NCIRS
National Centre for Immunisation Research and Surveillance

Research report 1: Coverage at the 2-year and 5-year age milestones

2 April 2020

Author details

Brynley Hull[1]

Aditi Dey[1]

Alexandra Hendry[1]

Peter McIntyre[1]

Kristine Macartney[1]

Frank Beard[1]

1 National Centre for Immunisation Research and Surveillance

Corresponding author

Brynley Hull

National Centre for Immunisation Research and Surveillance

The Children's Hospital at Westmead and The University of Sydney

Locked Bag 4001, Westmead NSW 2145.

Telephone: +61 2 9845 1435.

Facsimile: +61 2 9845 1418.

Email: brynley.hull@health.nsw.gov.au

Contents

Acknowledgements

The National Centre for Immunisation Research and Surveillance is supported by the Australian Government Department of Health, the NSW Ministry of Health and The Sydney Children's Hospital Network. The opinions expressed in this report are those of the authors, and do not necessarily represent the views of these organisations.

Glossary

13vPCV	13-valent pneumococcal conjugate vaccine
AIR	Australian Immunisation Register
ARIA++	Accessibility/Remoteness Index of Australia
DTPa	diphtheria-tetanus-acellular pertussis
Hib	*Haemophilus influenzae* type b
MenC	meningococcal C
MMRV	measles-mumps-rubella-varicella
NIP	National Immunisation Program
SEIFA	Socio-Economic Indexes for Areas

Executive summary

Background

Assessment of vaccination coverage is an important component of the monitoring and evaluation of immunisation programs. Since late 2014, 'fully vaccinated' coverage estimates at the 2-year age milestone in Australia have decreased, remaining several percentage points below those at the 1-year and 5-year age milestones. The coverage algorithms used assess a mix of vaccines and antigens usually given as part of 'combination' vaccines. As at March 2020, the 'fully vaccinated' coverage algorithm at the 2-year age milestone assessed antigens from one vaccine due at 6 months of age, two vaccines due at 12 months of age and three vaccines due at 18 months of age. In contrast, the algorithm at the 1-year age milestone assessed only two vaccines, due at 4 and 6 months of age, and the algorithm at the 5-year age milestone only one vaccine, due at 48 months of age. In comparison, in June 2013, 'fully vaccinated' coverage algorithms assessed one vaccine at the 1-year age milestone and two at both the 2-year and 5-year age milestones.

We aimed to examine the factors contributing to lower 'fully vaccinated' coverage at the 2-year age milestone and to assess the potential impact of using a more comprehensive coverage assessment algorithm on 'fully vaccinated' coverage at the 5-year age milestone.

Methods

Using the Australian Immunisation Register (AIR) data, we assessed 'fully vaccinated' coverage (using the 2-year assessment algorithm), and coverage for individual vaccines/antigens included in the 2-year assessment algorithm, at 24, 30, 36 and 48 months of age. We used three birth cohorts: Cohort 1, born in 2011 and eligible for monovalent varicella vaccine only at 18 months of age; Cohort 2, born in 2013 and eligible to receive measles-mumps-rubella-varicella (MMRV) vaccine at 18 months; and Cohort 3, born October 2014 – 30 June 2015 and eligible to receive both MMRV vaccine and a fourth dose of diphtheria-tetanus-acellular pertussis–containing vaccine (DTPa4) at 18 months. We also analysed 'fully vaccinated' and individual vaccine/antigen coverage at the 2-year age milestone, using Cohort 3, and data on children who had not received all three vaccines now due at 18 months of age (MMRV vaccine, DTPa4 and *Haemophilus influenzae* type b [Hib] booster dose) by the 2-year age milestone using a more recent cohort (Cohort 4, born October 2017 – December 2017). Finally, we calculated 'fully vaccinated' coverage at the 5-year age milestone using a 'full' algorithm incorporating all vaccines/antigens due by that age (other than rotavirus, for which there are strict upper age limits) and compared that with coverage using the standard assessment algorithm using Cohort 5 (born 1 July 2013 – 30 June 2014).

Results/Discussion

'Fully vaccinated' coverage at the 2-year age milestone, after being consistently higher than coverage at the 1-year and 5-year age milestones from 2010 to 2014, decreased in 2014 from 92.8% to 87.3%, and has remained lower than the coverage at other milestones since. This decrease coincided with changes in the 2-year coverage assessment algorithm, which included

addition of meningococcal C (MenC) vaccine, due at 12 months, along with varicella and the second dose of MMR vaccine (MMR2), due at 18 months as MMRV vaccine. Coverage at the 2-year age milestone rebounded but then dipped again in 2016 following the addition of DTPa4 to the algorithm. Notably the 2-year assessment algorithm had not included any vaccines due at 18 months since 2003.

Coverage estimates for individual vaccines due at 18 months of age that were included in the 2-year assessment algorithm were consistently lower over the study period, likely due in part to the shorter 6-month time period available for vaccination before coverage is assessed. While a 6-month period is also available for vaccines due at 6 months of age and assessed at the 1-year age milestone, children attend healthcare providers more frequently in the first year of life. Using the same 2-year assessment algorithm, 'fully vaccinated' coverage estimates for Cohort 2 increased at later age points and so coverage at 48 months was similar to that for Cohort 1, for which no vaccines due at 18 months had been included in the coverage algorithm. This indicates that while coverage is lower at 24 months of age using the current algorithm, a substantial amount of vaccination catch-up activity occurs.

'Fully vaccinated' and individual vaccine coverage in Cohort 3 was lower for Aboriginal and Torres Strait Islander (hereafter respectfully referred to as Indigenous) children and children in the lowest socio-economic quintile areas, but there was a greater increase in coverage between the 24- and 48-month age milestones in these groups. This lower timeliness of vaccination but greater catch-up activity likely reflects issues of access to immunisation services.

Another factor that could contribute to lower 'fully vaccinated' coverage estimates at the 2-year age milestone is splitting of and delay in vaccinations because of the increase in the number of vaccinations scheduled at 18 months of age. We found that 3.0% of children in Cohort 4 had received all three vaccines by the 2-year age milestone but not concomitantly, with a further 2.4% having received only one or two of the three vaccines due.

We calculated that coverage at 5 years of age for Cohort 5 would be 5.5 percentage points lower if assessed using a 'full' coverage algorithm (all vaccines/antigens a child should have received by their fifth birthday, other than rotavirus) compared to the current algorithm (88.5% versus 94.0%, respectively).

Conclusion

'Fully vaccinated' coverage at the 2-year age milestone has decreased due to changes in the coverage algorithm, particularly the increase from zero to three vaccines due at 18 months of age, only 6 months before the assessment age milestone. At the same time, the coverage assessment algorithm used at the 5-year age milestone now assesses only a single vaccine due at 4 years of age. As a result, 'coverage' assessed and reported for the 5-year age milestone is of substantially different scope to that at the 2-year age milestone. This has led to messaging and interpretation issues, given that most stakeholders are unaware of these differences in definition and scope, and also renders the 5-year coverage data less useful in monitoring and evaluating uptake and effectiveness of the National Immunisation Program (NIP). Expansion of the 5-year coverage assessment algorithm, to include a more comprehensive range of vaccines/antigens that should have been received by that age, would be useful in addressing these issues. Such a change would

present a significant communications challenge and introduce a range of potential risks which would require careful planning to address. For example, the change could be phased in with parallel reporting, using both the new and existing algorithms, to begin to address messaging issues related to the perception of a ‘drop’ in coverage.

Background

Regular assessment of vaccination coverage is an important component of monitoring and evaluation of immunisation programs. In Australia, childhood vaccination coverage, both 'fully vaccinated' and for individual vaccines, has been reported since the inception of the national immunisation register at three standard age milestones (1 year, 2 years and 5 years).

Since late 2014, estimates of 'fully vaccinated' coverage at the 2-year age milestone have decreased, and remain several percentage points below 'fully vaccinated' coverage at the 1-year and 5-year age milestones.[1] The algorithms used to derive 'fully vaccinated' coverage assess a mix of individual vaccines and antigens (or groups of antigens), many of which are given as components of 'combination' vaccines. Assessment based on a mix of individual antigens is necessary as antigens in combination vaccines in use in the NIP may change over time, and children who have been vaccinated overseas may have received different vaccine combinations.

As at March 2020, the 'fully vaccinated' coverage algorithm at the 2-year age milestone assessed two antigens (hepatitis B and polio) due at 6 months of age as last dose of the primary vaccination course for these antigens and usually given as part of the Infanrix hexa combination vaccine; two vaccine doses (pneumococcal and meningococcal conjugate vaccines) due at 12 months of age; and three vaccine doses (MMRV, Hib and DTPa) due at 18 months of age (refer to Box 1). In contrast, the 'fully vaccinated' coverage algorithm at the 1-year age milestone assessed only two vaccines (Infanrix hexa and pneumococcal conjugate), due at 6 and 4 months of age, respectively, and the 'fully vaccinated' coverage algorithm at the 5-year age milestone assessed only one vaccine (DTPa-polio), due at 48 months of age.

In comparison, in June 2013, 'fully vaccinated' coverage algorithm assessed one vaccine at the 1-year age milestone and two at both the 2-year and 5-year age milestones. Subsequent changes to the NIP Schedule and coverage algorithm are summarised in Box 2. It is notable that there were several changes to the 2-year age milestone coverage algorithm but only one to each of the 1-year and 5-year age algorithms. A number of factors may have contributed to reduced 'fully vaccinated' coverage at the 2-year age milestone:

1. an increased number of vaccines assessed
2. the shorter time period between doses due at 18 months and assessment (6 months compared with the 12-month period for vaccines due at 12 months of age)
3. delays through increases in instances where all due vaccines are not administered together because of more vaccine doses being due at 18 months.

Box 1: 'Fully vaccinated' coverage assessment algorithms for the 3 milestone ages, as of March 2020

1-year milestone age

'Fully vaccinated' at 12 months of age is a record on the AIR of a:

- third dose of a DTPa-containing vaccine
- third dose of a polio-containing vaccine
- second or third dose of PRP-OMP–containing Hib vaccine or a third dose of any other Hib-containing vaccine
- third dose of hepatitis B vaccine
- second or third dose of 13-valent pneumococcal conjugate vaccine (13vPCV)

2-year milestone age

'Fully vaccinated' at 24 months of age is a record on the AIR of a:

- fourth dose of a DTPa-containing vaccine
- third doses of hepatitis B and polio-containing vaccines
- a third or fourth dose of PRP-OMP Hib-containing vaccine, Infanrix Hexa or Hiberix (a third dose only of Infanrix Hexa or Hiberix if given after 11.5 months of age) or fourth dose of any other Hib-containing vaccine
- single dose of MenC-containing vaccine
- single dose of varicella-containing vaccine
- second dose of measles-containing vaccine (given as either MMR or MMRV)
- third dose of 13vPCV

5-year milestone age

'Fully vaccinated' at 60 months of age is a record on the AIR of a:

- fourth or fifth dose of a DTPa -containing vaccine
- fourth dose of polio-containing vaccine

Box 2: Changes to NIP Schedule and coverage assessment algorithms, 2013–2018

July 2013

- MMRV vaccine at 18 months of age replaces MMR vaccine previously scheduled at 4 years and monovalent varicella vaccine previously scheduled at 18 months of age.

