National Immunization Survey-Child

Error Profile for the 2023 NIS-Child

Centers for Disease Control and Prevention

National Center for Immunization
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1+ MMR	Measles, mumps, and rubella vaccine, ≥1 dose
1+ Var	Varicella vaccine, ≥1 dose
3+ Hep B	Hepatitis B vaccine, ≥3 doses
3+ Hib	*Haemophilus influenzae* type b conjugate vaccine, ≥3 doses
3+ Polio	Poliovirus vaccine, ≥3 doses
4+ DTaP	Diphtheria, tetanus, and acellular pertussis vaccine, ≥4 doses
4+ PCV	Pneumococcal conjugate vaccine, ≥4 doses
ACS	American Community Survey
Combined 7-vaccine series	≥4 doses of DTaP, ≥3 doses of poliovirus vaccine, ≥1 dose of measles-containing vaccine, the full series of Hib, ≥3 doses of Hep B, ≥1 dose of varicella vaccine, and ≥4 doses of PCV
CPR	Child Participation Rate
CPO	Cell-phone only
CPS ASEC	Current Population Survey Annual Social and Economic Supplement
DTaP/DTP/DT	Diphtheria, tetanus, and acellular pertussis vaccine; diphtheria, tetanus, and pertussis vaccine; or diphtheria and tetanus vaccine
Hep B birth dose	Hepatitis B dose within 3 days of birth
Hib-FS	Full series of Hib, ≥3 doses or ≥4 doses depending on brand
Hib-PS	Primary series of Hib, ≥2 doses or ≥3 doses depending on brand
IHQ	Immunization History Questionnaire
IIS	Immunization Information Systems
IISAR	Immunization Information Systems Annual Report
IRIS	Iowa Immunization Registry Information System
LLO	Landline only
MCIR	Michigan Care Improvement Registry
NHIS	National Health Interview Survey
NIS-Child	National Immunization Survey-Child
NIS-Teen	National Immunization Survey-Teen
NVSS	National Vital Statistics System
PRC	Provider Record Check
PUF	Public Use File
PUMS	Public Use Microdata Sample
RDD	Random digit dial
TIS	Tennessee Immunization Survey
TSE	Total survey error
UTD	Up-to-date
WAIIS	Washington State Immunization Information System
WIR	Wisconsin Immunization Registry

1. Introduction

Total survey error (TSE) is the difference between a survey estimate and the true value of the corresponding population parameter. TSE is the net effect of sampling error and all forms of nonsampling error, including sampling-frame coverage error, error due to survey nonresponse, and errors of measurement (such as reporting, record checking, coding, and other processing errors). TSE excludes conceptual errors committed in deciding what should be measured in the survey and judgmental errors made in interpreting the survey findings or in making public policy based on the survey data.

The main aim of this report is to provide a well-rounded but brief discussion of what is known about TSE for 2023 National Immunization Survey-Child (NIS-Child) estimated vaccination coverage at the national level. Recent reports discussed TSE for the 2022 National Immunization Survey-Child (NIS-Child) (NORC, 2023a) and the 2023 NIS-Teen (NORC, 2023b). The statistics and methodology of the NIS have been described by Smith et al. (2005) and Wolter et al. (2017).

The report is written in two parts. The first part, which appears in Section 2, compares NIS-Child statistics to corresponding benchmarks derived from censuses or large reference surveys, such as the National Health Interview Survey and the American Community Survey. A large difference between an NIS-Child statistic and its corresponding benchmark is likely a signal of error in the NIS-Child or of definitional differences between the NIS-Child and benchmark concepts. A small difference may be a signal of good accuracy in the NIS-Child or simply an indicator that the NIS-Child statistic and its benchmark are consistent with one another. This part of the report examines demographic statistics, vaccination coverage, and health insurance statistics.

The second part of the report, set forth in Section 3, focuses attention on the NIS-Child estimated vaccination coverage. The material presents what is known from special evaluation studies about the component errors and the total error in vaccination coverage estimates. The section culminates with discussion of the distribution of TSE in the 2023 NIS-Child and of the change in TSE between the 2022 and 2023 NIS-Child.

Both parts of the report are conducted at the national level. The report closes in Section 4 with a summary of findings and limitations.

Throughout the report, we analyze the following vaccines and vaccine series:

- diphtheria, tetanus, and acellular pertussis vaccine (DTaP), ≥4 doses (4+ DTaP);
- poliovirus vaccine, ≥3 doses (3+ Polio);

- measles, mumps, and rubella vaccine (MMR), ≥1 dose (1+ MMR);
- the full series of *Haemophilus influenzae* type b conjugate vaccine (Hib), ≥3 doses or ≥4 doses depending on brand (Hib-FS);[1]
- hepatitis B vaccine (Hep B), ≥3 doses (3+ Hep B);
- hepatitis B dose within 3 days of birth (Hep B birth dose);
- varicella vaccine, ≥1 dose (1+ Var);
- pneumococcal conjugate vaccine (PCV), ≥4 doses (4+ PCV); and
- the combined 7-vaccine series (≥4 doses of DTaP, ≥3 doses of poliovirus vaccine, ≥1 dose of measles-containing vaccine, the full series of Hib, ≥3 doses of Hep B, ≥1 dose of varicella vaccine, and ≥4 doses of PCV).

For the analysis of TSE, we focus on 4+ DTaP, 1+ MMR, Hep B birth dose, and the combined 7-vaccine series.

[1] At times in this report, we also refer to the Hib primary series (Hib-PS) which is ≥2 doses or ≥3 doses depending on brand. We refer to ≥3 doses of Hib vaccine as 3+ Hib.

2. Part I: Comparisons of NIS-Child Data to External Sources

We begin by comparing NIS-Child demographic distributions (child's age, child's sex, mother's race and ethnicity, mother's education, and mother's age) to benchmark distributions derived from National Vital Statistics System (NVSS) natality data and other sources. Second, we compare NIS-Child vaccination coverage estimates to estimates provided by the Immunization Information Systems Annual Report specifically for the combined 7-vaccine series. Third, we compare health insurance distributions derived from the NIS-Child Health Insurance Module to corresponding distributions obtained from (i) the American Community Survey (ACS), (ii) the National Health Interview Survey (NHIS), and (iii) the Current Population Survey Annual Social and Economic Supplement (CPS ASEC). Finally, we compare NIS-Child vaccination coverage estimates to corresponding coverage estimates produced by state immunization surveys and state immunization information systems for multiple vaccine series.

