Published in final edited form as:

J Infect Dis. 2014 November 01; 210(Suppl 1): S465–S474. doi:10.1093/infdis/jiu343.

Estimating the Likely Coverage of Inactivated Poliovirus Vaccine in Routine Immunization: Evidence From Demographic and Health Surveys

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Abstract

Background—The Strategic Advisory Group of Experts on Immunization (SAGE) has recommended introduction of at least 1 dose of inactivated poliovirus vaccine (IPV) at ≥14 weeks of age through the routine immunization program in countries currently not using IPV.

Methods—We analyzed all available unrestricted data obtained from the Demographic and Health Surveys since 2005 in sub-Saharan Africa (31 countries) and in South and Southeast Asia (9 countries) to determine coverage of the following injectable vaccines delivered through the routine immunization schedule: diphtheria-tetanus-pertussis vaccine dose 1 (DTP1), DTP2, DTP3, and measles vaccine. Coverage with these vaccines was used as a proxy measure of likely 1- and 2-dose IPV coverage.

Results—Coverage with 1 dose of IPV is expected to be lowest when offered with DTP3 (median coverage, 73%) and highest when offered with DTP1 (median coverage, 90%). The median DTP1-DTP3 drop-out rate was 14%, which equates to an additional 12 million children not receiving IPV if IPV is offered with DTP3, rather than with DTP1. An increased geographical clustering of children who have not received IPV is expected in sub-Saharan Africa and Asia if IPV is offered with DTP3, rather than with DTP1. Coverage with 2 doses of IPV is expected to be lowest if IPV is administered with DTP3 and measles vaccine (69%) and highest if administered with DTP1 and DTP2 (84%).

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A. A. was responsible for data analysis. All authors contributed equally to interpretation of results and to writing of the manuscript, and all approved the final draft.

Disclaimer. CDC staff were involved in the analysis and interpretation of data and writing of the manuscript, and the corresponding author had access to all data and the final responsibility to submit for publication. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Supplement sponsorship. This article is part of a supplement entitled “The Final Phase of Polio Eradication and Endgame Strategies for the Post-Eradication Era,” which was sponsored by the Centers for Disease Control and Prevention.

Potential conflicts of interest. All authors: No reported conflicts. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

Conclusions—Coverage with 1 dose of IPV is expected to be lowest if it is administered at the DTP3 visit. At present, there is insufficient evidence to determine whether the SAGE-recommended IPV schedule for the polio endgame would maximize population immunity to type 2 poliovirus.

Keywords

inactivated poliovirus vaccine; polio eradication; polio; routine immunization

Trivalent oral poliovirus vaccine (tOPV), a mixture of all 3 types of polioviruses, is the most commonly used polio vaccine in routine childhood immunization [1]. Typically, in the standard routine polio immunization schedule under the Expanded Program on Immunization (EPI), tOPV is administered at 6, 10, and 14 weeks of age along with diphtheria-tetanus-pertussis vaccine (DTP). Some countries administer an additional dose of tOPV at birth. tOPV is also used in campaigns to supplement routine childhood immunization; other preparations (monovalent formulations containing poliovirus types 1 or 3 and a bivalent formulation containing types 1 and 3) have also been used in campaigns.

The polioviruses in tOPV (Sabin) are live, attenuated strains, which can revert during replication and acquire neurovirulence, causing paralysis similar to wild polio-viruses (WPVs) [1]. Polio eradication will require eventual cessation of all OPVs [2]. The risk of acquiring neurovirulence varies by poliovirus type. Type 2 Sabin virus is most frequently associated with paralysis from reversion to circulating vaccine-derived polioviruses (cVDPVs), with >80% of reported cVDPV cases during the past decade being type 2 [1, 3, 4]. Additionally, of the estimated 250–500 annual vaccine-associated paralytic polio cases worldwide, almost 40% are caused by type 2 [4].

Considering that global interruption of WPV type 2 (WPV2) was achieved in 1999 [5] and that Sabin type 2 poliovirus has the potential to acquire neurovirulence, the global polio eradication initiative has proposed a phased removal of Sabin poliovirus types, starting with removal of type 2 Sabin poliovirus in routine and supplementary immunization after certain conditions are met [4]. In April 2013, the Strategic Advisory Group of Experts on Immunization (SAGE) of the World Health Organization supported the preeradication switch from tOPV to bivalent OPV (bOPV) and recommended introducing inactivated poliovirus vaccine (IPV) in routine immunization schedules in advance of the switch [5]. In November 2013, SAGE recommended that countries that introduce at least 1 dose of IPV in the routine immunization program should administer the first dose of IPV at ≥14 weeks of age [6]. In countries with a routine immunization schedule of 6, 10, and 14 weeks of age or 2, 3, and 4 months of age, IPV would then be added to the DTP dose 3 (DTP3) visit for children on schedule or administered at the first immunization visit at 14 weeks or later if children are off schedule [6]. For countries with a month 2, 4, and 6 schedule, IPV could be added to either the DTP2 visit or the DTP3 visit. SAGE also proposed that countries have the flexibility to consider alternative schedules, including administering IPV earlier than 14 weeks of age or administering >1 dose of IPV.

The principal objective of the preeradication introduction of IPV is to mitigate the risk associated with an increased susceptibility to type 2 polioviruses when bOPV is introduced.