December 2013

- Assessment algorithm for 'fully vaccinated' at the 1-year age milestone amended to include third dose of 13vPCV due at 6 months of age.

December 2014

- Assessment algorithm for 'fully vaccinated' at the 2-year age milestone amended to include dose of MenC-containing vaccine due at 12 months of age, and dose of varicella-containing vaccine and second dose of MMR-containing vaccine (usually given as MMRV vaccine) due at 18 months of age.

March 2016

- Booster dose of DTPa-containing vaccine funded on NIP at 18 months of age.

October 2016

- Assessment algorithm for 'fully vaccinated' at the 2-year age milestone age amended to include fourth dose of a DTPa-containing vaccine due at 18 months of age.

July 2018

- Schedule for 13vPCV changed from 2, 4 and 6 months to 2, 4 and 12 months of age. Assessment algorithm for 'fully vaccinated' at the 2-year age milestone amended to include the third dose of 13vPCV.
- Meningococcal ACWY conjugate vaccine at 12 months of age replaces combined Hib-MenC vaccine. Hib booster dose moved to 18 months of age and given as monovalent Hib vaccine.

October 2018

- Assessment algorithm for 'fully vaccinated' at the 5-year milestone age amended to remove the second dose of MMR-containing vaccine.

Aims

In this report, we aimed to:

1. conduct exploratory analysis of coverage estimates of vaccines/antigens assessed at the 2-year age milestone and factors contributing to lower ‘fully vaccinated’ coverage
2. examine impacts on coverage of recent coverage assessment algorithm changes
3. investigate to what degree coverage estimates are influenced by the shorter period between vaccines due at 18 months of age and assessment at 2 years and how coverage (‘fully vaccinated’ and individual vaccines/antigens) changes when assessed at older ages
4. assess the impact of the increase in vaccines due at 18 months of age on non-concomitant vaccination and coverage estimates at the 2-year assessment milestone
5. assess the potential impact of an assessment algorithm requiring incorporating receipt of all vaccines/antigens other than rotavirus on ‘fully vaccinated’ coverage at the 5-year age milestone.

Methods

The Australian Immunisation Register

The Australian Childhood Immunisation Register (ACIR) was established in 1996 by incorporating Medicare data on all children under the age of 7 years.[3] On 1 January 2016, the ACIR expanded to include all people aged up to 20 years, and then on 30 September 2016 to become the whole-of-life Australian Immunisation Register (AIR).[4,5] All people registered with Medicare, Australia's universal healthcare system, are automatically added to AIR. Participation in AIR is 'opt-out' and so constitutes a nearly complete population register for Australian residents.[3] Individuals not enrolled in Medicare can be added to AIR when a recognised vaccination provider submits their immunisation data. Since 2001, vaccinations given overseas may be recorded if a provider endorses their validity. Data are transferred to AIR when a recognised immunisation provider supplies details of an eligible vaccination. This could occur via practice management software, through direct data entry on the AIR website or by submitting paper encounter or history forms.

Exploratory analysis

We used AIR data as of 30 September 2019, unless otherwise specified, and assessed vaccination encounters given up to 30 June 2019 to allow a 3-month lag period for late notification. We assessed 'fully vaccinated' coverage (using the 2-year assessment algorithm) at 24, 30, 36 and 48 months of age, and coverage for individual vaccines/antigens included in the 2-year assessment algorithm at the same age points. The cohort method was used for calculating coverage at the population level.[6] We used three birth cohorts:

- Cohort 1, born 1 January 2011 – 31 December 2011 (for whom only monovalent varicella vaccine was scheduled at 18 months of age)
- Cohort 2, born 1 January 2013 – 31 December 2013 (eligible to receive MMRV vaccine at 18 months of age)
- Cohort 3, born 1 October 2014 – 30 June 2015 (eligible to receive both MMRV vaccine and fourth dose of a DTPa-containing vaccine [DTPa4] at 18 months of age).

This last cohort was 9 months wide rather than 12 months, as children born before 1 October 2014 were not eligible for DTPa4, and children born after 30 June 2015 could not be assessed at 48 months of age at 30 June 2019.

If a child's records indicated receipt of the last dose of a vaccine that requires more than 1 dose to complete the series, it was assumed that earlier vaccines in the sequence were given. This assumption has been shown to be valid in the past.[7,8] The proportion of children designated as 'fully vaccinated' was calculated using the number of children vaccinated with the vaccines of interest as the numerator and the total number of AIR-registered children in the age cohort as the denominator.

We also analysed 'fully vaccinated' coverage and coverage of individual vaccines/antigens at the 2-year age milestone by Indigenous status and remoteness/socioeconomic status of area of

residence. For these sub-analyses, we used Cohort 3. SAS software[9] was used in all data analyses.

Analysis of missing and concomitant vaccinations

We analysed data on children who had not received all three vaccines due at 18 months of age (MMRV, DTPa4 and Hib booster dose) by the 2-year age milestone, by jurisdiction, vaccine type, Indigenous status and remoteness of area of residence. We also calculated the percentage of children who did not receive all three vaccines due at 18 months of age at the same visit, by vaccine type missed and Indigenous status. For these analyses we used a later 3-month birth cohort (Cohort 4) born 1 October 2017 – 31 December 2017 and eligible to receive Hib vaccine booster at 18 months, and AIR data as at 31 December 2019.

Analysis of coverage at 5-year age milestone incorporating all vaccines

We calculated 'fully vaccinated' coverage at the 5-year age milestone at national and jurisdictional levels using an algorithm which required a record of all vaccines/antigens due to be administered before 5 years of age (except rotavirus, for which there are strict upper age limits). We then compared trends in coverage nationally since 2012 using this algorithm with those using the standard algorithm. For this analysis we used the birth cohort (Cohort 5) born 1 July 2013 – 30 June 2014.

Indigenous status

Aboriginal and Torres Strait Islander status on AIR is recorded as 'Indigenous', 'non-Indigenous' or 'unknown', as reported by the child's parent/carer to Medicare. The 0.4% of children whose Indigenous status was not specified were classified as non-Indigenous for the purposes of our analysis.

Remoteness of area of residence

Area of residence was defined as 'Major cities', 'Inner regional', 'Outer regional', 'Remote' and 'Very remote' using the Accessibility/Remoteness Index of Australia (ARIA++).[10] For analysis in this report, we combined the two 'Regional' categories ('Inner Regional' and 'Outer Regional') into one category and the two 'Remote' categories ('Remote' and 'Very Remote') into one category. The ARIA Accessibility/Remoteness category was assigned for each individual, using their recorded postcode of residence on AIR.

Socioeconomic status

We used the Australian Bureau of Statistics Socio-Economic Indexes for Areas (SEIFA) Index of Economic Resources to assess vaccination coverage by socioeconomic status of area of

residence.[11] The SEIFA index category was assigned for each individual using their recorded postcode of residence on AIR.

Ethics approval

This study was exempted from ethics approval by The Sydney Children's Hospitals Network Human Research Ethics Committee on the basis that it involves analysis of de-identified, population-based, administrative data for surveillance activities, under approval from the Australian Government Department of Health.

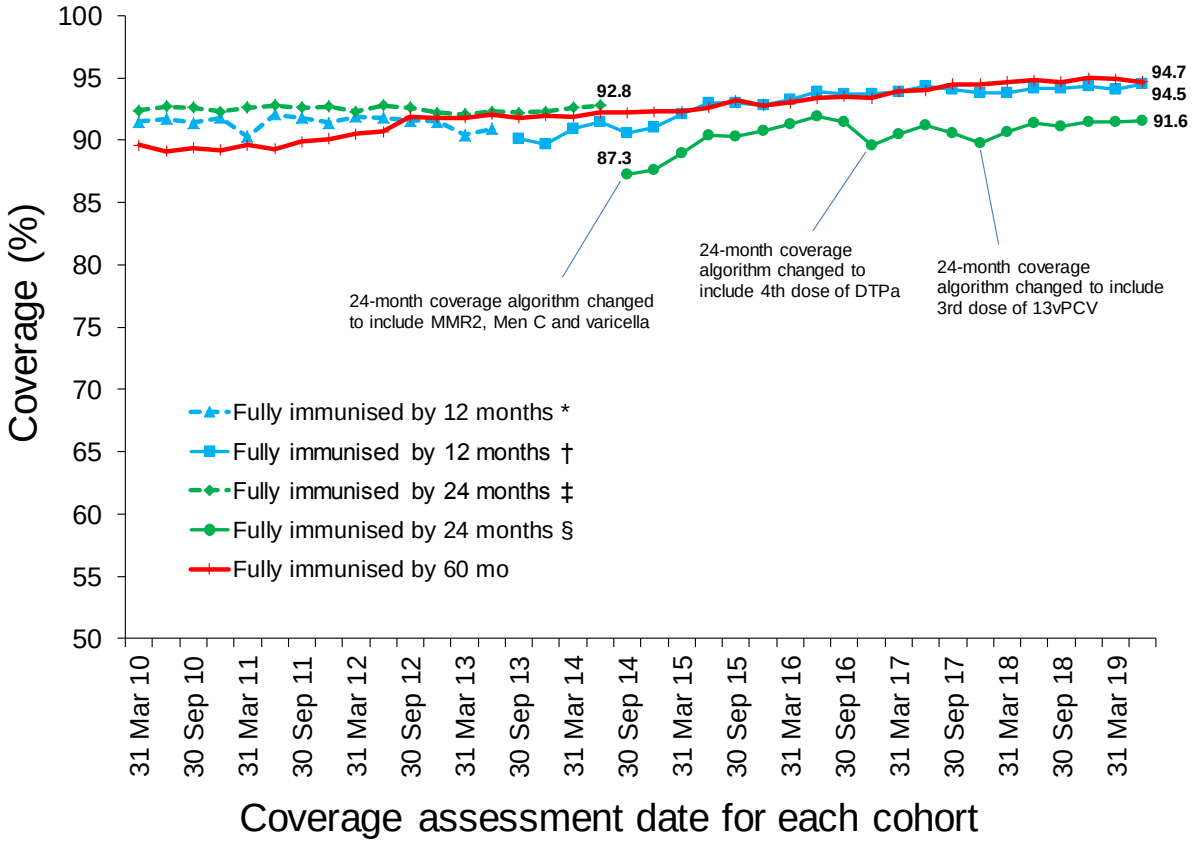
Results

2-year age milestone analysis

‘Fully vaccinated’ coverage estimates

‘Fully vaccinated’ coverage estimates at the 2-year age milestone, after being consistently higher than coverage at the 1-year and 5-year age milestones for several years, decreased in the second half of 2014 by 5.5 percentage points, from 92.8% to 87.3%. This decrease occurred when the coverage assessment algorithm was changed to also require doses of MenC- and varicella-containing vaccines and a second dose of MMR-containing vaccine (MMR2) (refer to Figure 1). Since 2014, coverage at this milestone age has remained consistently below that at the 1-year and 5-year age milestones. Although 2-year coverage, measured using the 2014 algorithm, increased from 87.3% to 91.3% in March 2016, it decreased again in late 2016 (following the algorithm change to include DTPa4) to 89.6%, and again in mid-2018 (following the inclusion of the third dose of 13vPCV in the algorithm), before increasing in June 2019 to 91.6%.