2.1 Demographic Distributions: Comparison of NIS-Child Distributions to Population Distributions

A direct method of estimating survey error is to compare the survey estimates to benchmark estimates from other data sources, including census data and surveys with high response rates. While high-quality benchmark estimates of national-level vaccination coverage are not available, we can compare the survey estimates of demographic distributions to those derived from NVSS natality data. These data yield population counts for several important characteristics of children: mother's race and ethnicity, mother's education, mother's age, child's sex, and child's age.

To create benchmark population demographic distributions for children aged 19 to 35 months in 2023, we began by obtaining the counts of live births from the 2020 and 2021 NVSS natality data[2] for children that would be 19 to 35 months old as of July 1, 2023, the midpoint of the reference year. These counts were obtained overall and by mother's race and ethnicity, mother's education, mother's age, child's sex, and child's age as of July 1, 2023. The raw NVSS counts were then adjusted to account for infant mortality and immigration into the United States to produce counts of children aged 19 to 35 months living in the United States on July 1, 2023. These adjustments were applied separately by race and ethnicity group to account for differences in mortality and immigration across these groups.

[2] https://www.cdc.gov/nchs/nvss/nvss-restricted-data.htm

We produced 2023 NIS-Child national-level demographic distribution estimates first using design weights and then using final weights. The design weights reflect the sample design but do not include any adjustments for sampling-frame noncoverage or interview nonresponse and are not calibrated to population control totals. Final weights are the design weights, with adjustments for noncoverage, nonresponse, and calibration to population control totals. (See the footnotes to Table 2.1 for the demographic variables used in this calibration.)

Table 2.1 compares 2023 NIS-Child national-level survey estimates of demographic distributions for children with adequate provider data to benchmark distributions for child's age, sex, mother's race and ethnicity, mother's education, and mother's age. We observe that the survey distribution for child's age and child's sex is close to the population distribution, even when using the design weights. The differences are zero when the final weights are used due to calibration based on child's age and child's sex. The design-weighted distribution of mother's race and ethnicity differs somewhat from the population distribution, with the largest differences being for non-Hispanic White only mothers (58.1 percent in survey, 51.4 percent in population), Hispanic mothers (20.0 percent in survey, 24.5 percent in population), and non-Hispanic Black only mothers (10.0 percent in survey, 14.4 percent in population). The differences are small when the final weights are used due to calibration using race and ethnicity.

Differences between the respondent set and the population are also observed for mother's education and mother's age. For mother's education, the respondent set over-represents children whose mothers have a four-year college degree when the design weights are used (51.3 percent in survey, 34.9 percent in population) and under-represents children whose mothers do not have a four-year college degree. When the final weights are used, the survey still somewhat over-represents children whose mothers have a four-year college degree (40.7 percent in survey, 34.9 percent in population) and under-represents children whose mothers have some college but not a four-year degree (21.5 percent in survey, 27.3 percent in population). The survey also over-represents children whose mothers are age 30 or older when the final weights are used (68.3 percent in survey, 63.5 percent in population) and under-represents children whose mothers are age 20 to 29 (30.8 percent in survey, 35.6 percent in population).

Comparisons of demographic distributions were made between survey estimates and population values for all two-way combinations of child's age, child's sex, mother's race and ethnicity, and mother's education, first using design weights and then using final weights. While final weights are controlled to marginal population totals for these characteristics individually, the weights are not controlled to totals for cross-classifications of these characteristics. Differences between survey estimates and population values for these cross-classifications are all less than 5.0 percentage points when final weights are used.

Table 2.1: One-Way Demographic Distributions Among Children with Adequate Provider Data vs. Population Distributions: NIS-Child, 2023

Demographic Domain	Population Distribution (%)	Design-Weighted Estimates		Final-Weighted Estimates*	
		Survey Distribution (%)	Survey - Population	Survey Distribution (%)	Survey - Population
Child's Age					
19-23 months	30.9	31.8 ± 1.8	0.9 ± 1.8	30.9 ± 1.4	0.0 ± 1.4
24-29 months	33.8	30.7 ± 2.0	-3.1 ± 2.0	33.8 ± 1.4	0.0 ± 1.4
30-35 months	35.3	37.5 ± 1.9	2.2 ± 1.9	35.3 ± 1.4	0.0 ± 1.4
Child's Sex					
Male	51.1	50.5 ± 2.0	-0.6 ± 2.0	51.1 ± 1.5	0.0 ± 1.5
Female	48.9	49.5 ± 2.0	0.6 ± 2.0	48.9 ± 1.5	0.0 ± 1.5
Mother's Race and Ethnicity					
Hispanic	24.5	20.0 ± 1.7	-4.6 ± 1.7	24.1 ± 1.5	-0.5 ± 1.5
Non-Hispanic White only	51.4	58.1 ± 2.1	6.7 ± 2.1	50.2 ± 1.4	-1.1 ± 1.4
Non-Hispanic Black only	14.4	10.0 ± 1.7	-4.5 ± 1.7	14.2 ± 1.1	-0.3 ± 1.1
Non-Hispanic Other	9.6	12.0 ± 1.5	2.4 ± 1.5	11.5 ± 1.0	1.9 ± 1.0
Mother's Education					
Less than high school	11.4	7.0 ± 0.8	-4.4 ± 0.8	11.0 ± 1.0	-0.4 ± 1.0
High school	26.4	16.8 ± 1.3	-9.6 ± 1.3	26.8 ± 1.5	0.3 ± 1.5
Some college	27.3	24.9 ± 2.1	-2.4 ± 2.1	21.5 ± 1.2	-5.8 ± 1.2
4-year college graduate	34.9	51.3 ± 2.0	16.4 ± 2.0	40.7 ± 1.4	5.8 ± 1.4
Mother's Age					
< 20 years	0.9	0.6 ± 0.2	-0.3 ± 0.2	0.9 ± 0.3	-0.1 ± 0.3
20-29 years	35.6	27.3 ± 1.9	-8.3 ± 1.9	30.8 ± 1.5	-4.8 ± 1.5
>= 30 years	63.5	72.1 ± 1.9	8.6 ± 1.9	68.3 ± 1.5	4.8 ± 1.5

NOTE: Excludes U.S. territory samples in Guam, Puerto Rico, and U.S. Virgin Islands. Table presents survey estimate and 95% confidence interval and presents the difference between the survey and the population percentages, along with a 95% confidence interval for the difference, assuming no error in the population proportion.
* Final provider-phase weights are calibrated within each geographic estimation area to marginal totals for child's age (19-23, 24-29, 30-35), child's sex (male, female), child's race and ethnicity (Hispanic, non-Hispanic Black only, all other race/ethnicity groups), mother's education (high school or less, more than high school), household telephone status (cell-phone only, other), and quintile of the estimated propensity to have adequate provider data for the child, given the household interview was completed for the child. The marginal totals for child's race and ethnicity are estimated by summing the final household-phase weight within each category; the final household-phase weight itself had been calibrated to marginal control totals for mother's race and ethnicity. Some geographic areas' categories for calibration may be collapsed due to small sample sizes.