Therefore, it is essential to achieve the highest possible type 2 population immunity with IPV, which is a product of the per-dose immunogenicity of IPV and the coverage achieved by IPV at that vaccination visit in routine immunization. During infancy, the presence of maternally acquired antibodies diminishes the immunogenicity of IPV [1]. Because maternal antibody levels decline over time, vaccination schedules that delay the start of IPV immunization are associated with improved IPV immunogenicity [7, 8]. The improvement in IPV immunogenicity during infancy with increasing age of vaccination needs to be balanced against per-dose coverage levels of childhood vaccines, as these levels vary considerably from country to country. Furthermore, data on immunogenicity (seroconversion and priming) of IPV, by age, are limited. In a clinical trial conducted in Cuba, a single dose of IPV at 4 months of age achieved limited seroconversion (63%) although considerable priming (98%) against type 2 poliovirus [9]. This study is the only study that assessed seroconversion and priming with IPV at an age that corresponds to an age for vaccination according to the routine immunization schedule in some countries.

The objective of this analysis was to estimate the coverage of injectable routine childhood vaccination (DTP1/2/3 or pentavalent 1/2/3 and measles vaccine) as a proxy for likely IPV coverage. This analysis will aid in identifying the most appropriate target age and timing in the routine immunization schedule for introduction of IPV to achieve optimal vaccination coverage and the highest level of population immunity.

METHODS

Countries and Data Sources

The Demographic and Health Surveys (DHS) are nationally representative multistage cluster sample surveys [10]. We analyzed data from all countries in sub-Saharan Africa, South Asia, and Southeast Asia that have conducted a DHS since 2005 and for which unrestricted data sets were publicly available as of 5 November 2013 (sub-Saharan Africa, 31 countries [Benin, Burkina Faso, Burundi, Cameroon, Chad, Republic of the Congo, Cote d'Ivoire, Democratic Republic of the Congo, Ethiopia, Gabon, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Swaziland, Tanzania, Uganda, Zambia, and Zimbabwe]; South and Southeast Asia: 9 countries [Bangladesh, Cambodia, India, Indonesia, Maldives, Nepal, Pakistan, Philippines, and Timor-Leste]). If a country conducted >1 DHS during this period, data from the most recent survey were analyzed.

Outcome Variables

We determined the vaccination status of the youngest child aged 12–23 months in each household surveyed. The coverage of routinely administered injectable EPI vaccines (DTP1, DTP2, DTP3, measles vaccine, and their combinations) was estimated and used as a proxy measure for likely IPV coverage. In all selected countries except for Maldives, the DTP3 visit was the first recommended vaccine-associated visit at ≥14 weeks of age.

1 Dose of IPV—SAGE has recommended introduction of 1 dose of IPV at ≥14 weeks of age. Therefore, DTP3 coverage was determined and compared with coverage with DTP1,

DTP2, and measles vaccine, the vaccine-associated visits other than that for DTP3, at which an injectable vaccine is administered. The absolute percentage difference between DTP1 and DTP3 coverage was estimated, and the DTP1–DTP3 drop-out rate was calculated as follows: [DTP1 coverage – DTP3 coverage]/DTP1 coverage. The number of children in the birth cohort of each country who would not be able to receive IPV was estimated using the DHS DTP3 coverage estimate and the size of the 2011 birth cohort as estimated by the United Nations Children's Fund (UNICEF) [11]. By use of DTP1 and DTP3 coverage estimates, the number of additional children who would receive a single dose of IPV if DTP1 was used for administering IPV instead of DTP3 was estimated.

2 Doses of IPV—SAGE has recommended that countries have the flexibility to choose their IPV schedules. Hence, coverage with 2 doses of injectable EPI vaccines given at 2 different target age visits through the routine immunization program was estimated as a proxy for likely coverage with 2 IPV doses. The vaccine-associated visit combinations were as follows: DTP1 and DTP3; DTP2 and DTP3; DTP1 and DTP2; DTP3 and measles vaccine; and DTP1 and measles vaccine. These visit combinations were selected because they are being actively considered by countries as visits during which 2 doses of IPV can be administered.

Data Analysis

Analysis was conducted using the survey feature of Stata, release 11.2 [12]. The analysis was weighted to account for the survey design and was based on households with at least 1 child aged 12–23 months at the time of the survey, with a sample size of 379 to 9994 children per country.

Coverage estimates with 95% confidence intervals were determined by country and by vaccine visit. Medians and ranges of coverage estimates were calculated from country-level estimates for 1 and 2 doses of IPV, overall and separately for sub-Saharan Africa and for South and Southeast Asia.

RESULTS

Likely Coverage With 1 Dose of IPV

Using coverage of injectable EPI vaccines as a proxy for IPV coverage, the overall median coverage of IPV is expected to be lowest if offered with DTP3 in the countries examined (overall, 73% [range, 21%–98%]; sub-Saharan Africa, 73% [range, 21%–97%]; South and Southeast Asia, 85% [range, 56%–98%]; Table 1). Among the 4 different target age visits at which injectable EPI vaccines are administered, overall IPV coverage is expected to be highest when offered at DTP1 (overall, 90% [range, 45%–99%]; sub-Saharan Africa, 90% [range, 45%–99%]; South and Southeast Asia, 93% [range, 75%–99%]).

Overall, the median IPV coverage is estimated to be 13% (range, 0.7%–27%) higher if administered at the DTP1 visit, compared with the DTP3 visit. Using the 2011 birth cohort, this difference in coverage translates to an additional 12 million children receiving IPV (data not shown). The overall median DTP1–DTP3 drop-out rate is expected to be 14% (range, 0.7%–55%). Figure 1 illustrates the DTP1–DTP3 drop-out rate by DTP3 coverage.