Figure 1: Trends in ‘fully vaccinated’ coverage estimates by quarter, Australia, 2010 to 2019



By 3-month birth cohorts born between 1 January 2005 and 30 June 2018. Coverage assessment date was 12, 24 or 60 months after the last birth date of each cohort. Vaccination coverage estimates are calculated by quarter and may differ slightly from estimates published elsewhere using rolling annualised data.

* Coverage algorithm before 1 July 2013

† Coverage algorithm from 1 July 2013

‡ Coverage algorithm before 1 July 2014

§ Coverage algorithm from 1 July 2014

MMR2 – second dose of MMR-containing vaccine

MenC – meningococcal C vaccine

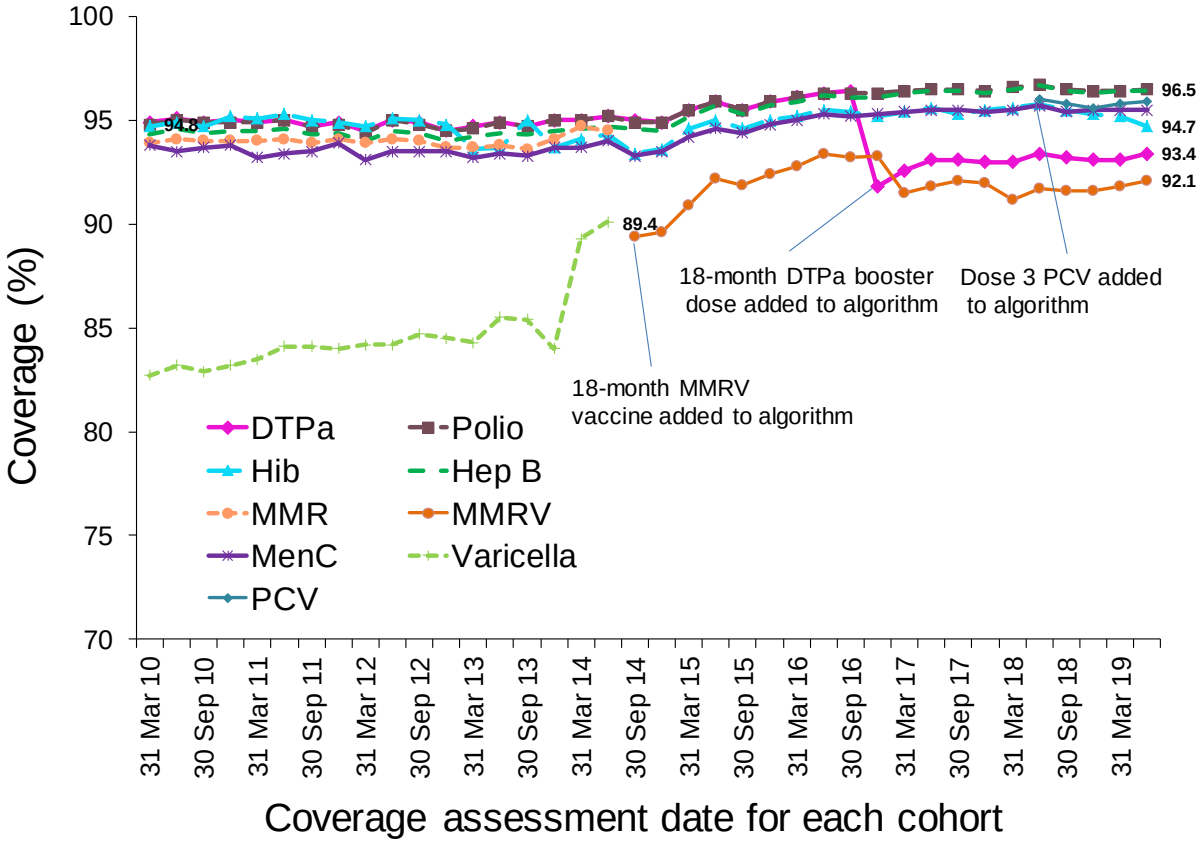
DTPa – diphtheria-tetanus-acellular pertussis–containing vaccine

Source: Australian Immunisation Register, data as at 30 September 2019.

Individual vaccine/antigen coverage estimates

Coverage estimates for MMRV vaccine (added to the NIP in July 2013 and included in the 2-year age milestone assessment algorithm from the September 2014 quarter) have been consistently lower than those for other vaccines/antigens assessed at 2 years (refer to Figure 2). Coverage estimates for DTPa4 (added to the NIP in March 2016 and included in the 2-year age milestone assessment algorithm from the December 2016 quarter) have also been consistently lower than those for other vaccines/antigens at the 2-year age milestone (93.4% in June 2019), except for MMRV vaccine (92.1%). As at June 2019, the difference in coverage between polio-containing vaccine (96.5%; third dose scheduled at 6 months of age) and MMRV vaccine (92.1%; dose scheduled at 18 months of age) was 4.4 percentage points (refer to Figure 2).

Figure 2: Trends in vaccination coverage estimates at 24 months of age, by vaccine/antigen* and quarter, Australia, 2010 to 2019



By 3-month birth cohorts born between 1 January 2008 and 30 June 2017. Coverage assessment date was 24 months after the last birth date of each cohort. Vaccination coverage estimates are calculated by quarter and may differ slightly from estimates published elsewhere using rolling annualised data.

* Fourth dose of DTPa-containing vaccine (from October 2016), third dose of polio-containing vaccine, third or fourth dose of Hib vaccine, third dose of hepatitis B-containing vaccine, second dose of MMR-containing vaccine (MMRV vaccine from September 2014), first dose of MenC-containing vaccine

DTPa = diphtheria-tetanus-acellular pertussis–containing vaccine

Hib = *Haemophilus influenzae* type b vaccine

Hep B = hepatitis B-containing vaccine

MMR = measles-mumps-rubella-containing vaccine

MenC = meningococcal C vaccine

MMRV = measles-mumps-rubella-varicella vaccine

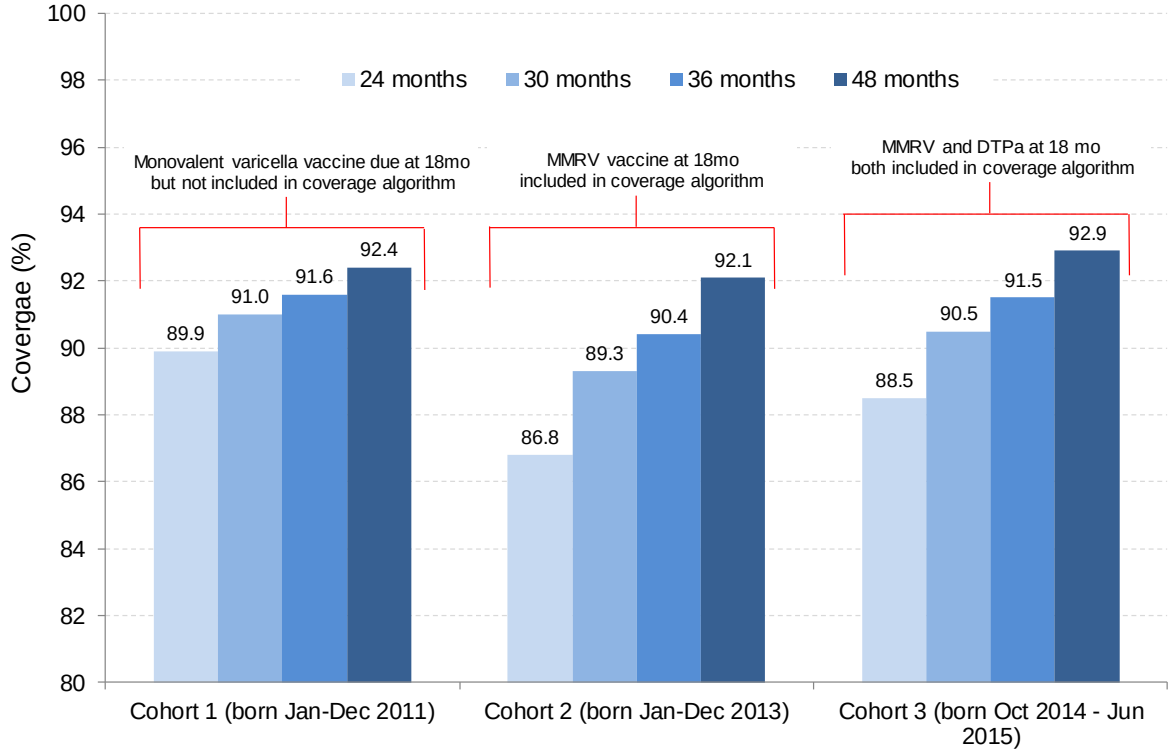
PCV = pneumococcal conjugate vaccine

Source: Australian Immunisation Register, data as at 30 September 2019.

‘Fully vaccinated’ and individual vaccine/antigen coverage estimates assessed at 24, 30, 36 and 48 months of age

Figure 3 shows ‘fully vaccinated’ coverage estimates, assessed at 24 months (baseline) and the later ages of 30, 36 and 48 months for three cohorts of children, using the 2-year assessment algorithm that was in place at the time for each cohort. In Cohort 1, born in 2011 when only monovalent varicella vaccine was scheduled at 18 months of age, although not included in the coverage assessment algorithm, ‘fully vaccinated’ coverage was 89.9% at 24 months of age but increased by 2.5 percentage points to 92.4% when assessed at 48 months of age. In Cohort 2, born in 2013 and eligible to receive MMRV vaccine at 18 months of age, ‘fully vaccinated’ coverage was lower at 24 months of age (86.8%) compared to that in Cohort 1, but increased by a greater amount (5.3 percentage points) reaching 92.1% at 48 months of age. In cohort 3, born October 2014 to June 2015 and eligible to receive both MMRV vaccine and DTPa4 at 18 months of age, ‘fully vaccinated’ coverage at 24 months was 88.5%, higher than that in Cohort 2 but lower than that in Cohort 1, and increased by 4.4 percentage points to 92.9% at 48 months of age, higher than the coverage in both other cohorts.