2.2 Comparison of NIS-Child and IISAR Vaccination Coverage

This subsection compares NIS-Child vaccination coverage estimates to Immunization Information System Annual Report (IISAR) data in 2022.[3] The comparison is given for estimates of coverage with the combined 7-vaccine using the data available from IISAR, recognizing that the findings may not apply to other vaccines or vaccine series. Note that the combined 7-vaccine estimates are the only vaccination coverage estimates for children provided by IISAR for the NIS-Child age range. Agreement between the vaccination coverage estimates signals consistency between NIS-Child and IISAR, and it may signal that both sources provide an accurate measurement of the true vaccination coverage in the age-eligible child population (19-35 months old). Lack of agreement between the vaccination coverage estimates signals inconsistency and that one or both sources is less accurate.

Our work in this subsection is divided into four parts. First, we describe some definitions we will use in this analysis. Second, we compare the vaccination coverage estimates in NIS-Child and IISAR visually using scatterplots. Third, we introduce the concept of the IIS (Immunization Information System)[4] Child Participation Rate (CPR) as a measure of IIS quality before demonstrating through regression analysis that higher quality IIS, as indicated by the CPR, tend to have smaller differences between the combined 7-vaccine coverage estimates in NIS-Child and IISAR.

What is IISAR?

IISAR is an annual assessment of IIS activity among the 64 immunization program awardees, which include the 50 states, six cities (Chicago, District of Columbia, Houston, New York City, Philadelphia, and San Antonio), and eight U.S. territories (American Samoa, Guam, Marshall Islands, Micronesia, Northern Mariana Islands, Palau, Puerto Rico, and Virgin Islands). To evaluate each awardee's performance, the immunization program manager in the awardee area is asked to complete a self-administered and web-based questionnaire asking for demographic and immunization information about vaccine recipients, public and private provider site participation levels, and information about fulfillment of IIS functional standards. Because the questionnaire is self-administered and web-based, some awardees may report partial data or no data at all.

In what follows, we compare 2022 NIS-Child vaccination estimates to 2022 IISAR vaccination estimates. Because 2023 IISAR vaccination coverage estimates are not available as of this

[3] https://www.cdc.gov/iis/about/?CDC_AAref_Val=https://www.cdc.gov/vaccines/programs/iis/about.html

[4] IIS are computer databases that aspire to contain information about all of the doses of all vaccines administered to all child residents within a jurisdiction. It is known that different IIS vary in their completeness of both children and the doses they received. https://www.cdc.gov/iis/annual-report-iisar/?CDC_AAref_Val=https://www.cdc.gov/vaccines/programs/iis/annual-report-iisar/index.html

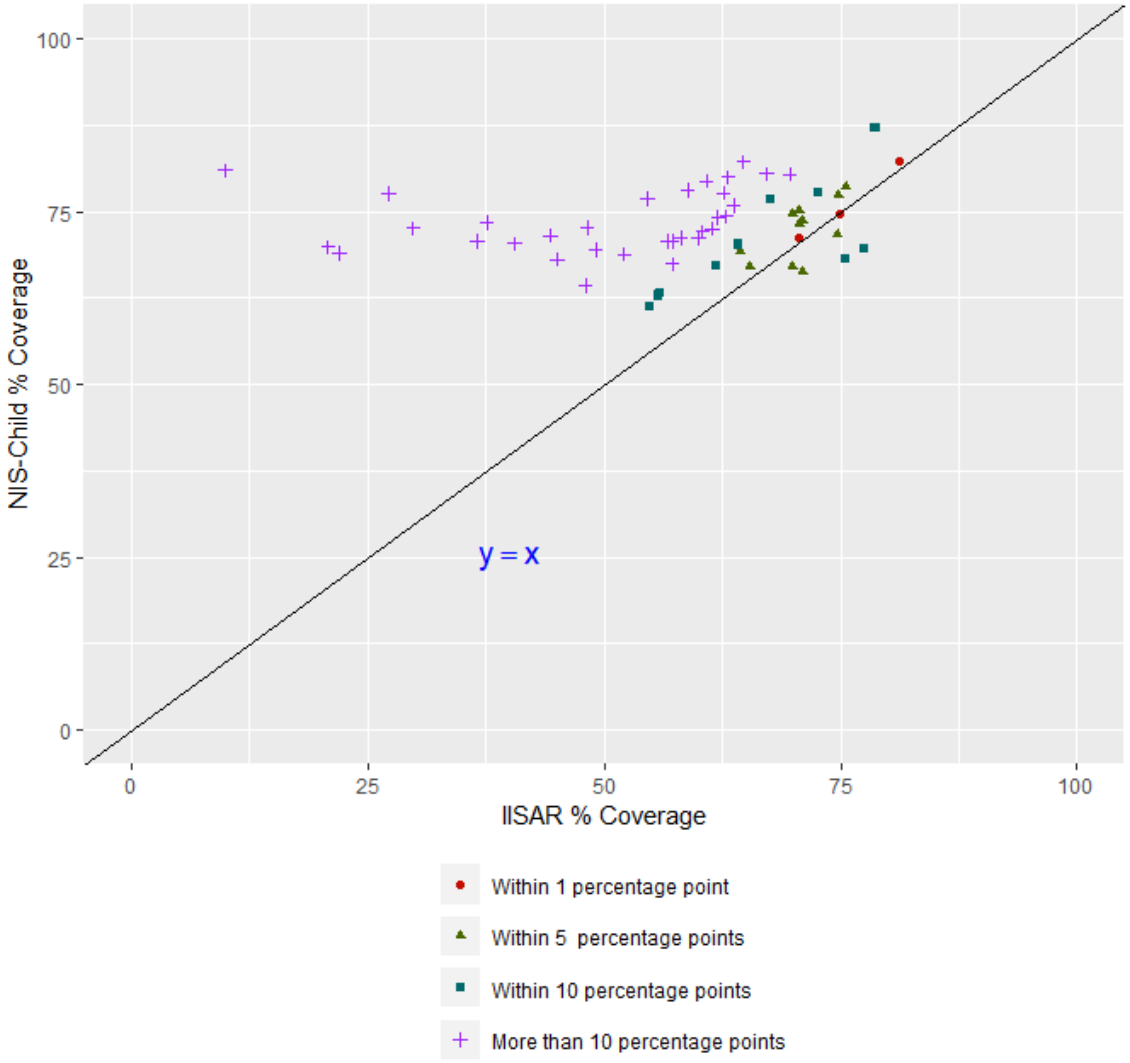
writing, the 2022 comparison will serve as the most current information available about the relative accuracy of the 2023 NIS-Child.