Countries with the lowest DTP3 coverages are also more likely to have the largest number of children who will not receive IPV if IPV is administered at the time DTP3 is administered (Figure 1). These countries also have the highest DTP1–DTP3 drop-out rates. Figure 2*A* shows geographical clustering of children who did not receive DTP3. Figure 2*B* shows the potential impact of using the DTP1 visit for IPV administration on reducing the number of children who do not receive IPV.

Likely Coverage With 2 Doses of IPV

Among the target age visits at which injectable EPI vaccines are administered, the overall median coverage with 2 doses of IPV is expected to be lowest if offered at the visits for DTP3 and measles vaccine (overall, 69% [range, 14%–94%]; sub-Saharan Africa, 66% [range, 14%–94%]; South and Southeast Asia, 80% [range, 48%–94%]; Table 2). Overall, the highest median 2-dose IPV coverage is expected with DTP1 and DTP2 (overall, 84% [range, 35%–99%]; sub-Saharan Africa, 82% [range, 35%–98%]; South and Southeast Asia, 90% [range, 67%–99%]).

DISCUSSION

This is the first systematic analysis to assess likely IPV coverage in the context of the proposed tOPV–bOPV switch as part of the endgame for polio eradication. In November 2013, SAGE recommended that in countries currently using OPV only in routine immunization, IPV should be added at the first immunization visit at ≥14 weeks of age whether DTP is recommended at 6, 10, and 14 weeks or 2, 3, and 4 months of age. SAGE also stated that countries have the flexibility to choose alternative schedules, including administering IPV earlier than 14 weeks of age. Our findings document the extent to which coverage with 1 dose of IPV at the DTP3 visit would be lower than at the DTP1 visit, particularly since the DTP1–DTP3 drop-out rate tends to be higher in countries with lower DTP3 coverage. If IPV is offered at the DTP3 visit, the countries with the lowest DTP3 coverage (and the highest DTP1–DTP3 drop-out rates) are countries that would likely have the largest cohorts of children who would not receive IPV. We noted geographical clustering of these countries in sub-Saharan Africa and in South and Southeast Asia. Therefore, if IPV is administered at the DTP3 visit instead of earlier and coverage levels are not substantially improved in these countries, there could be increased geographical clustering of children who have not received IPV and hence increased clustering of type 2 poliovirus susceptibility in countries of sub-Saharan Africa and of South and Southeast Asia.

In weighing the potential benefit of administering a single IPV dose with DTP1 or DTP3, data on the immunogenicity of IPV (ie, seroconversion and priming with IPV) by age is limited. A clinical trial in Cuba that assessed priming with IPV at 4 months of age is the only study that assessed priming with IPV at an age that corresponds to an existing age of routine vaccination in some countries [9]. Because population immunity is a function of both coverage and per-dose IPV immunogenicity, estimates of alternative schedules are limited by the uncertainty of per-dose immunogenicity by age and by the relative importance of priming and seroconversion. This highlights the need for clinical trials to obtain these data.

In addition, efforts continue to improve the immunization programs in these countries, so the relative impact of options in the years when IPV is introduced may change.

Our findings, although not unexpected, should be interpreted with caution. As IPV has not been introduced in the analyzed countries, these coverage estimates may differ from IPV coverage in actual practice after IPV has been introduced. Administration of an additional injectable vaccine at the DTP1, DTP2, DTP3, or measles vaccine visit could positively or negatively affect acceptance of IPV (or even of DTP1, DTP2, DTP3, or measles vaccine). Vaccine receipt information in the DHS is a combination of observed card-recorded information and self-reports by the mother or caregiver. Therefore, vaccination information from DHS data could be affected by nonresponse, recall bias, and social-desirability bias. These theoretical estimates of IPV coverage are likely to be affected by the unique situation and the health centers in the country. The ability to deliver an additional injectable vaccine efficiently depends on many factors that cannot be accounted for in this analysis, including acceptability of the vaccine to the public and health providers, ability of the vaccine management system to cope with an additional vaccine in the schedule, adequate cold chain space for a new vaccine, and sufficient staffing and training of health providers.

In conclusion, country-specific IPV introduction decisions regarding the target age and the number of doses as part of the tOPV-bOPV switch needs to balance carefully the tradeoff between the expected age-related immune response to IPV and the likely age-related IPV coverage. This analysis is essentially the first step in assessing the impact on type 2 poliovirus susceptibility with IPV introduction and withdrawal of tOPV. Studies are needed to determine the immunogenicity (ie, priming and seroconversion) of IPV under different schedules of administration in the routine immunization program. Immunogenicity of IPV at different vaccination visits, combined with likely IPV coverage estimates at different vaccination visits, as determined in this analysis, should be used to estimate the type 2 poliovirus population immunity of the birth cohort, which would be the critical step in evaluating the different options for introducing IPV into the routine immunization schedule. As the primary purpose of introducing IPV is to prevent an increase in population susceptibility to type 2 polio-virus, choosing the vaccination schedule that offers the highest population immunity against type 2 poliovirus is important. At present, there is insufficient evidence to determine whether the SAGE-recommended IPV schedule for the polio endgame would maximize type 2 poliovirus population immunity.