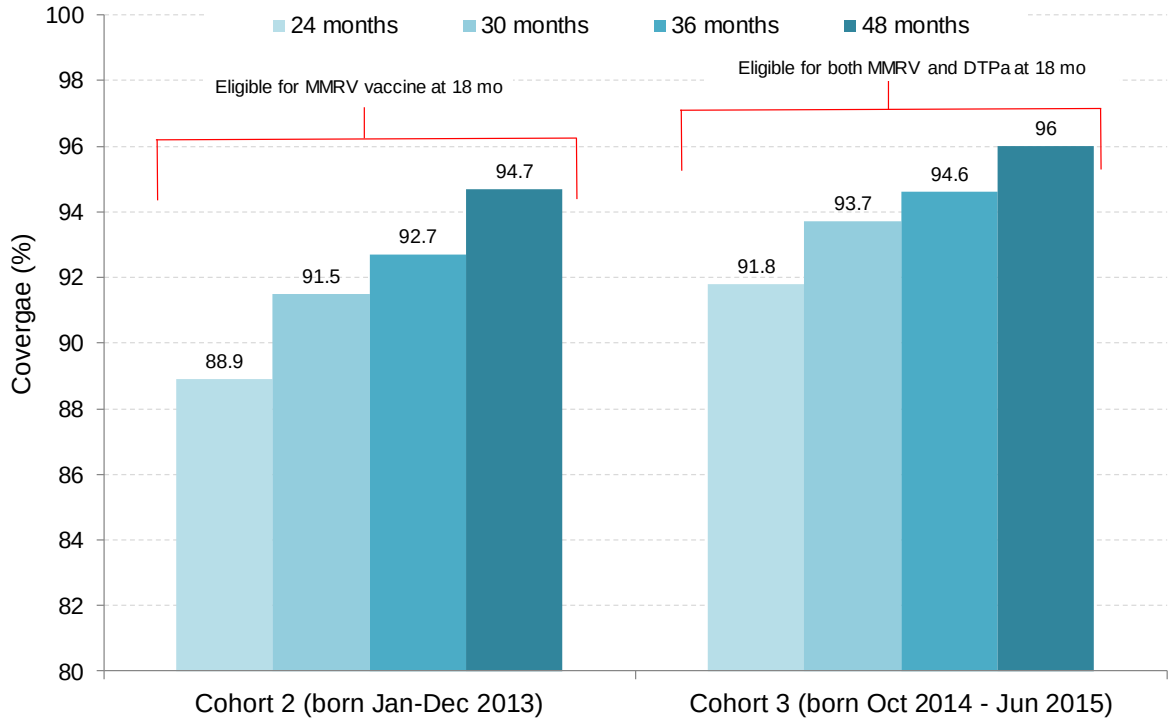
Figure 3: 'Fully vaccinated' coverage estimates, using 2-year assessment algorithm, assessed at 24, 30, 36 and 48 months of age, by birth cohort



Source: Australian Immunisation Register, data as at 30 September 2019.

Figure 4 shows coverage estimates for MMR2, due as MMRV at 18 months of age, assessed at the 24-month baseline and then at 30, 36 and 48 months of age for Cohorts 2 and 3. In Cohort 2, born in 2013, MMR2 coverage was 88.9% at 24 months of age but increased by 5.8 percentage points to 94.7% when assessed at 48 months of age. In Cohort 3, born in 2015 and eligible for both MMRV and DTPa4 at 18 months of age, MMR2 coverage was higher than that in Cohort 2 at the 24-month baseline (91.8%) and at 30 and 36 months, reaching 96.0% at 48 months of age.

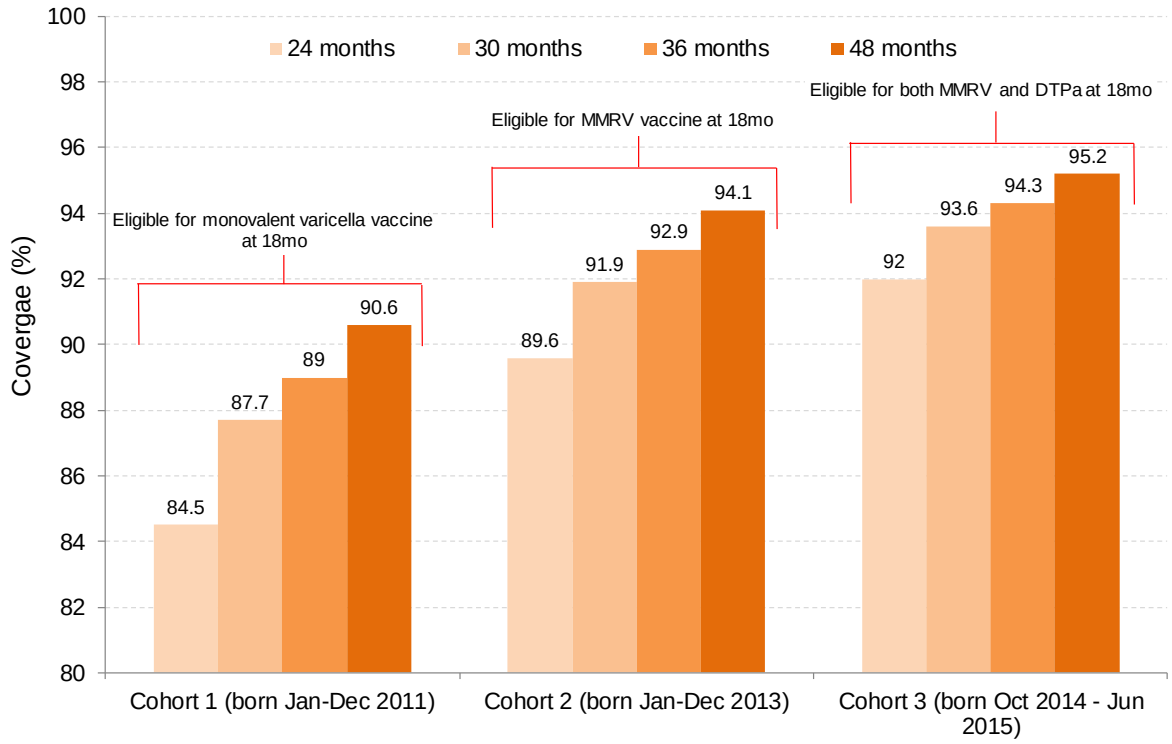
Figure 4: Coverage estimates of the second dose of measles-mumps-rubella (MMR)–containing vaccine assessed at 24, 30, 36 and 48 months of age, by birth cohort



Source: Australian Immunisation Register, data as at 30 September 2019.

Figure 5 shows coverage estimates for varicella-containing vaccine, due as MMRV at 18 months of age, assessed at 24, 30, 36 and 48 months of age for Cohorts 1, 2 and 3. In Cohort 1, eligible for monovalent varicella vaccine only at 18 months of age, varicella coverage was 84.5% at 24 months of age but increased progressively by a total of 6.1 percentage points to reach 90.6% at 48 months of age. In Cohort 2, eligible to receive MMRV vaccine at 18 months of age, varicella coverage was higher at both 24 months (89.6%) and 48 months of age (94.1%) than that in Cohort 1. In Cohort 3, eligible to receive both MMRV vaccine and DTPa4 at 18 months of age, varicella coverage at 24 months was higher again at 24 months (92.0%) and reached 95.2% at 48 months of age.

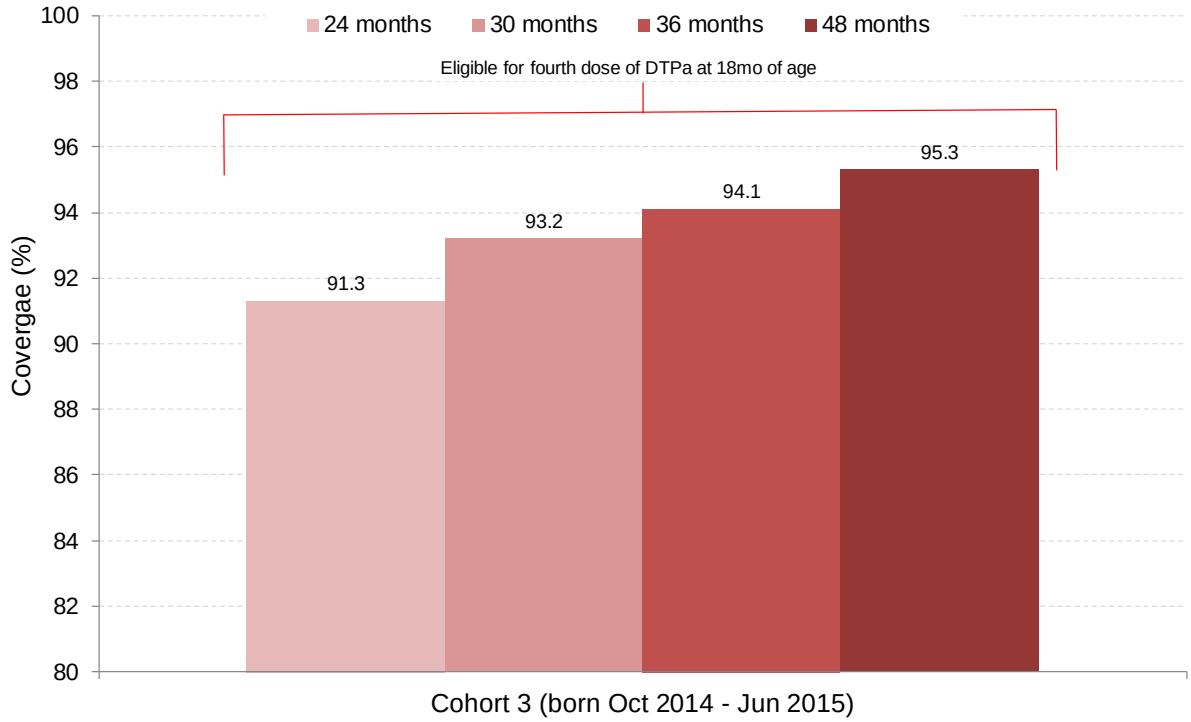
Figure 5: Coverage estimates of varicella-containing vaccine assessed at 24, 30, 36 and 48 months of age for three separate cohorts of children



Source: Australian Immunisation Register, data as at 30 September 2019.

Figure 6 shows coverage estimates for DTPa4, due at 18 months of age, assessed at 24, 30, 36 and 48 months of age for Cohort 3. In this cohort, eligible to receive both MMRV vaccine and DTPa4 at 18 months, DTPa4 coverage at 24 months was 91.3%, increasing by 4.0 percentage points to 95.3% when assessed at 48 months of age.

Figure 6: Coverage of the fourth dose of diphtheria-tetanus-acellular pertussis (DTPa)–containing vaccine at 24, 30, 36 and 48 months of age in children born 1 October 2014 to 30 June 2015



Source: Australian Immunisation Register, data as at 30 September 2019.