Visual Comparison of the Vaccination Coverage Estimates

Figure 2.1 displays a plot of the NIS-Child vaccination coverage estimate versus the IISAR vaccination coverage estimate for the combined 7-vaccine for the year 2022. Figure 2.1 includes the 56 core estimation areas used in NIS-Child; it does not include points corresponding to eight U.S. territories. IISAR vaccination coverage estimates use an IIS count of vaccinated children as the numerator and a U.S. Census count of children living in the area as the denominator; this can result in some IISAR vaccination estimates being greater than 100 percent, for example if children in the IIS catchment area have moved away from the area. Duplicate records in the IIS could also contribute to higher IIS vaccination coverage estimates when a Census denominator is used.

In Figure 2.1, the straight line through the origin reflects the line where NIS-Child and IISAR vaccination coverage estimates would be equal. Points above the line represent areas in which the NIS-Child vaccination coverage estimate is greater than the IISAR estimate, and points below the line represent areas in which the IISAR estimate is greater. The line itself represents complete agreement between the estimates. In addition, the color and symbol of each point signifies the magnitude of the difference between the NIS-Child and IISAR rates. The plot shows a range of levels of agreement between NIS-Child vaccination coverage and IISAR estimates across areas, including some areas where the NIS-Child estimates are greater and some where the IISAR estimates are greater.

Figure 2.1: Scatterplot of National Immunization Survey-Child (NIS-Child, in Percentage Points) vs. Immunization Information Systems (IISAR, in Percentage Points) Vaccination Coverage Estimates for Combined 7-Vaccine Series: 56 Estimation Areas, 2022

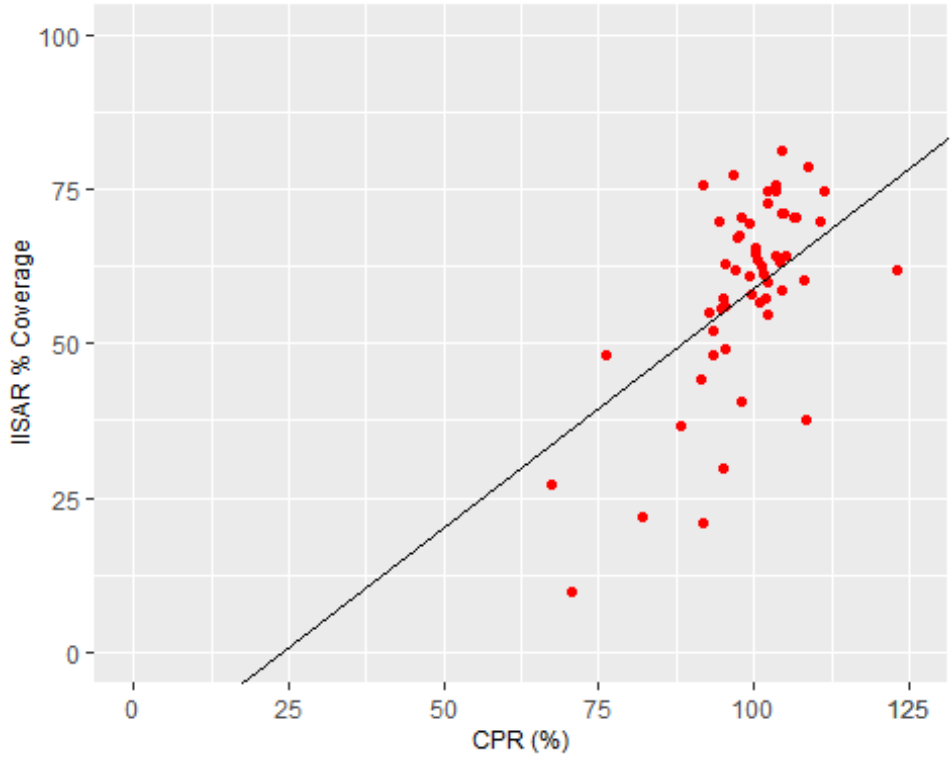


Child Participation Rate (CPR)

To test the hypothesis that increasing quality of a state's IIS data implies increasing agreement between the NIS-Child and IISAR vaccination coverage estimates, we introduce the CPR and evaluate it as a possible measure of the quality of the IIS. The CPR is defined as the proportion of children in the area who have two or more doses of any vaccine recorded in the IIS relative to a U.S. Census Bureau count of children living in the area. Note that the use of two data sources can result in some IISAR CPR values being greater than 100 percent. In Figure 2.2, we plot the IISAR vaccination coverage estimate for the combined 7-vaccine series versus the CPR for the year 2022, including 56 core estimation areas.

We fit a linear regression model to the points in Figure 2.2, and the corresponding fit is represented by the solid line depicted in the figure. The association of CPR with the IISAR vaccination coverage estimate is positive and strongly statistically significant. The Pearson correlation is 0.519 with a 95% confidence interval of [0.297, 0.688]. We conclude that CPR is positively associated with higher vaccination coverage estimates.