Acknowledgments

We thank Mr Robert C. Neurath in the Situation Awareness Team, Division of Emergency Operations, Office of Public Health Preparedness and Response, CDC, for preparing Figures 2*A* and 2*B*.

Financial support. This work was supported by the Centers for Disease Control and Prevention.

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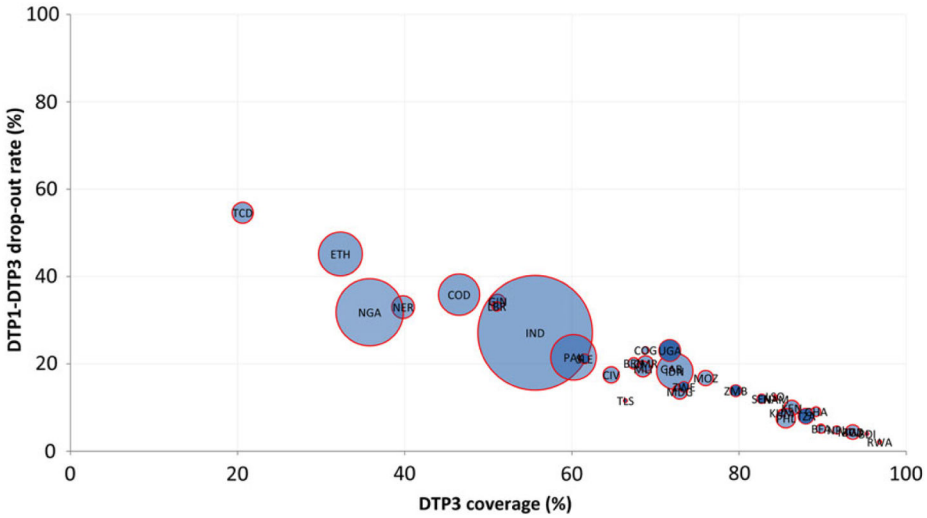
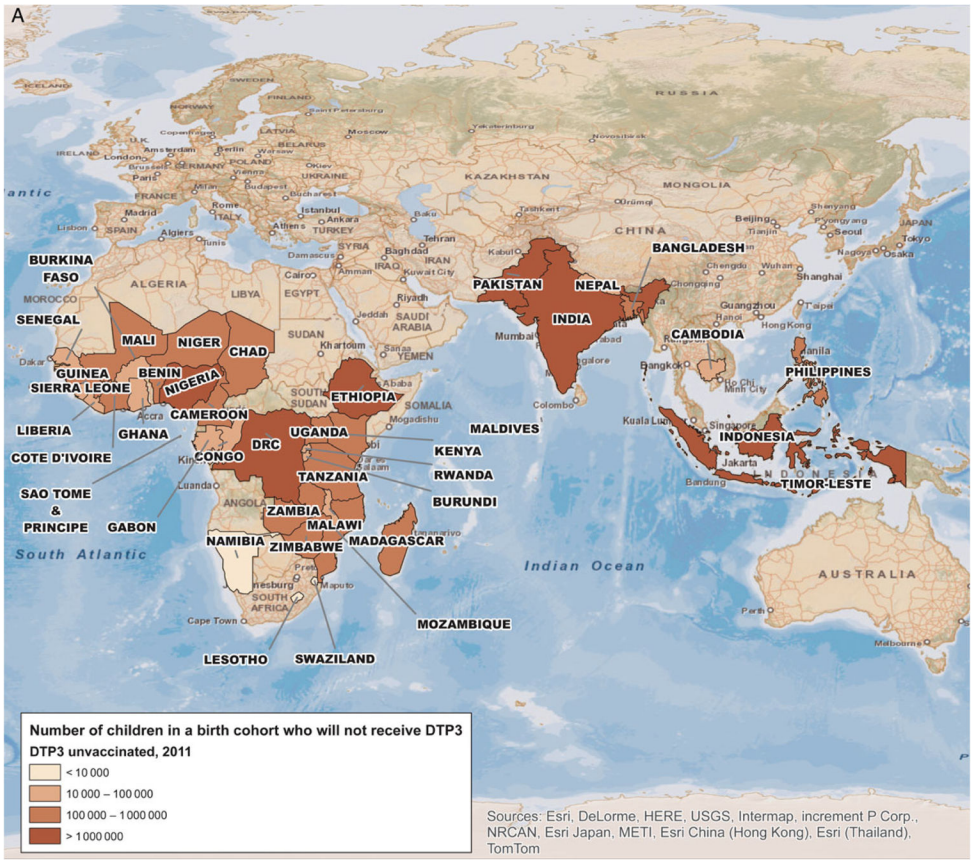


Figure 1.

Coverage with dose 3 of diphtheria-tetanus-pertussis vaccine (DTP3) and DTP1–DTP3 drop-out rate among children 12–23 months of age. The size of circles is proportional to number of children in a birth cohort who will not receive DTP3.