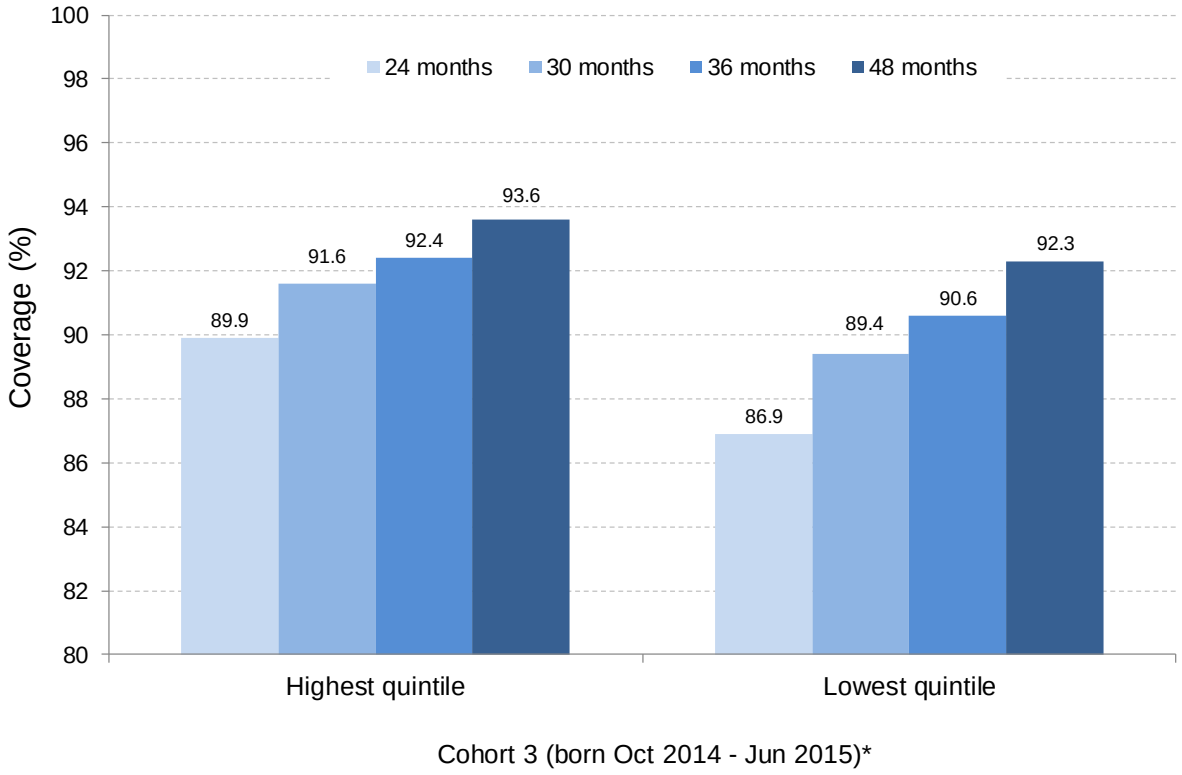
Vaccine coverage estimates for MenC, polio, hepatitis B and Hib vaccines, due at 6 and/or 12 months of age, were assessed at 24, 30, 36 and 48 months of age for the three birth cohorts and showed increases in coverage between 24 months and 48 months of age, ranging from 0.7 of a percentage point (Hib vaccine) to 3.4% (MenC vaccine) (data not shown).

‘Fully vaccinated’ coverage estimates assessed at 24, 30, 36 and 48 months of age by socioeconomic status

In Cohort 3, eligible to receive both MMRV and DTPa4 vaccines at 18 months, ‘fully vaccinated’ coverage at 24 months of age for children in the highest socio-economic quintile was 89.9% and increased by 3.7 percentage points to 95.3% when assessed at 48 months using the 2-year assessment algorithm (refer to Figure 7). In comparison, children in the lowest socio-economic quintile had ‘fully vaccinated’ coverage which remained about 3 percentage points lower at both 24 months (86.9%) and 48 months of age (92.3%), although coverage increased by 5.4 compared with 3.7 percentage points between 24 and 48 months (refer to Figure 7).

The overall picture was similar for DTPa4, MMR2 and varicella-containing vaccine, that is, higher coverage at all age points among children in the highest socio-economic quintile but greater increases in coverage estimates between 24 and 48 months.

Figure 7: 'Fully vaccinated' coverage at 24, 30, 36 and 48 months of age, by area socioeconomic status, Cohort 3 (born 1 October 2014 – 30 June 2015)



* Eligible to receive MMRV vaccine and DTPa4 at 18 months of age, post inclusion of both in coverage algorithm.

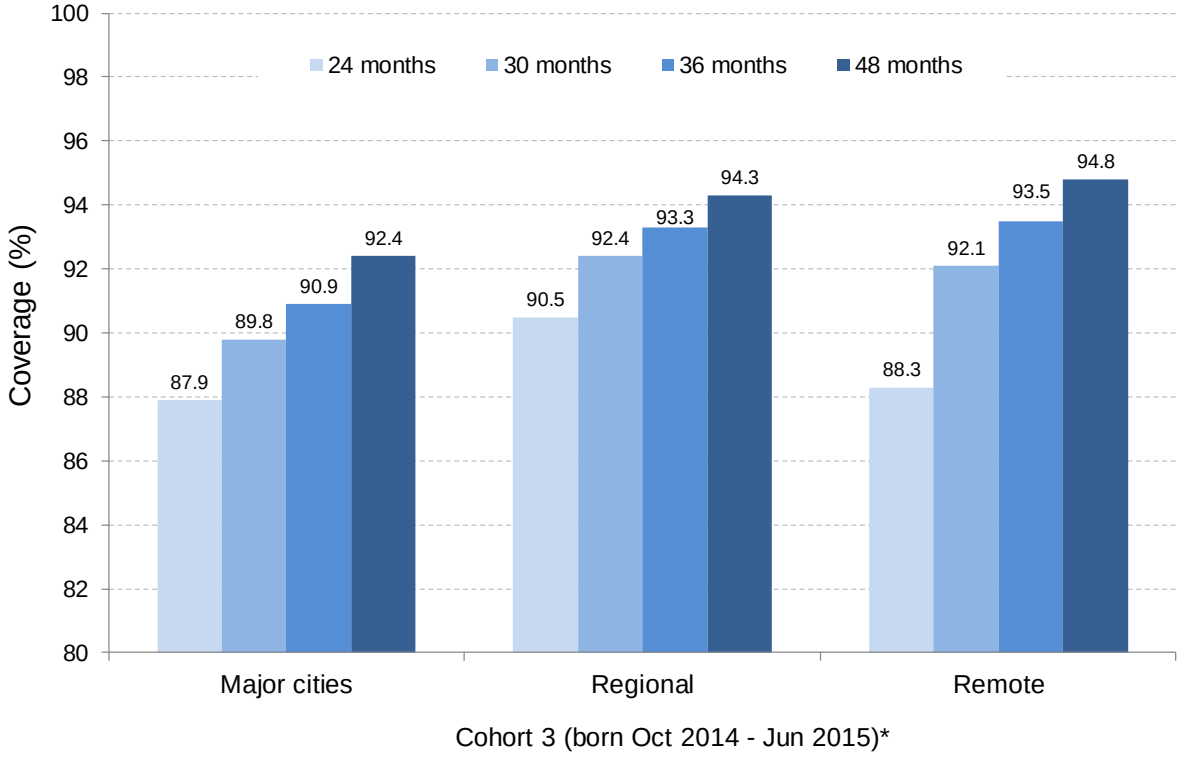
Source: Australian Immunisation Register, data as at 30 September 2019.

'Fully vaccinated' coverage estimates assessed at 24, 30, 36 and 48 months of age by remoteness category

'Fully vaccinated' coverage at 24 months of age for children in Cohort 3 residing in major cities was 87.9%, increasing by 4.5 percentage points to 92.4% at 48 months of age using the 2-year assessment algorithm (refer to Figure 8). For children residing in regional areas, 'fully vaccinated' coverage was higher at both 24 (90.5%) and 48 months of age (94.3%) than that for children in major cities. Among children residing in remote areas, 'fully vaccinated' coverage was lower at 24 months (88.3%) than that for children in regional areas, but was higher at 48 months of age (94.8%) than that for children in urban and regional areas (refer to Figure 8). The differential between remote and other areas is largely driven by the higher proportion of Indigenous children in remote areas, with coverage in remote areas lower at 24 months for Indigenous children (85.3% versus 90.5% for non-Indigenous), but higher at 48% (95.9% versus 94.0%).

Similar results were found when comparing individual vaccines (DTPa-containing, MMR-containing and varicella-containing), with higher coverage in regional and remote areas, than in major cities, and the greatest increase between 24 and 48 months seen in children residing in remote areas (data not shown).

Figure 8: 'Fully vaccinated' coverage estimates, using the 2-year assessment algorithm, assessed at 24, 30, 36 and 48 months of age, by remoteness category of area of residence, Cohort 3 (born 1 October 2014 – 30 June 2015)



* Eligible to receive MMRV vaccine and DTPa4 at 18 months of age, post inclusion of both in coverage algorithm.

Source: Australian Immunisation Register, data as at 30 September 2019.

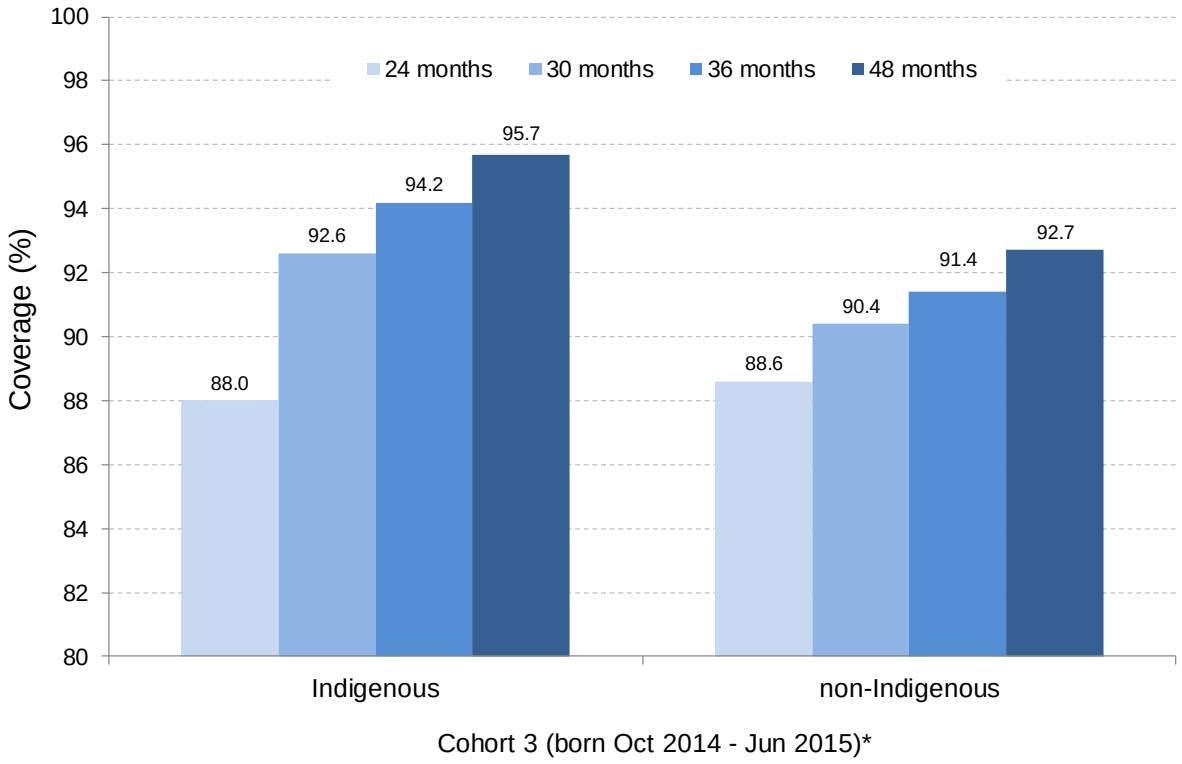
'Fully vaccinated' coverage estimates assessed at 24, 30, 36 and 48 months of age by Indigenous status

'Fully vaccinated' coverage at 24 months in Cohort 3 was lower for Indigenous (88.3%) than non-Indigenous children (88.6%) but increased more over time in Indigenous children, so that at 48 months it was 95.7% compared with 92.7% in non-Indigenous children (refer to Figure 9).