Figure 2.2: Scatterplot of Vaccination Coverage Estimates for Combined 7-Vaccine Series (in Percentage Points) vs. Child Participation Rate (CPR, in Percentage Points): Immunization Information Systems Annual Report (IISAR) Data for 56 Estimation Areas, 2022

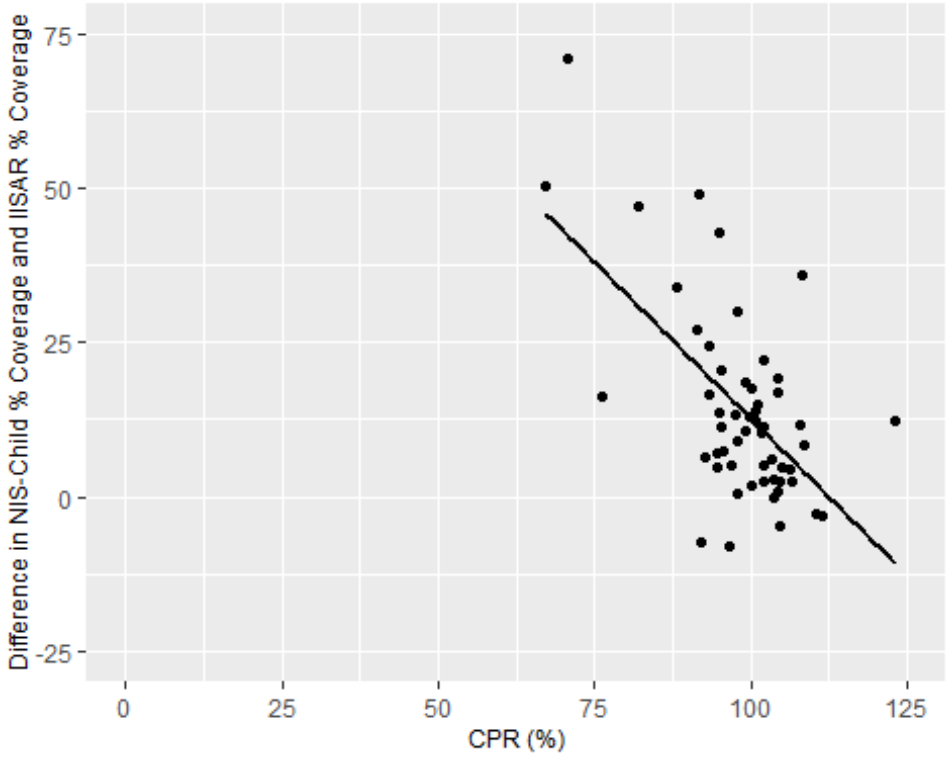


Negative Relationship Between Difference in Vaccination Coverage and CPR

We conducted further evaluation of the hypothesis that increasing quality of state IIS data as indicated by the CPR is associated with increasing agreement between the NIS-Child and IISAR vaccination coverage estimates. Specifically, taking CPR to be a measure of IIS quality, we calculated the difference between the combined 7-vaccine coverage estimates in NIS-Child and IISAR and fit a simple linear regression model relating the difference to the CPR. Figure 2.3 presents the scatterplot of the difference versus the CPR for the set of 56 core estimation areas in 2022, and the straight line depicted in the figure is the regression line. The CPR has a strong and statistically significant relationship with the difference. The coefficient on the CPR is negative (-0.741 percentage points with a 95% confidence interval of [-1.093, -0.388]), which implies that the difference declines with increasing CPR, or in other words, the difference between NIS-Child and IISAR vaccination coverage estimates declines as IIS quality increases.

As the CPR, as an indicator of IIS data quality, increases, IISAR vaccination estimates tend to converge towards NIS-Child vaccination estimates, thus supporting the correlation and accuracy of both estimates.

Figure 2.3: Scatterplot of the Difference in Vaccination Coverage Estimates (National Immunization Survey-Child (NIS-Child) Minus Immunization Information Systems Annual Report (IISAR), Both in Percentage Points) vs. Child Participation Rate (CPR, in Percentage Points) with Regression Line: 56 Estimation Areas, 2022



We conducted an additional analysis pooling the data over the period 2017 to 2022 to achieve greater precision and regressed the difference between NIS-Child and IISAR vaccination coverage estimates on CPR, and dummy variables for year and estimation area. Similar to the 2022 results in Figure 2.3, the pooled results showed that CPR has a statistically significant, negative relationship with the difference, with a regression slope coefficient of -0.243 percentage points with a 95% confidence interval of [-0.359, -0.127].

Summarizing, we have analyzed IISAR vaccination coverage estimates to assess the quality of NIS estimates. In this investigation, we find evidence suggesting that the CPR is correlated with IIS quality. We have shown that as the CPR increases, the difference between the NIS-Child and IISAR vaccination coverage estimates tends to decline, noting that there are certainly other factors contributing to these differences. IIS and NIS are independent data sources. The findings suggest that as the CPR increases, NIS and IIS tend to provide mutual support for one another's accuracy.

2.3 Comparison of Children by Type of Health Insurance Coverage

In this subsection, we compare NIS-Child health insurance estimates to those from the ACS, the CPS ASEC, and the NHIS. We discuss the percentages of children with any private insurance coverage, any public insurance coverage, and no insurance coverage, with a comparison in Table 2.2. Before reviewing the results presented in the table, we provide an overview of each data source.

Table 2.2: Comparison of Alternative Estimates of Health Insurance Coverage Among Children: NIS-Child, ACS, CPS ASEC, and NHIS for 2022 and NIS-Child, CPS ASEC and NHIS for 2023

Type of Health Insurance Coverage	2022				2023		
	ACS	CPS ASEC	NHIS	NIS-Child[a]	CPS ASEC	NHIS	NIS-Child[a]
Any private[b]	55.8%	58.1%	47.3%	53.7%	59.5%	53.2%	53.1%
Any public[c]	45.9%	42.7%	51.0%	56.1%	40.6%	45.4%	57.7%
Uninsured[d]	3.9%	4.7%	4.3%	1.9%	4.4%	3.2%	3.0%

NIS-Child: National Immunization Survey-Child.
ACS: American Community Survey. https://www.census.gov/programs-surveys/acs/microdata.html
CPS ASEC: Current Population Survey Annual Social and Economic Supplement. https://www.census.gov/data/datasets/time-series/demo/cps/cps-asec.html
NHIS: National Health Interview Survey. https://www.cdc.gov/nchs/nhis/data-questionnaires-documentation.htm
[a] NIS-Child estimates were produced among children with adequate provider data using the final NIS-Child survey weights, which are adjusted for noncoverage and nonresponse and calibrated to demographic population control totals.
[b] Private: Includes coverage provided through an employer or union or purchased directly from an insurance company that helps pay for both doctor visits and hospital stays.
[c] Public: Includes Medicaid, Children's Health Insurance Program, Indian Health Service, TRICARE, Civilian Health and Medical Program of the Uniformed Services, and Civilian Health and Medical Program of the Department of Veterans Affairs.
[d] Uninsured: Children are defined as uninsured if they do not have private insurance that helps pay for both doctor visits and hospital stays and do not have any other form of health insurance.