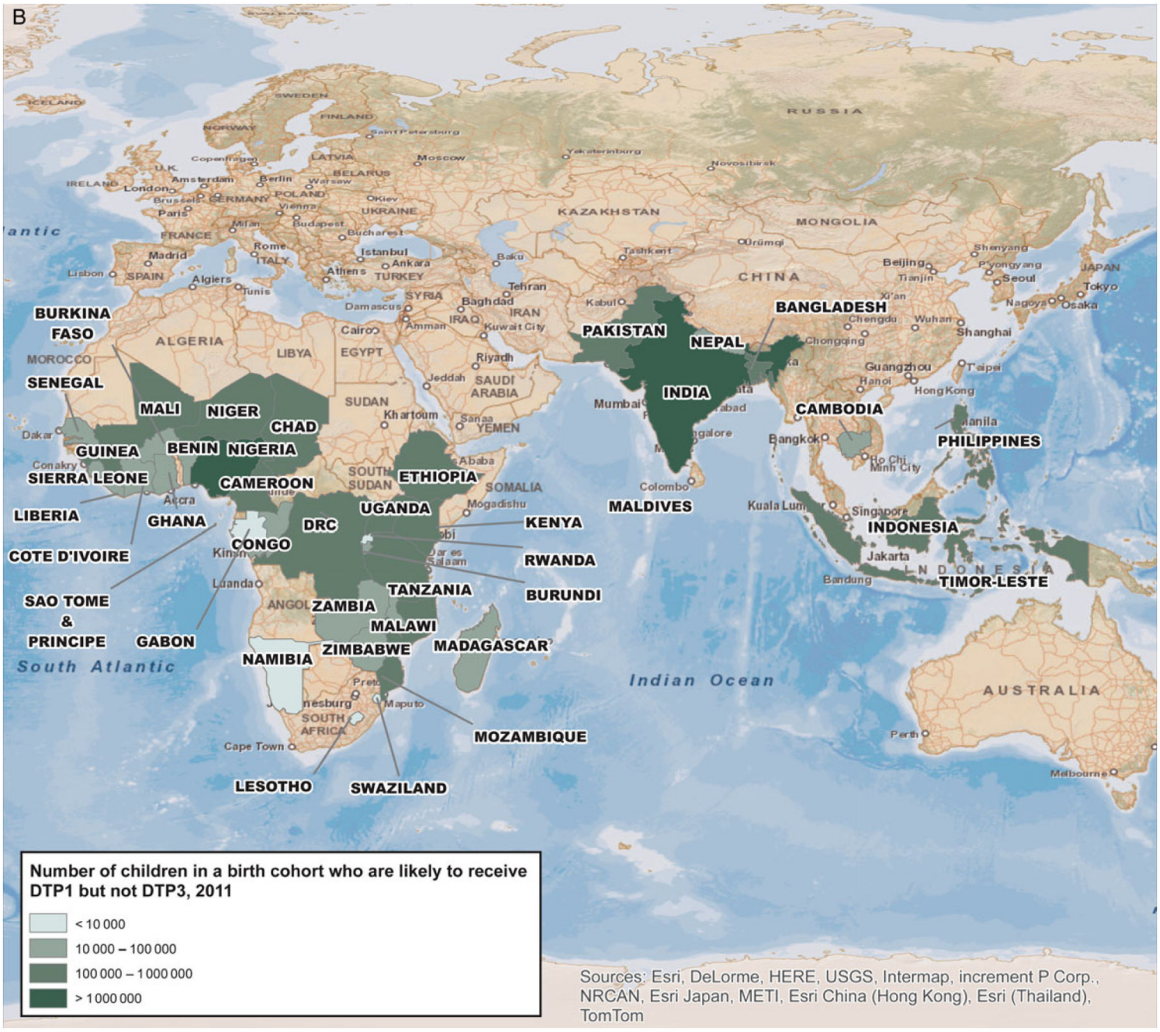


Figure 2.

A, Number of children in a birth cohort who are likely to not receive dose 3 of diphtheria-tetanus-pertussis vaccine (DTP3), 2011.

B, Number of children in a birth cohort who are likely to receive DTP1 but not DTP3, 2011.

Table 1

Likely Coverage of 1 Dose of Inactivated Poliovirus Vaccine in Children 12–23 Months of Age if Introduced in the Routine Immunization Schedule, by Country, Year of Survey, and Vaccination Opportunities

Region, Country, Survey Year(s)	DTP Dose 1, % (95% CI)	DTP Dose 2, % (95% CI)	DTP Dose 3, % (95% CI)	Measles Vaccine, % (95% CI)	Drop-out Rate, (%)[a]
Sub-Saharan Africa					
Benin, 2006	84.4	77.6	67.4	62	20.1
	82.5–86.1	75.5–79.5	64.9–69.8	59.7–64.3	
Burkina Faso, 2010	94.7	93	89.8	87.7	5.2
	93.4–95.7	91.6–94.3	88.2–91.3	86.0–89.2	
Burundi, 2010	99	98	95.3	94.3	3.7
	98.4–99.4	97.0–98.6	93.8–96.5	92.8–95.6	
Cameroon, 2011	86.1	78.9	68.8	71.5	20.1
	83.9–88.1	76.2–81.3	65.6–71.7	68.7–74.2	
Chad, 2004–2005	45.4	34.6	20.6	23.3	54.6
	38.7–52.3	29.0–40.7	16.9–24.9	19.3–27.9	
Republic of the Congo, 2011–2012	89.5	81.7	68.8	74.9	23.1
	87.1–91.5	78.2–84.7	64.6–72.6	71.2–78.3	
Cote d'Ivoire, 2011–2012	78.4	72.7	64.7	65.2	17.5
	74.6–81.8	68.7–76.3	60.5–68.7	60.5–69.7	
DRC, 2007	72.5	60.7	46.5	63.7	35.9
	67.8–76.7	55.8–65.4	41.3–51.8	59.2–68.0	
Ethiopia, 2010–2011	58.9	47.5	32.3	36.5	45.2
	54.8–62.8	43.0–52.0	28.6–36.2	32.8–40.4	
Gabon, 2012	88.6	82.1	71.9	75.8	18.8
	85.5–91.1	78.7–85.1	67.6–75.7	72.0–79.1	
Ghana, 2008	98.1	95.6	89.2	90.1	9.1
	96.4–99.0	93.4–97.0	85.7–91.8	86.9–92.6	
Guinea, 2005	77.8	67.3	51.1	51.6	34.3
	73.7–81.3	62.7–71.6	46.1–56.0	46.8–56.3	