Coverage of MMR2 in Cohort 3 was slightly higher at 24 months for Indigenous children than non-Indigenous children (92.0% versus 91.8%) but was substantially higher at 48 months (98.4% versus 92.7%) (refer to Figure 10).

Similarly, coverage of varicella-containing vaccine in Cohort 3 was lower at 24 months for Indigenous children than non-Indigenous children (91.2% versus 92.0%) but was higher at 48 months (97.3% versus 95.1%) (refer to Figure 11). Likewise, findings for DTPa4 (89.4% versus 91.4% at 24 months and 97.2% versus 95.2% at 48 months) (refer to Figure 12) and for MenC-containing vaccine (96.6% at 24 months and 98.8% at 48 months of age for Indigenous versus 93.5% at 24 months and 96.4% at 48 months of age for non-Indigenous children) followed the same trends (data not shown).

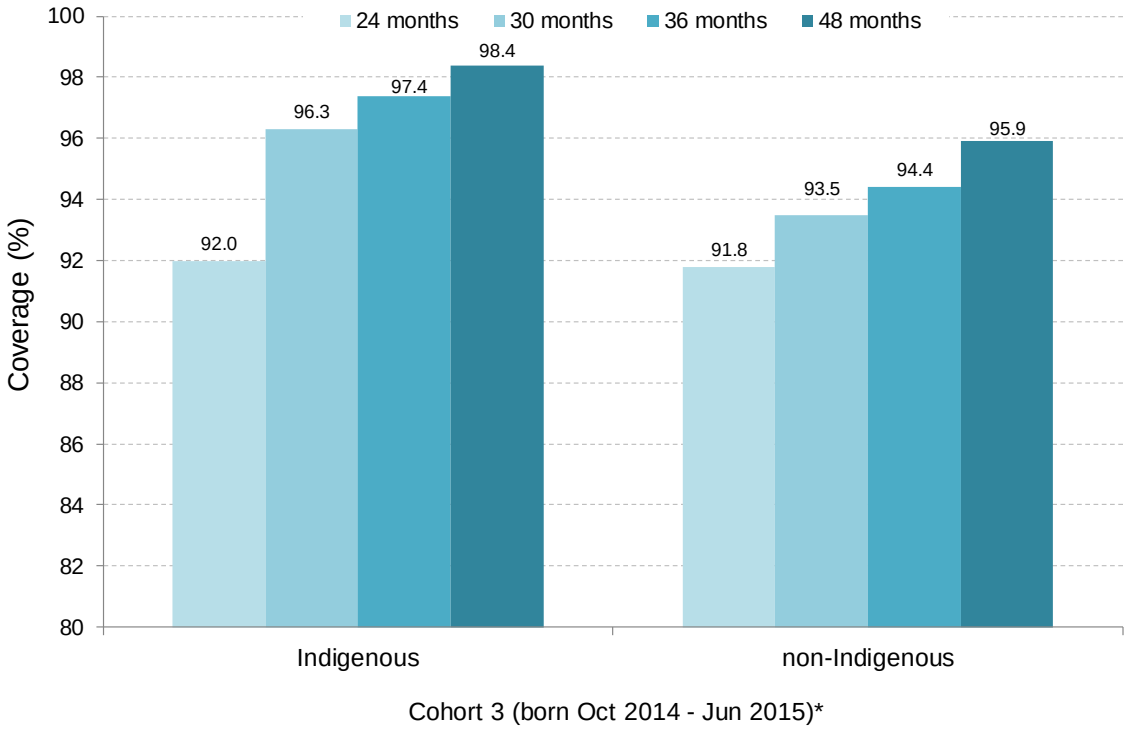
Figure 9: 'Fully vaccinated' coverage assessed at 24, 30, 36 and 48 months of age, by Indigenous status, Cohort 3 (born 1 October 2014 – 30 June 2015)



* Eligible to receive MMRV vaccine and DTPa4 at 18 months of age, post inclusion of both in coverage algorithm.

Source: Australian Immunisation Register, data as at 30 September 2019.

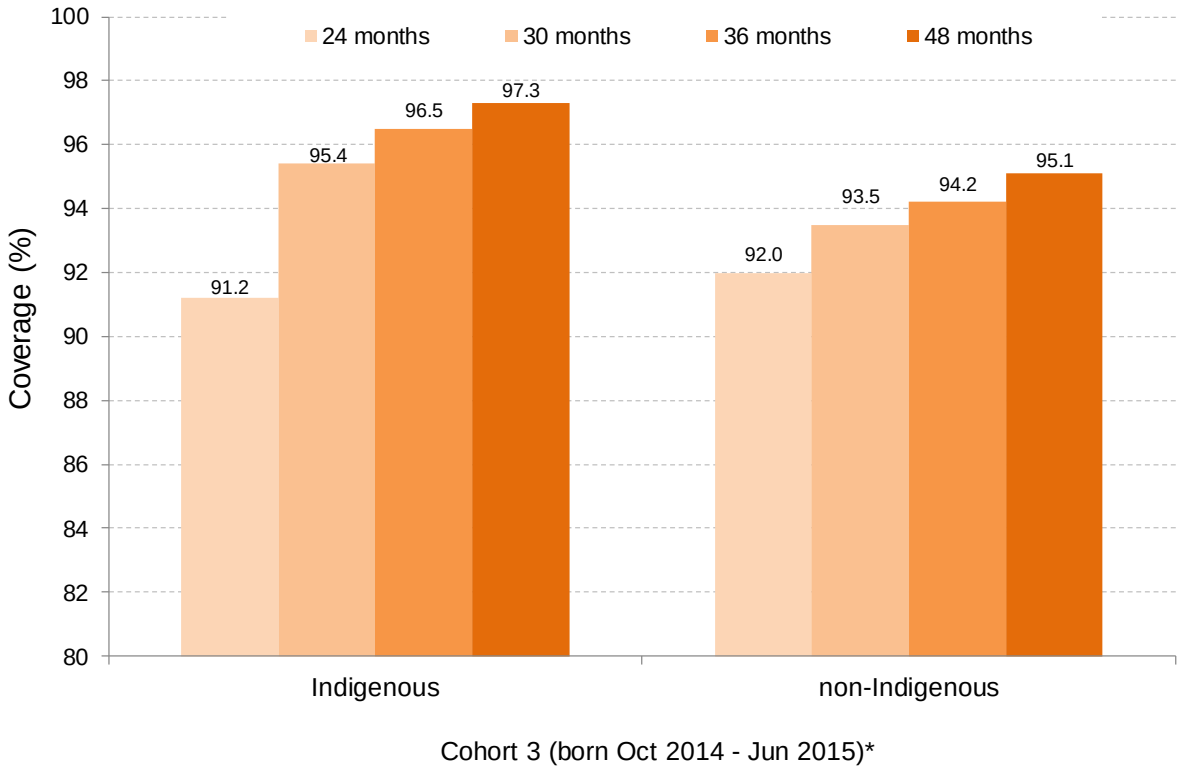
Figure 10: Coverage for the second dose of measles-mumps-rubella (MMR)–containing vaccine at 24, 30, 36 and 48 months by Indigenous status in children born 1 October 2014 – 30 June 2015



* Eligible to receive MMRV vaccine and DTPa4 at 18 months of age, post inclusion of both in coverage algorithm.

Source: Australian Immunisation Register, data as at 30 September 2019.

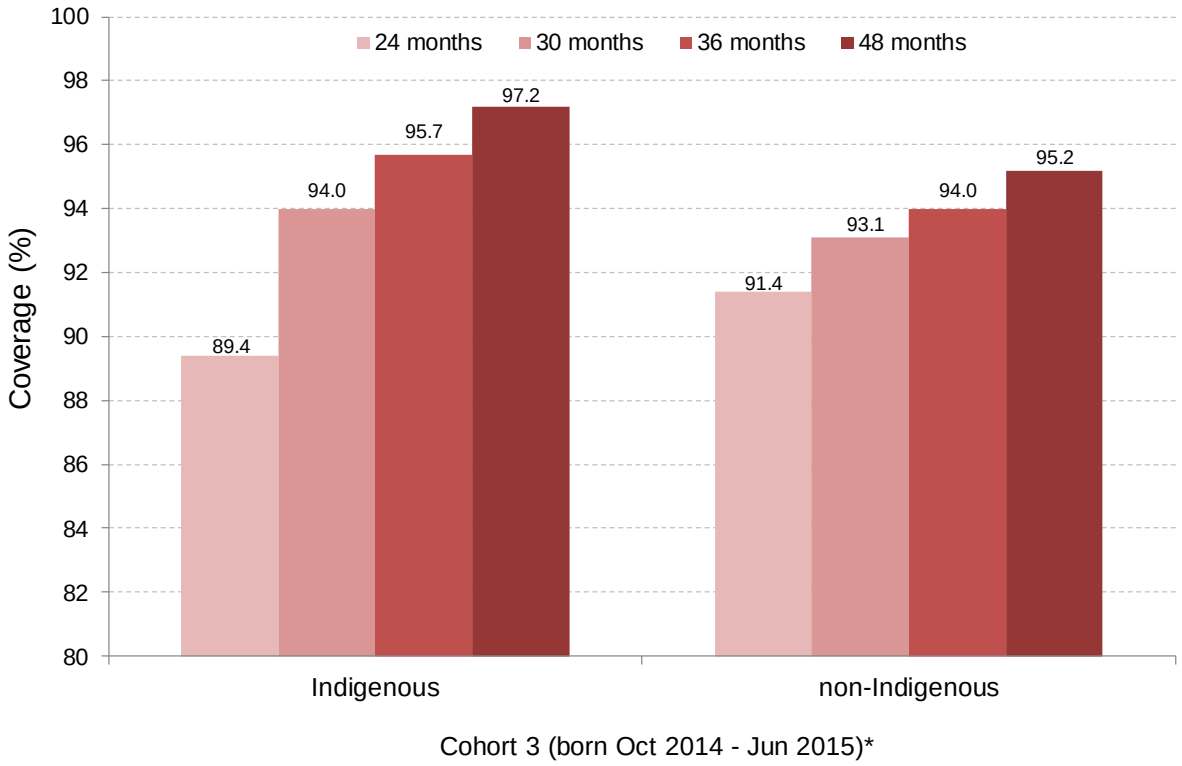
Figure 11: Coverage of varicella-containing vaccine at 24, 30, 36 and 48 months of age, by Indigenous status for children born 1 October 2014 – 30 June 2015



* Eligible to receive MMRV vaccine and DTPa4 at 18 months of age, and post inclusion of both in coverage algorithm.

Source: Australian Immunisation Register, data as at 30 September 2019.