Conducted by the U.S. Census Bureau, the ACS is an ongoing survey that provides essential information about the population of the United States on an annual basis, including statistics related to social, housing, economic, and demographic characteristics of the population. Estimates in Table 2.2 contain information on health insurance status for the child population aged 12 to 35 months based on the 2022 ACS at the national level, the most recently available ACS data as of this writing. ACS interviews are conducted throughout the calendar year, and the ACS instrument assesses health insurance status as of the date of the interview.

CPS ASEC is conducted in March of every year. While CPS is a monthly household survey conducted by the U.S. Census Bureau and the Bureau of Labor Statistics and designed mainly for measuring employment and unemployment, CPS ASEC provides additional detailed statistics related to household income, poverty, health insurance status, and other topics. The CPS ASEC asks current health insurance status as of the time of the interview. Based on data

from the March 2022 and 2023 CPS ASEC, national-level estimates of the health insurance distribution in 2022 and 2023 among children aged 12 to 35 months old are shown in Table 2.2.

The NHIS is a cross-sectional household interview survey, conducted by the National Center for Health Statistics, that covers the civilian noninstitutionalized population in the United States. The objective of the NHIS is to monitor the health status of the U.S. population. In addition to collecting variables related to health status, the survey collects many demographic and socioeconomic characteristics of household members. NHIS national-level estimates of the health insurance distribution in 2022 and 2023 for children aged 12 to 35 months old are shown in Table 2.2. In the NHIS, health insurance status is assessed as of the time of the interview.

In reviewing Table 2.2, we find NIS-Child estimates, which are also based on health insurance status as of the date of the interview, to be smaller than those from the ACS and CPS ASEC for the privately-insured population for 2022 and also less than the CPS ASEC estimate in 2023. While the NIS-Child estimate is larger than the NHIS estimate for 2022, it is about the same in 2023. We find the estimates for public health insurance in NIS-Child to be larger than the corresponding estimates from ACS, CPS ASEC, and NHIS in 2022 and also larger than the CPS ASEC and NHIS estimates in 2023. Finally, we find NIS-Child estimates of the size of the uninsured population are less than corresponding estimates from ACS, CPS ASEC, and NHIS in 2022 and less than the CPS ASEC and NHIS estimates for 2023. The differences in estimates between the NIS-Child and the other three sources could be due to differential error in the NIS-Child relative to the other sources (due to differential sampling-frame coverage error, nonresponse error, or measurement error), or to definitional differences (questionnaire differences) in how health insurance status is measured.

2.4 Comparison of Vaccination Coverage Estimates: NIS-Child vs. State Immunization Surveys and Immunization Information Systems

In this subsection, we compare vaccination coverage estimates from NIS-Child to available estimates from state immunization surveys and from IIS data, focusing on the years 2022 and 2023. Agreement between NIS-Child and either state surveys or IIS estimates signals consistency between the two sources and may indicate the accuracy of the sources. Disagreement between the estimates signals inconsistency and that at least one of the sources may be inaccurate.

As of this writing, Tennessee is the only state immunization survey we are aware of that reports estimates for 2023. Additionally, we identified five state IIS that have produced vaccination coverage estimates for resident children for the NIS-Child age range for 2023: Iowa, Michigan, Oregon, Washington and Wisconsin. Additional recent comparisons to estimates from other state surveys and IIS are discussed in NORC (2023a).

Specifically, this subsection compares:

- NIS-Child vaccination coverage estimates for Tennessee to those from the Tennessee Immunization Survey (TIS)[5], sponsored and conducted by the Tennessee Department of Health;
- NIS-Child vaccination coverage estimates for Iowa to those from the Iowa Immunization Registry Information System (IRIS)[6], sponsored and conducted by the Iowa Department of Health and Human Services;
- NIS-Child vaccination coverage estimates for Michigan to those from the Michigan Care Improvement Registry (MCIR)[7], sponsored and conducted by the Michigan Department of Health and Human Services;
- NIS-Child vaccination coverage estimates for Oregon to those from Oregon's Immunization Information System, called ALERT IIS[8], conducted by the Oregon Health Authority;
- NIS-Child vaccination coverage estimates for Washington to those from the Washington State Immunization Information System (WAIIS)[9], conducted by the Washington State Department of Health; and
- NIS-Child vaccination coverage estimates for Wisconsin to those from Wisconsin Immunization Registry (WIR)[10], conducted by the Wisconsin Department of Health Services.

Regarding the IIS comparisons, these analyses differ from the IISAR comparisons in subsection 2.2, which only focused on the combined 7-vaccine series. Comparisons in this subsection are made for additional vaccines.

The TIS utilizes a retrospective cohort research design to determine the up-to-date (UTD) vaccination coverage estimates for 24-month-old children born in the state of Tennessee. It is based on random samples of children selected from state listings of registered births. Table 2.3 shows that the TIS sample size is about four times as large as the NIS-Child sample size in Tennessee.

IRIS, MCIR, ALERT IIS, WAIIS and WIR are population-based computerized systems that contain immunization information for individuals of all ages residing in the state. The numerator

[5] https://www.tn.gov/content/dam/tn/health/2023_Immunization_Status_Survey_of_24-Month-Old_Children.pdf

[6] https://hhs.iowa.gov/public-health/data/health/immunization/childhood-immunization-data

[7] https://www.michigan.gov/mdhhs/adult-child-serv/childrenfamilies/immunization/localhealthdepartment/county-immunization-report-card

[8] https://public.tableau.com/app/profile/oregon.immunization.program/viz/OregonChildImmunizations/D-Landing

[9] https://doh.wa.gov/data-and-statistical-reports/washington-tracking-network-wtn/immunization-data/county-public-health-measures-dashboard

[10] https://www.dhs.wisconsin.gov/publications/p02003a.pdf

of their estimates is the number of vaccinated individuals. IRIS uses Census population estimates for the denominator, and MCIR, ALERT IIS, WAIIS and WIR use individuals in their IIS as the denominator. Due to their population-based systems, Table 2.3 shows that IRIS, MCIR and WAIIS have much larger sample sizes than the NIS-Child estimates for corresponding state. ALERT IIS and WIR do not report sample sizes.