Region, Country, Survey Year(s)	DTP Dose 1, % (95% CI)	DTP Dose 2, % (95% CI)	DTP Dose 3, % (95% CI)	Measles Vaccine, % (95% CI)	Drop-out Rate, (%)[a]
Kenya, 2008–2009	95.8	93.1	86.3	85	9.9
	94.1–97.0	90.5–95.0	83.1–89.0	81.8–87.7	
Lesotho, 2009–2010	96.4	92.1	84.3	80.9	12.6
	94.9–97.6	89.7–93.9	80.8–87.2	77.1–84.2	
Liberia, 2007	76.3	66.3	51	63.5	33.2
	70.2–81.5	60.0–72.1	45.3–56.6	57.7–69.0	
Madagascar, 2008–2009	84.4	79.8	72.9	70.1	13.6
	82.0–86.5	77.1–82.3	69.8–75.8	67.2–72.8	
Malawi, 2010	97.6	96.3	93.3	93.1	4.4
	96.8–98.2	95.3–97.1	92.0–94.5	91.9–94.1	
Mali, 2006	84.4	77.6	68.5	69.9	18.8
	81.2–87.0	74.3–80.6	65.2–71.7	65.8–73.7	
Mozambique, 2011	91.3	86	76	81.5	16.8
	89.3–92.9	83.4–88.2	73.1–78.8	78.9–83.9	
Namibia, 2006–2007	95.8	90.6	84.4	84.5	11.9
	93.8–97.1	87.8–92.8	81.1–87.2	81.6–86.9	
Niger, 2006	59.4	49.4	39.8	47.8	33.0
	54.6–64.0	44.6–54.3	35.2–44.6	43.4–52.1	
Nigeria, 2008	52.5	45.1	35.8	42	31.8
	50.6–54.4	43.2–47.0	33.9–37.7	40.1–43.8	
Rwanda, 2011	98.9	98.3	96.8	95.1	2.1
	98.2–99.3	97.3–98.9	95.6–97.7	93.7–96.2	
Sao Tome and Principe, 2008–2009	93.9	89.9	87.8	84.5	6.5
	93.9–93.9	89.9–89.9	87.8–87.8	84.5–84.5	
Senegal, 2010–2011	94	90.9	82.7	82.2	12.0
	92.3–95.3	89.0–92.5	80.2–85.0	80.0–84.2	
Sierra Leone, 2008	78	71.9	61.5	60.5	21.2
	74.5–81.3	68.0–75.5	57.4–65.4	56.0–64.9	
Swaziland, 2006–2007	96.6	95	92.2	91.7	4.6

J Infect Dis. Author manuscript; available in PMC 2023 June 23.

Region, Country, Survey Year(s)	DTP Dose 1, % (95% CI)	DTP Dose 2, % (95% CI)	DTP Dose 3, % (95% CI)	Measles Vaccine, % (95% CI)	Drop-out Rate, (%)[a]
	94.1–98.0	92.4–96.7	89.4–94.3	88.4–94.0	
Tanzania, 2010	95.7	92.8	88	84.5	8.0
	95.7–95.7	92.8–92.8	88.0–88.0	84.5–84.5	
Uganda, 2011	93.2	85.8	71.7	75.8	23.1
	91.3–94.7	83.3–88.0	68.3–74.8	72.8–78.7	
Zambia, 2007	92.4	88.7	79.6	84.7	13.9
	90.1–94.2	86.1–90.9	76.2–82.5	81.9–87.2	
Zimbabwe, 2010–2011	86.1	81.4	73.4	79.5	14.8
	82.9–88.7	78.0–84.5	69.4–77.0	76.2–82.4	
Median (range)	89.5 (45.4–99.0)	82.1 (34.6–98.3)	72.9 (20.6–96.8)	75.8 (23.3–95.1)	16.8 (2.1–54.6)
South and Southeast Asia					
Bangladesh, 2011	97.9	95.9	93.6	87.6	4.4
	96.7–98.6	94.3–97.0	91.8–95.1	85.2–89.6	
Cambodia, 2010	93.3	90.4	85.1	82.4	8.8
	91.7–94.7	88.5–92.1	82.7–87.2	79.5–84.9	
India, 2005–2006	76.3	67	55.6	59.9	27.1
	74.8–77.8	65.4–68.6	53.9–57.2	58.3–61.6	
Indonesia, 2012	88.5	81	72.3	80.3	18.3
	86.8–90.0	79.0–82.9	70.0–74.5	78.3–82.2	
Maldives, 2009	99	99	98.3	94.8	0.7
	97.8–99.5	97.8–99.5	96.9–99.1	92.7–96.3	
Nepal, 2011	96.4	94.6	91.7	88.4	4.9
	94.6–97.6	91.9–96.4	88.3–94.1	83.5–91.9	
Pakistan, 2006–2007	76.7	68.4	60.2	61.7	21.5
	73.7–79.4	65.1–71.6	56.7–63.5	58.3–64.9	
Philippines, 2008	92.6	89.7	85.6	84.5	7.6
	90.9–94.0	87.8–91.4	83.4–87.6	82.1–86.6	
Timor-Leste, 2009–2010	75.1	71.2	66.4	68	11.6
	72.1–77.8	68.3–74.1	63.3–69.5	64.8–71.0	

J Infect Dis. Author manuscript; available in PMC 2023 June 23.