Figure 12: Coverage estimates of the fourth dose of diphtheria-tetanus-acellular pertussis (DTPa)–containing vaccine assessed at 24, 30, 36 and 48 months of age, by Indigenous status, Cohort 3 (born 1 October 2014 – 30 June 2015)



Cohort 3 (born Oct 2014 - Jun 2015)*

*Eligible to receive MMRV vaccine and DTPa4 at 18 months of age, post inclusion of both in coverage algorithm.

Source: Australian Immunisation Register, data as at 30 September 2019.

Analysis of missing vaccinations due at 18 months, assessed at 2 years of age

Table 1 shows the number and percentage of children in Cohort 4 (born between 1 October and 31 December) who had not received all three vaccines due at 18 months of age by 24 months of age, by missing vaccine type. Of the 5,818 children (7.8% of all children in the cohort) who had not received all three vaccines due at 18 months of age, approximately two-thirds (68.8%; 5.4% of the overall cohort) were missing all three, 16% were missing the 18-month dose of Hib vaccine and smaller percentages were missing other permutations, that is, 2.4% of the overall cohort 4 were missing either one or two of the three doses due at 18 months.

Table 1. Number and percentage of children who had not received all vaccines due at 18 months by 24 months, Cohort 4 (born 1 October 2017 – 31 December 2017)

Missing vaccines	Number of children	%

All three vaccines	3,990	68.8
Hib4 only	932	16.0
DTPa4 and Hib4	398	6.8
MMR2 only	211	3.6
DTPa4 only	181	3.1
DTPa4 and MMR2	57	1.0
MMR2 and Hib4	49	0.8
Total	5,818	100.0

Hib4 = fourth dose of *Haemophilus influenzae* type b vaccine

DTPa4 = fourth dose of diphtheria-tetanus-acellular pertussis–containing vaccine

MMR2 = second dose of measles-mumps-rubella–containing vaccine

Source: Australian Immunisation Register, data as at 30 September 2019.

Analysis of concomitant vaccinations

Of the 7,150 children (3.0%) in Cohort 4 who received all three vaccines due at 18 months by 24 months of age but did not receive them at the same visit, 65.6% received their fourth dose of Hib vaccine on a different date and 21.2% their MMR2 on a different date – only 4.9% received all three vaccines on different dates (refer to Table 2).

Table 2. Number and percentage of children who received all three vaccines due at 18 months by 24 months of age but not concomitantly, Cohort 4 (born 1 October 2017 – 31 December 2017)

Vaccines received on same date	Number of children	%
DTPa4 with MMR2 (Hib4 on different date)	4,691	65.6
DTPa4 with Hib4 (MMR2 on different date)	1,517	21.2
MMR2 with Hib4 (DTP4 on different date)	595	8.3
All 3 vaccines on different dates	347	4.9
Total	7,150	100.0

Hib4 = fourth dose of *Haemophilus influenzae* type b vaccine

DTPa4 = fourth dose of diphtheria-tetanus-acellular pertussis–containing vaccine

MMR2 = second dose of measles-mumps-rubella–containing vaccine

Source: Australian Immunisation Register, data as at 30 September 2019.

The number and percentage of children who received all three vaccines due at 18 months by 24 months of age but not at the same visit, was similar by Indigenous status (refer to Table 3).

Table 3. Number and percentage of children who received all three vaccines due at 18 months by 24 months of age, but not all on same date, by Indigenous status and vaccine type, Cohort 4 (born 1 October 2017 – 31 December 2017)

Vaccine	Indigenous (%)	Non-Indigenous (%)	Total
Hib4 on different date	69.2	65.4	4,691
MMR2 on different date	19.2	21.4	1,517
DTPa4 on different date	9.5	8.2	595
All on different dates	2.2	5.0	347

Hib4 = fourth dose of *Haemophilus influenzae* type b vaccine

DTPa4 = fourth dose of diphtheria-tetanus-acellular pertussis–containing vaccine

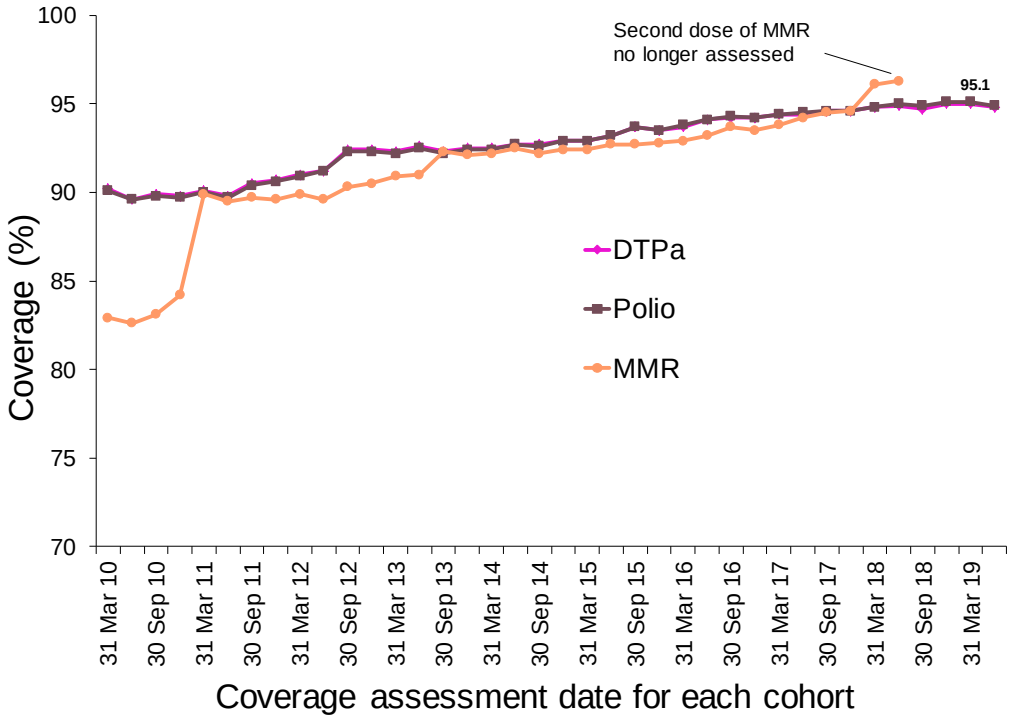
MMR2 = second dose of measles-mumps-rubella–containing vaccine

Source: Australian Immunisation Register, data as at 30 September 2019.

5-year age milestone analysis

Coverage estimates for vaccines/antigens assessed at the 5-year age milestone have increased over time, reaching just over 95% for DTPa and polio (usually given as a single combined vaccine) in early 2019 (refer to Figure 13).

Figure 13: Trends in vaccination coverage at 5 years of age, Australia, 2010 to 2019



By 3-month birth cohorts born between 1 January 2005 and 30 June 2014. Coverage assessment date was 60 months after the last birth date of each cohort. Vaccination coverage estimates are calculated by quarter and may differ slightly from estimates published elsewhere using rolling annualised data.

* Fourth or fifth dose of DTPa and fourth dose of polio, second dose of MMR (up until June 2017)

DTPa = diphtheria-tetanus-acellular pertussis–containing vaccine

MMR = measles-mumps-rubella–containing vaccine

Source: Australian Immunisation Register, data as at 30 September 2019.

Table 4 shows 'fully vaccinated' coverage estimates for Cohort 5 (born 1 July 2013 – 30 June 2014) assessed at 5 years of age using both the current algorithm (fourth or fifth dose of DTPa-containing vaccine and fourth dose of polio-containing vaccine) versus a 'full' algorithm (fourth or fifth dose of DTPa-containing vaccine + fourth dose of polio-containing vaccine + fourth dose of Hib-containing vaccine + third dose of hepatitis B-containing vaccine + second dose of MMR-containing vaccine + first dose of MenC-containing vaccine + first dose of varicella vaccine + third dose of PCV), by state or territory. Coverage calculated using this 'full' algorithm was 5.5 percentage points lower at national level compared with estimates using the current algorithm, ranging from 5.9 percentage points lower in New South Wales and Victoria to 4.2 percentage points lower in Tasmania.

Table 4. 'Fully vaccinated' coverage estimates at 5 years of age[*] by state or territory, calculated using current[†] and 'full'[‡] algorithms

	State or territory								
	ACT	**NSW**	**NT**	**Qld**	**SA**	**Tas**	**Vic**	**WA**	**Australia**
Coverage % - current algorithm†	94.4	93.7	93.2	93.7	94.2	95.5	95.0	92.8	94.0
Coverage % - 'full' algorithm‡	89.9	87.8	87.8	88.8	88.8	91.3	89.1	88.0	88.5
Difference (percentage points)	-4.5	-5.9	-5.4	-4.9	-5.4	-4.2	-5.9	-4.8	-5.5

* Cohort born 1 July 2013 – 30 June 2014

† Fourth or fifth dose of DTPa-containing vaccine and fourth dose of polio-containing vaccine.

‡ Fourth or fifth dose of DTPa-containing vaccine, fourth dose of polio-containing vaccine, fourth dose of Hib-containing vaccine, third dose of hepatitis B-containing vaccine, second dose of MMR-containing vaccine, first dose of MenC-containing vaccine, first dose of varicella vaccine and third dose of PCV.

DTPa = diphtheria-tetanus-acellular pertussis

Hib = *Haemophilus influenzae* type b

MMR = measles-mumps-rubella

MenC = meningococcal C

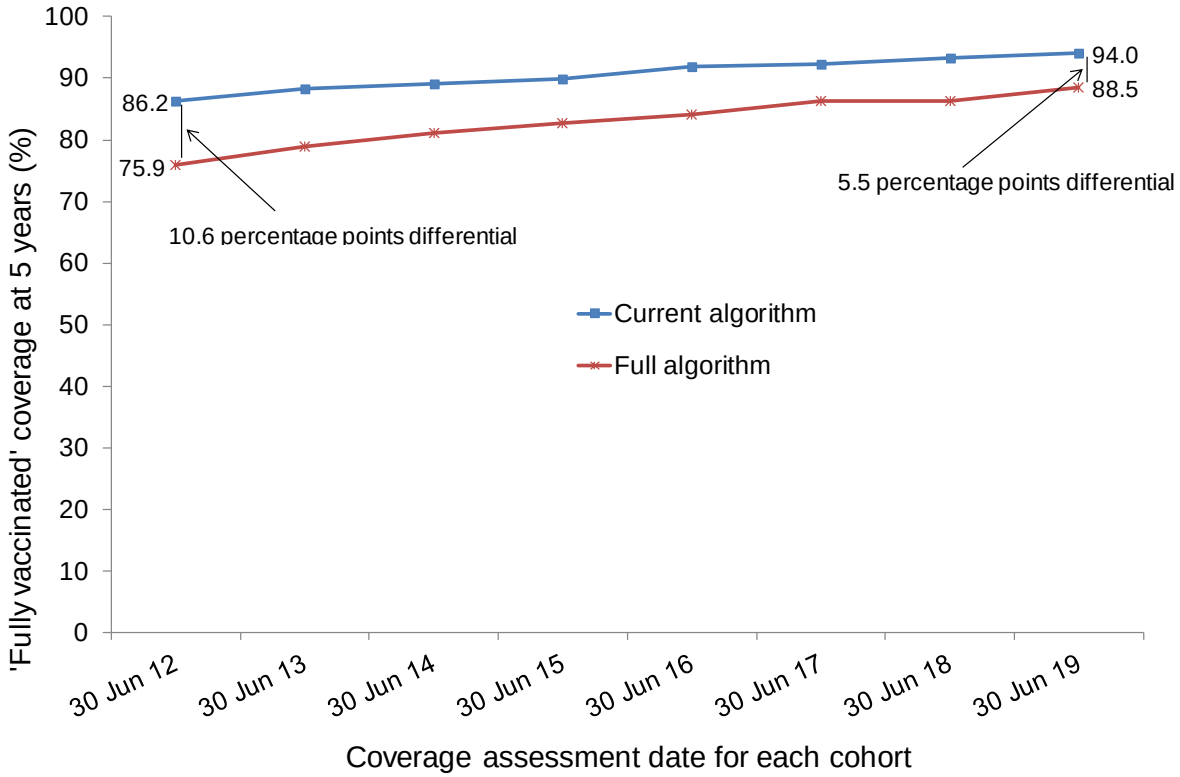
MMRV = measles-mumps-rubella-varicella

PCV = pneumococcal conjugate vaccine

Source: Australian Immunisation Register, data as at 30 September 2019.