Table 2.3: Sample Sizes of Children for NIS-Child, State Immunization Surveys, and Immunization Information Systems in 2022 and 2023

Survey and IIS	2022			2023		
	Children 24 Months	Children 24-35 Months	Children 19-35 Months	Children 24 Months	Children 24-35 Months	Children 19-35 Months
Tennessee Immunization Status Survey (TIS)[1),2)]	1,399			1,414		
NIS-Child in Tennessee, Children with Adequate Provider Data		347			365	
Iowa Immunization Registry Information System (IRIS) [3)]	38,298			38,790		
NIS-Child in Iowa, Children with Adequate Provider Data		271			301	
Michigan Care Improvement Registry (MCIR)[4)]			165,763			166,582
NIS-Child in Michigan, Children with Adequate Provider Data			457			494
Oregon Immunization Information System (ALERT IIS)[5)]	NA			NA		
NIS-Child in Oregon, Children with Adequate Provider Data		215			220	
Washington Immunization Information System (WAIIS)[6)]			132,369			132,398
NIS-Child in Washington, Children with Adequate Provider Data			394			462
Wisconsin Immunization Registry (WIR)[7)]	NA			NA		
NIS-Child in Wisconsin, Children with Adequate Provider Data		278			318	

1) https://www.tn.gov/content/dam/tn/health/2023_Immunization_Status_Survey_of_24-Month-Old_Children.pdf

2) https://www.tn.gov/content/dam/tn/health/documents/cedep-weeklyreports/2022-24-Month-Old-Survey.pdf

3) https://data.idph.state.ia.us/t/IDPH-DataViz/views/Immunization2yearold/Map

4) https://www.michigan.gov/mdhhs/adult-child-serv/childrenfamilies/immunization/localhealthdepartment/county-immunization-report-card

5) https://public.tableau.com/app/profile/oregon.immunization.program/viz/OregonEarlyChildhoodImmunizationRates/StatewideDashboard

6) https://doh.wa.gov/data-and-statistical-reports/washington-tracking-network-wtn/immunization-data/county-public-health-measures-dashboard

7) https://www.dhs.wisconsin.gov/publications/p02003a.pdf

The Tennessee TIS and NIS-Child estimates are compared for children at age 24 months in Figure 2.4. We find a reasonable degree of agreement between the two sets of estimates for 4+ DTaP, 3+ Polio, 3+ Hepatitis B, and 4+ PCV, but NIS-Child estimates are much lower than the corresponding TIS estimates for the Hib full series (Hib-FS) and the combined 7-vaccine series.

Figure 2.4: Comparison of Vaccination Coverage Estimates for Children by Age 24 Months: Tennessee Immunization Status Survey (TIS) vs. National Immunization Survey-Child (NIS-Child) in Tennessee, 2022 and 2023

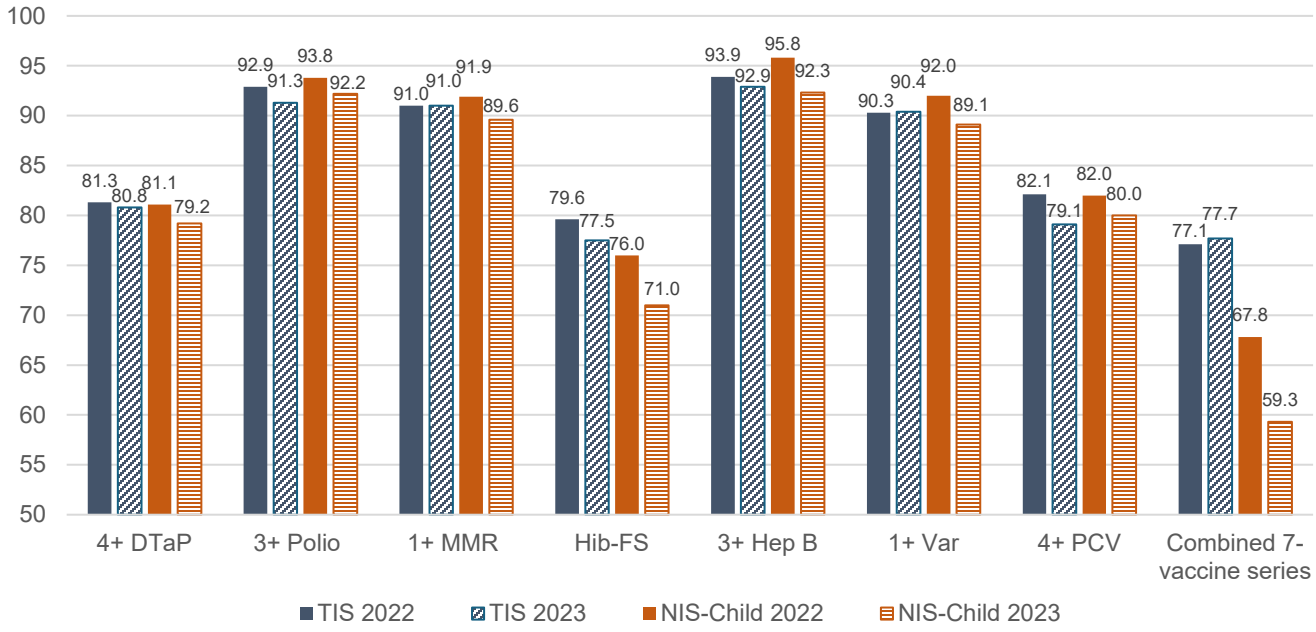


Figure 2.5 presents a comparison of the Iowa IRIS and NIS-Child vaccination coverage estimates for children by age 24 months for 1+ MMR, 1+ Varicella (Var), 3+ Hep B, 3+ Hib, 3+ Polio, 4+ DTaP, 4+ PCV, and the combined 7-vaccine series. NIS-Child estimates are modestly higher than the corresponding IRIS estimates for all vaccines examined.

