohort (females and males, aged 15 years in 2020) for vaccination encounters recorded up to 31 December 2020.^a

	Dose 1		Dose 2	
	Females	Males	Females	Males
By Remoteness				
Major Cities	86.8	85.2	82.2	79.6
Regional	87.9	86.1	82.4	79.3
Remote	86.8	84.0	78.1	73.9
By SEIFA Quintile				
Quintile 1 – most disadvantaged	86.7	83.9	80.3	76.0
Quintile 2	87.2	85.2	81.9	78.8
Quintile 3	86.6	85.3	81.8	79.5
Quintile 4	87.1	85.8	82.6	80.4
Quintile 5 – least disadvantaged	87.7	86.3	83.8	81.6

Notes:

a: All HPV vaccinations administered up to and on 31st December 2020, irrespective of whether administered before or after 15th birthday.

Source: Australian Immunisation Register, data as at 31 March 2021

females, lower dose completion amongst Indigenous adolescents, relatively small absolute differences by remoteness and socioeconomic status of area of residence) but is generally several percentage points lower due mostly to differences in the denominator population used. The move to a two-dose schedule resulted in a small increase in course completion at age 15 years in 2019, a cohort including individuals offered either two or three doses depending on jurisdiction, with a further small increase in the 2020 15-year-old cohort. However, this was lower than two-dose coverage achieved in previous years when the second dose

was part of a three-dose schedule. This may be because the advantage of only needing two doses is somewhat offset by the longer interval between the doses (six months or more). A recent analysis of HPV Register data showed that the third dose, usually given in the last half of the school year as the second dose is now, was the dose most frequently missed in schools.²⁶ The ongoing incremental improvement in coverage year on year is consistent with historical trends.

While historical HPV Register coverage estimates were universally higher than AIR estimates for females aged 13–18 years and males aged 13–17 years, they were lower

for 19-year-old females and 18–19-year-old males, due to ABS ERP being smaller than AIR denominator in the younger age groups but larger in the older age groups. These differences are notable and require consideration of the population captured in each denominator. In each of the 13- and 14-year-old cohorts in 2017, Medicare denominators included over 10,000 more individuals than ABS ERP. This is in direct contrast to a study from 10 years earlier assessing HPV coverage using both denominators, which found that in 2007 there was only a minor difference of <250 individuals in these younger age groups, and that it was older adolescents who had the greatest discrepancy, with 8,800 more 18–19-year-olds enumerated in the ABS ERP than Medicare.²⁷ It is unclear why there is now a more substantial discrepancy between Medicare and ABS ERP estimates of the population in these age groups, whilst noting that the purposes of each dataset are slightly different. ABS ERP²⁸ estimates are based on the concept of usual residence and refer to all people, regardless of nationality, citizenship or visa status, who usually live in Australia, excepting foreign diplomats. They include residents who are overseas for less than a year and exclude overseas visitors in Australia for less than a year. ABS ERP estimates are based on the five-yearly Census, adjusted for estimated undercount, and are updated between censuses based on birth, death and migration data. In contrast, Medicare enrolments include people living in Australia who are: Australian citizens, permanent residents or who have applied for permanent residency, New Zealand citizens and temporary residents covered by a Ministerial order.²⁹ People from 11 countries with reciprocal health care agreements can also enrol to receive care under Medicare whilst visiting Australia.³⁰ While using AIR denominators for HPV vaccination coverage has the advantage of both numerator and denominator coming from the same data source at the same point in time, AIR denominators may overestimate true eligible population e.g. if they include people who are no longer eligible (e.g. deceased or who have left Australia but not recorded as such in AIR). Both the HPV Register and AIR are examples of population level immunisation registers, with both enabled by national legislation and used to facilitate accurate monitoring of vaccination coverage at both population and individual level. However

both may underestimate true coverage to some degree.^{31–35} Both registers had in place processes to support the entry and maintenance of clean and accurate data eg deduplication and automated matching. Coverage estimates for other vaccines administered in adolescence have recently been estimated from the AIR for the first time, with coverage of the diphtheria-tetanus-pertussis booster in 2020 estimated at 77.4% by age 15, slightly lower than for HPV and similarly substantially lower than vaccination coverage in young children (over 90% for all vaccines due up to 4 years of age).²⁰

Strong partnerships with the education sector, effective community sensitisation and communication with parents to support consent, and supplementary methods for ensuring vaccination of children who are not at school are known to be key features of school-based programs that achieve high HPV vaccine coverage.³⁶ Our findings are consistent with international data which show that a two-dose HPV vaccine schedule does not necessarily result in higher coverage than a three-dose schedule. This is apparent in the wide variation in coverage achieved in countries on two- or three-dose schedules³⁷ and in countries such as England which have also moved from a three- to two-dose schedule.³⁸ Fortunately, sustained coverage of $\geq 80\%$ in a both-sex HPV vaccination program such as Australia's (a rate we are currently achieving) should result in local elimination of targeted HPV types.³⁹ However, equity in coverage remains important given the currently much higher rates of cervical cancer in Indigenous women, women of lower socioeconomic status and women who live in remote areas.⁴⁰ Should one dose of HPV vaccine prove to be sufficient for effective prevention of infection and subsequent disease,^{41–43} the task of reaching and maintaining desired levels of coverage will become simpler and cheaper, both in Australia and globally.

Implications for public health

The transition to a two-dose schedule on the NIP produced only a modest increase in coverage, likely due to the wider spacing between doses required. Systems and reminders to promote both initiation and completion of HPV vaccination are important both locally (school programs and community settings) and nationally (via AIR).^{44–46} Disruption to school vaccination

programs caused by the COVID-19 pandemic is a reminder of the need to ensure that systems are in place to systematically and actively identify those who have missed out on routine HPV vaccination in the school setting and may require provision of flexible alternative catch-up opportunities.^{47–49} The AIR has a critical role in this process, given that those who miss out may be unknown to local vaccination teams.

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