Region, Country, Survey Year(s)	DTP Dose 1, % (95% CI)	DTP Dose 2, % (95% CI)	DTP Dose 3, % (95% CI)	Measles Vaccine, % (95% CI)	Drop-out Rate, (%)[a]
Median (range)	92.6 (75.1–99.0)	89.7 (67.0–99.0)	85.1 (55.6–98.3)	82.4 (59.9–94.8)	8.8 (0.7–27.1)
All countries, median (range)	90.4 (45.4–99.0)	84.0 (34.6–99.0)	73.2 (20.6–98.3)	79.9 (23.3–95.1)	14.3 (0.7–54.6)

Abbreviations: CI, confidence interval; DRC, Democratic Republic of the Congo; DTP, diphtheria-tetanus-pertussis vaccine.

[a]Calculated as 100 × [(DTP1 coverage – DTP3 coverage)/DTP1 coverage].

Table 2

Likely Coverage of 2 Doses of Inactivated Poliovirus Vaccine in Children 12–23 Months of Age if Introduced in the Routine Immunization Schedule, by Country, Year of Survey, and Vaccination Opportunities

Region, Country, Survey Year(s)	DTP Doses 1 and 3, % (95% CI)	DTP Doses 2 and 3, % (95% CI)	DTP Doses 1 and 2, % (95% CI)	DTP Dose 3 and Measles Vaccine, % (95% CI)	DTP Dose 1 and Measles Vaccine, % (95% CI)
Sub-Saharan Africa					
Benin, 2006	67.4	67.4	77.6	53.9	60.3
	64.9–69.8	64.9–69.8	75.5–79.5	51.3–56.4	57.9–62.7
Burkina Faso, 2010	89.8	89.8	93	84.3	86.4
	88.2–91.3	88.2–91.3	91.6–94.3	82.4–86.1	84.6–88.0
Burundi, 2010	95.3	95.3	98	91.8	94.3
	93.8–96.5	93.8–96.5	97.0–98.6	89.8–93.4	92.8–95.6
Cameroon, 2011	68.8	68.8	78.9	60.8	70.1
	65.6–71.7	65.6–71.7	76.2–81.3	57.8–63.7	67.3–72.8
Chad, 2004–2005	20.6	20.6	34.6	14.3	21.8
	16.9–24.9	16.8–24.9	29.0–40.7	11.3–18.0	17.8–26.5
Republic of the Congo, 2011–2012	68.8	68.8	81.7	60.1	73.1
	64.6–72.6	64.6–72.6	78.2–84.7	55.7–64.4	69.3–76.5
Cote d'Ivoire, 2011–2012	64.7	64.7	72.7	55.3	61
	60.5–68.7	60.5–68.7	68.7–76.3	50.8–59.8	56.4–65.5
DRC, 2007	46.5	46.3	60.7	40.8	60
	41.3–51.8	41.1–51.6	55.8–65.4	35.9–45.9	55.2–64.6
Ethiopia, 2010–2011	32.3	32.3	47.5	23.8	33
	28.6–36.2	28.6–36.2	43.0–52.0	20.6–27.3	29.4–36.8
Gabon, 2012	71.9	71.9	82.1	61	72
	67.6–75.7	67.6–75.7	78.7–85.1	56.4–65.4	68.2–75.5
Ghana, 2008	89.2	88.9	95.6	84.1	90
	85.7–91.8	85.4–91.6	93.4–97.0	80.0–87.4	86.7–92.5
Guinea, 2005	51.1	51.1	67.3	41.2	51.2
	46.1–56.0	46.1–56.0	62.7–71.6	36.5–46.0	46.4–55.9