Figure 14 shows trends in 'fully vaccinated' coverage assessed at 5 years of age using the current and 'full' algorithms. The differential approximately halved from 10.6 percentage points in June 2012 to 5.5 percentage points in June 2019 (refer to Figure 14).

Figure 14: Trends in 'fully vaccinated coverage estimates assessed at 5 years of age, retrospectively calculated using current* and 'full'† algorithms



By 12-month birth cohorts born between 1 July 2006 and 30 June 2014. Coverage assessment date was 60 months after the last birth date of each cohort. Vaccination coverage estimates are calculated by quarter and may differ slightly from estimates published elsewhere using rolling annualised data.

* Fourth or fifth dose of DTPa-containing vaccine, fourth dose of polio-containing vaccine.

† Fourth or fifth dose of DTPa-containing vaccine + fourth dose of polio-containing vaccine + fourth dose of Hib-containing vaccine + third dose of hepatitis B-containing + second dose of MMR-containing vaccine + single dose of MenC-containing vaccine + single dose of varicella vaccine + third dose of PCV.

Source: Australian Immunisation Register, data as at 30 September 2019.

Discussion

'Fully vaccinated' coverage at the 2-year age milestone, after being consistently higher than coverage at the 1-year and 5-year age milestones for several years, decreased in 2014 from 92.8% to 87.3%, and has remained lower since. This decrease in 2014 coincided with changes in the 2-year coverage assessment algorithm, specifically the addition of MenC vaccine, due at 12 months, and varicella and MMR2, due at 18 months as MMRV vaccine. Coverage at the 2-year age milestone rebounded after the 2014 algorithm change, decreasing again in late 2016 following the addition of DTPa4 to required vaccines. Historically the last change to vaccines due at 18 months was removal of DTPa4 from the NIP Schedule in 2003, which was followed by a 3.1 percentage point increase in coverage at 2 years by mid-2004.[12]

Our analysis shows that coverage for individual vaccines due at 18 months of age that were included in the 2-year coverage assessment algorithm was consistently lower over the study period, with MMRV vaccine coverage the lowest and DTPa4 coverage the next lowest. As at June 2019, coverage for polio-containing vaccine was 96.5%, DTPa4 93.4% and MMRV vaccine 92.1%. It is likely that the lower coverage for vaccines due at 18 months is due at least in part to the 6-month time period available for vaccination before coverage is assessed. Although a 6-month period also applies to vaccines due at 6 months assessed at the 1-year coverage milestone, more frequent attendance of infants at GPs and other immunisation providers in the first year of life is likely responsible for less impact on coverage.

Our analysis of coverage at older ages, using the same algorithm in place at the 2-year age milestone for each cohort, found that 'fully vaccinated' coverage estimates for Cohort 2 (born in 2013 and eligible for MMRV vaccine at 18 months), increased at later ages such that coverage at 48 months of age was similar to that for Cohort 1, born in 2011, with no vaccines due at 18 months in the assessment algorithm. This indicates that substantial vaccination catch-up activity occurs.

Key reasons for moving the second dose of MMR vaccine from 4 years to 18 months and giving as MMRV vaccine from 2013 were to promote earlier and higher 2-dose measles coverage and higher varicella coverage, as varicella coverage had been relatively low since the vaccine introduction in 2005, partly due to poor patient and provider acceptance.[12] Importantly, varicella coverage at 2 years of age increased from 84.5% in Cohort 1 (eligible for monovalent varicella vaccine) to 92.0% in Cohort 3 (born in 2014–2015 and eligible for MMRV vaccine) and MMR2 coverage at 2 years of age in Cohort 3 was similar (91.8%) to coverage assessed at 6 years of age in 2012 (91.6%),[13] reaching 96% by 48 months of age.

Focusing on Cohort 3, eligible for both MMRV vaccine and DTPa4 at 18 months, we found that while 'fully vaccinated' and individual vaccine coverage were higher in areas in the highest socio-economic quintile, there was a greater increase in coverage between the 24 and 48 month age assessment milestones in areas in the lowest socio-economic quintile. We found a similar pattern in coverage for Indigenous compared to non-Indigenous children. This pattern of less timely vaccination, but greater catch-up activity, in lower socio-economic and Indigenous children likely reflects access to immunisation services. The increase in coverage assessed at older milestone ages was most marked in Indigenous children, in whom timeliness has been a well-documented and longstanding issue.[14] 'Fully vaccinated' coverage in Indigenous children in Cohort 3 increased

from 88.0% at 24 months to 95.7% at 48 months; DTPa4 coverage from 89.4% to 97.2%; and MMR2 from 92.0% to 98.4%.

Another factor that could have potentially contributed to the lower 'fully vaccinated' coverage estimates observed at the 2-year age milestone is provider/parent delay or spacing of vaccinations because of the increase in the number of injections required at 18 months of age. We found that 3.0% of children in Cohort 4 (born 1 October 2017 – 31 December 2017 and eligible to receive MMRV vaccine, DTPa4 and monovalent Hib booster dose at 18 months of age) received all three vaccines by the 2-year assessment milestone but not concomitantly.

We estimated that coverage at 5 years of age for Cohort 5 (born July 2013 – June 2014), as of 30 September 2019, would be 5.5 percentage points lower if assessed by a 'full' coverage algorithm (requiring all vaccines/antigens scheduled before the fifth birthday, except rotavirus) compared with the current algorithm which requires only one vaccine, DTPa-polio, due at 4 years of age (88.5% versus 94.0%, respectively). Notably, coverage at the 2-year age milestone in 2019 using this 'full algorithm' was three percentage points lower than that using the current algorithm.

In conclusion, although 'fully vaccinated' coverage estimates at the 2-year age milestone have decreased and remain below those at the 1-year and 5-year age milestones, we documented substantial and increasing catch-up vaccination activity over subsequent years. It is possible that requirements for childcare attendance in some states, and for benefit eligibility at Commonwealth level, have driven higher pre-school vaccination catch-up since their inception in 2014. It is important to note that the coverage assessment algorithm currently used at the 5-year age milestone now measures only a single vaccine due at 4 years of age, which has led to messaging and interpretation issues among stakeholders and rendered the 5-year coverage data less useful in monitoring and evaluating the uptake and effectiveness of the NIP. Expansion of the 5-year coverage assessment algorithm, to include a more comprehensive range of vaccines/antigens that should have been received by that age, would be useful to address these issues. A comprehensive risk/benefit analysis may be required to inform an approach to implementing the changed algorithm. Communication of the change would need to address identified risks and is likely to require significant planning and effort to ensure that stakeholders understand the potential public health benefits a more accurate representation of immunisation coverage could provide. A range of strategies may need to be employed: for example, the change could be phased in with parallel reporting, using both the new and existing algorithms, to minimise potential messaging issues related to the resultant perception of a 'drop' in coverage.

References

1. Hull B, Hendry A, Dey A, McIntyre P, Macartney K, Beard F. Annual Immunisation Coverage Report 2018. Sydney: National Centre For Immunisation Research and Surveillance; 2019 [updated 26/11/2019; cited 2019 10/12/2019]; Available from: http://ncirs.org.au/sites/default/files/2019-11/NCIRS%20Annual%20Immunisation%20Coverage%20Report%202018.pdf.
2. Australian Government Productivity Commission. National Partnership Agreement on Essential Vaccines: Performance Report 1 April 2016 – 31 March 2017. 2017.
3. Hull BP, McIntyre PB, Heath TC, Sayer GP. Measuring immunisation coverage in Australia: a review of the Australian Childhood Immunisation Register. Australian Family Physician. 1999 01 /;28(1):55-60.
4. Australian Government Australian Digital Health Agency. Australian Immunisation Register. 2019 [cited 2019 27 August 2019]; Available from: https://developer.digitalhealth.gov.au/products/australian-immunisation-register.
5. Australian Government Department of Health. Using the Australian Immunisation Register. Canberra2018 [updated 27 November 2018; cited 2019 08 April 2019]; Available from: https://beta.health.gov.au/health-topics/immunisation/health-professionals/using-the-australian-immunisation-register.
6. O'Brien ED, Sam GA, Mead C. Methodology for measuring Australia's childhood immunisation coverage. Communicable Diseases Intelligence. 1998 03 19/;22(3):36-7.
7. Hull BP, McIntyre PB. Immunisation coverage reporting through the Australian Childhood Immunisation Register – an evaluation of the third-dose assumption. Australian and New Zealand Journal of Public Health. 2000 02 /;24(1):17-21.
8. Hull BP, Lawrence GL, MacIntyre CR, McIntyre PB. Estimating immunisation coverage: is the 'third dose assumption' still valid? Communicable Diseases Intelligence. 2003 09 /;27(3):357-61.
9. SAS Institute Inc. SAS. 9.4 ed. Cary, North Carolina: SAS Insitute Inc.; 2012.
10. Hugo Centre for Migration and Population Research. Accessibility/Remoteness Index of Australia - ARIA++(2011). 2011 [cited 2017 17 November 2017]; Available from: https://www.adelaide.edu.au/hugo-centre/spatial_data/.
11. Australian Bureau of Statistics. Socio Economic Indexes for Areas (SEIFA). Canberra: Australian Bureau of Statistics; 2013 [updated 23 September 2013; cited 2018 26/02/2018]; Available from: http://www.abs.gov.au/websitedbs/censushome.nsf/home/seifa.
12. Hull B, Deeks S, Menzies R, McIntyre P. Immunisation coverage annual report, 2007. Communicable Diseases Intelligence. 2009 06 /;33(2):170-87.
13. Hull BP, Dey A, Menzies RI, Brotherton JM, McIntyre PB. Immunisation coverage, 2012. Communicable Diseases Intelligence. 2014;38(3):E208-31.
14. Ioannides S, Beard F, Larter N, Clark K, Wang H, Hendry A, et al. Vaccine Preventable Diseases and Vaccination Coverage in Aboriginal and Torres Strait Islander People, Australia, 2011-2015. Commun Dis Intell. 2018;15:43.