Region, Country, Survey Year(s)	DTP Doses 1 and 3, % (95% CI)	DTP Doses 2 and 3, % (95% CI)	DTP Doses 1 and 2, % (95% CI)	DTP Dose 3 and Measles Vaccine, % (95% CI)	DTP Dose 1 and Measles Vaccine, % (95% CI)
Kenya, 2008–2009	86.3	86.3	93.1	79.1	84.8
	83.1–89.0	83.1–89.0	90.5–95.0	75.5–82.3	81.5–87.5
Lesotho, 2009–2010	84.3	84.3	92.1	73.9	80.7
	80.8–87.2	80.8–87.2	89.7–93.9	69.9–77.5	76.9–84.0
Liberia, 2007	51	50.9	66.3	45.5	59
	45.3–56.6	45.3–56.6	60.0–72.1	40.2–51.0	53.3–64.5
Madagascar, 2008–2009	72.9	72.9	79.8	65.7	69
	69.8–75.8	69.8–75.8	77.1–82.3	62.4–68.8	66.1–71.8
Malawi, 2010	93.3	93.3	96.3	89.4	92.5
	92.0–94.5	92.0–94.4	95.3–97.1	87.9–90.8	91.3–93.6
Mali, 2006	68.5	68.5	77.6	60.6	69.1
	65.2–71.7	65.2–71.7	74.3–80.6	56.7–64.4	65.0–72.9
Mozambique, 2011	76	76	86	71.5	80.1
	73.1–78.8	73.1–78.8	83.4–88.2	68.2–74.5	77.2–82.6
Namibia, 2006–2007	84.4	84.4	90.6	77.1	83.6
	81.1–87.2	81.1–87.2	87.8–92.8	73.6–80.3	80.7–86.1
Niger, 2006	39.8	39.8	49.4	33.2	43.5
	35.2–44.6	35.2–44.6	44.6–54.3	29.2–37.5	39.2–47.9
Nigeria, 2008	35.8	35.8	45.1	30.8	39.3
	33.9–37.7	33.9–37.7	43.2–47.0	29.0–32.6	37.5–41.2
Rwanda, 2011	96.8	96.8	98.3	94	95
	95.6–97.7	95.6–97.7	97.3–98.9	92.4–95.2	93.6–96.1
Sao Tome and Principe, 2008–2009	87.8	87.8	89.9	78.8	82
	87.8–87.8	87.8–87.8	89.9–89.9	78.8–78.8	82.0–82.0
Senegal, 2010–2011	82.7	82.7	90.9	74.8	80.8
	80.2–85.0	80.2–85.0	89.0–92.5	72.0–77.4	78.4–83.0
Sierra Leone, 2008	61.5	61.4	71.9	51.6	58.7
	57.4–65.4	57.3–65.3	68.0–75.5	47.4–55.8	54.3–63.0
Swaziland, 2006–2007	92.2	92.2	95	87.8	90.9

Region, Country, Survey Year(s)	DTP Doses 1 and 3, % (95% CI)	DTP Doses 2 and 3, % (95% CI)	DTP Doses 1 and 2, % (95% CI)	DTP Dose 3 and Measles Vaccine, % (95% CI)	DTP Dose 1 and Measles Vaccine, % (95% CI)
	89.4–94.3	89.4–94.3	92.4–96.7	84.4–90.5	87.5–93.4
Tanzania, 2010	88	88	92.8	80.3	84.1
	88.0–88.0	88.0–88.0	92.8–92.8	80.3–80.3	84.1–84.1
Uganda, 2011	71.7	71.7	85.8	63.7	75
	68.3–74.8	68.3–74.8	83.3–88.0	60.1–67.1	71.9–77.8
Zambia, 2007	79.6	79.4	88.7	74.7	83.4
	76.2–82.5	76.1–82.4	86.1–90.9	71.2–78.0	80.4–86.0
Zimbabwe, 2010–2011	73.4	73.3	81.4	69.2	78.8
	69.4–77.0	69.2–76.9	78.0–84.5	65.1–72.9	75.3–81.9
Median (range)	72.9 (20.6–96.8)	72.9 (20.6–96.8)	82.1 (34.6–98.3)	65.7 (14.3–94.0)	75.0 (21.8–95.0)
South and Southeast Asia					
Bangladesh, 2011	93.6	93.6	95.9	86.4	87.5
	91.8–95.1	91.8–95.1	94.3–97.0	84.0–88.5	85.1–89.5
Cambodia, 2010	85.1	85.1	90.4	80	82.2
	82.7–87.2	82.7–87.2	88.5–92.1	77.2–82.6	79.3–84.7
India, 2005–2006	55.6	55.5	67	48.3	58.4
	53.9–57.2	53.9–57.2	65.4–68.6	46.7–50.0	56.8–60.0
Indonesia, 2012	72.3	72.3	81	68.1	79.4
	70.0–74.5	70.0–74.5	79.0–82.9	65.7–70.5	77.3–81.3
Maldives, 2009	98.3	98.3	99	94.3	94.8
	96.9–99.1	96.9–99.1	97.8–99.5	92.2–95.9	92.7–96.3
Nepal, 2011	91.7	91.7	94.6	87.1	88.2
	88.3–94.1	88.3–94.1	91.9–96.4	82.5–90.7	83.4–91.8
Pakistan, 2006–2007	60.2	60.2	68.4	53.3	60.6
	56.7–63.5	56.7–63.5	65.1–71.6	49.9–56.7	57.2–63.9
Philippines, 2008	85.6	85.6	89.7	80.6	84
	83.4–87.6	83.4–87.6	87.8–91.4	78.0–82.9	81.6–86.2
Timor-Leste, 2009–2010	66.4	66.4	71.2	62.6	67.5
	63.3–69.5	63.3–69.5	68.3–74.1	59.4–65.8	64.3–70.5

Region, Country, Survey Year(s)	DTP Doses 1 and 3, % (95% CI)	DTP Doses 2 and 3, % (95% CI)	DTP Doses 1 and 2, % (95% CI)	DTP Dose 3 and Measles Vaccine, % (95% CI)	DTP Dose 1 and Measles Vaccine, % (95% CI)
Median (range)	85.1 (55.6–98.3)	85.1 (55.5–98.3)	89.7 (67.0–99.0)	80.0 (48.3–94.3)	82.2 (58.4–94.8)
Overall, median (range)	73.2 (20.6–98.3)	73.1 (20.6–98.3)	84.0 (34.6–99.0)	68.7 (14.3–94.3)	79.1 (21.8–95.0)

Abbreviations: CI, confidence interval; DRC, Democratic Republic of the Congo; DTP, diphtheria-tetanus-pertussis vaccine.