Figure 2.5: Comparison of Vaccination Coverage Estimates for Children by Age 24 Months: Iowa Immunization Registry Information System (IRIS) vs. National Immunization Survey-Child (NIS-Child) in Iowa, 2022 and 2023

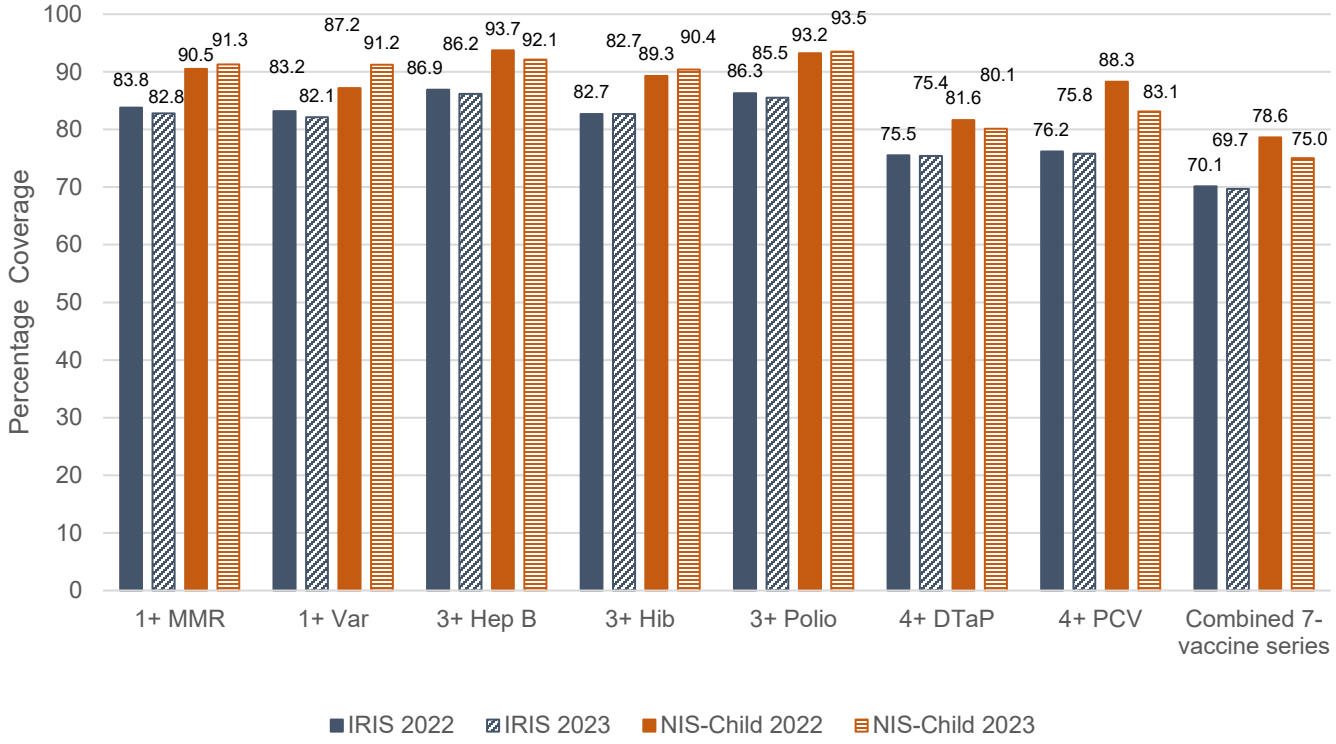


Figure 2.6 presents a comparison of the Michigan MCIR and NIS-Child vaccination coverage estimates for children by age 19-35 months for 4+ DTaP, 4+ PCV, and the combined 7-vaccine series. We find the NIS-Child estimates are generally somewhat higher than the corresponding MCIR estimates, but that the differences between estimates are smaller in 2023 than in 2022.

Figure 2.6: Comparison of Vaccination Coverage Estimates for Children Aged 19-35 Months: Michigan Care Improvement Registry (MCIR) vs. National Immunization Survey-Child (NIS-Child) in Michigan, 2022 and 2023

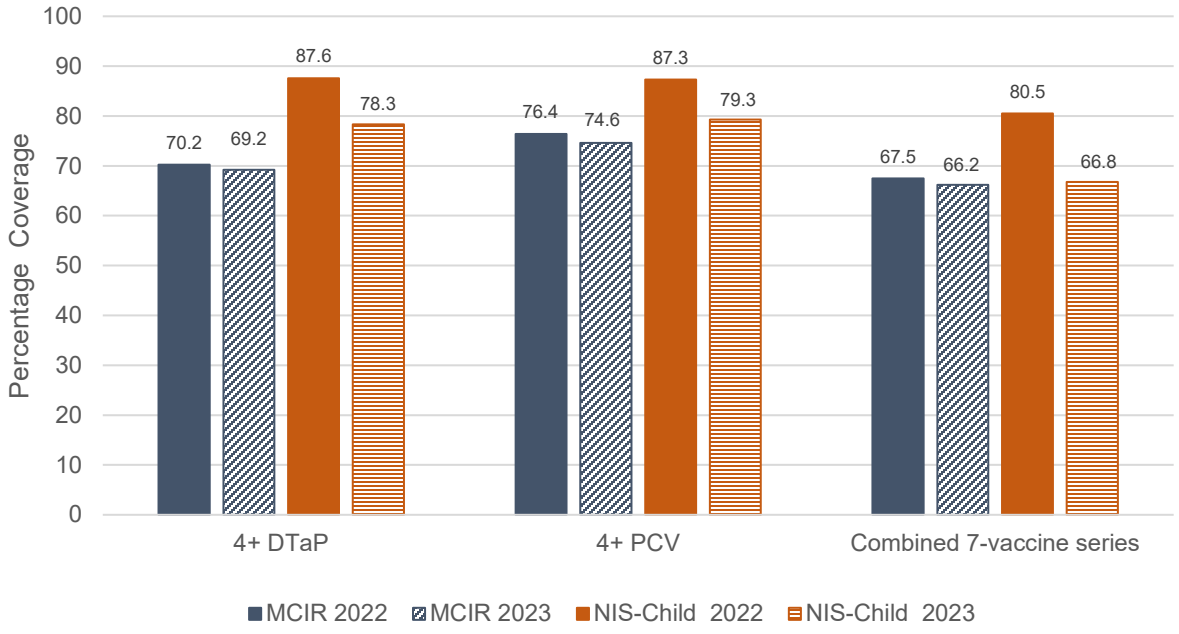
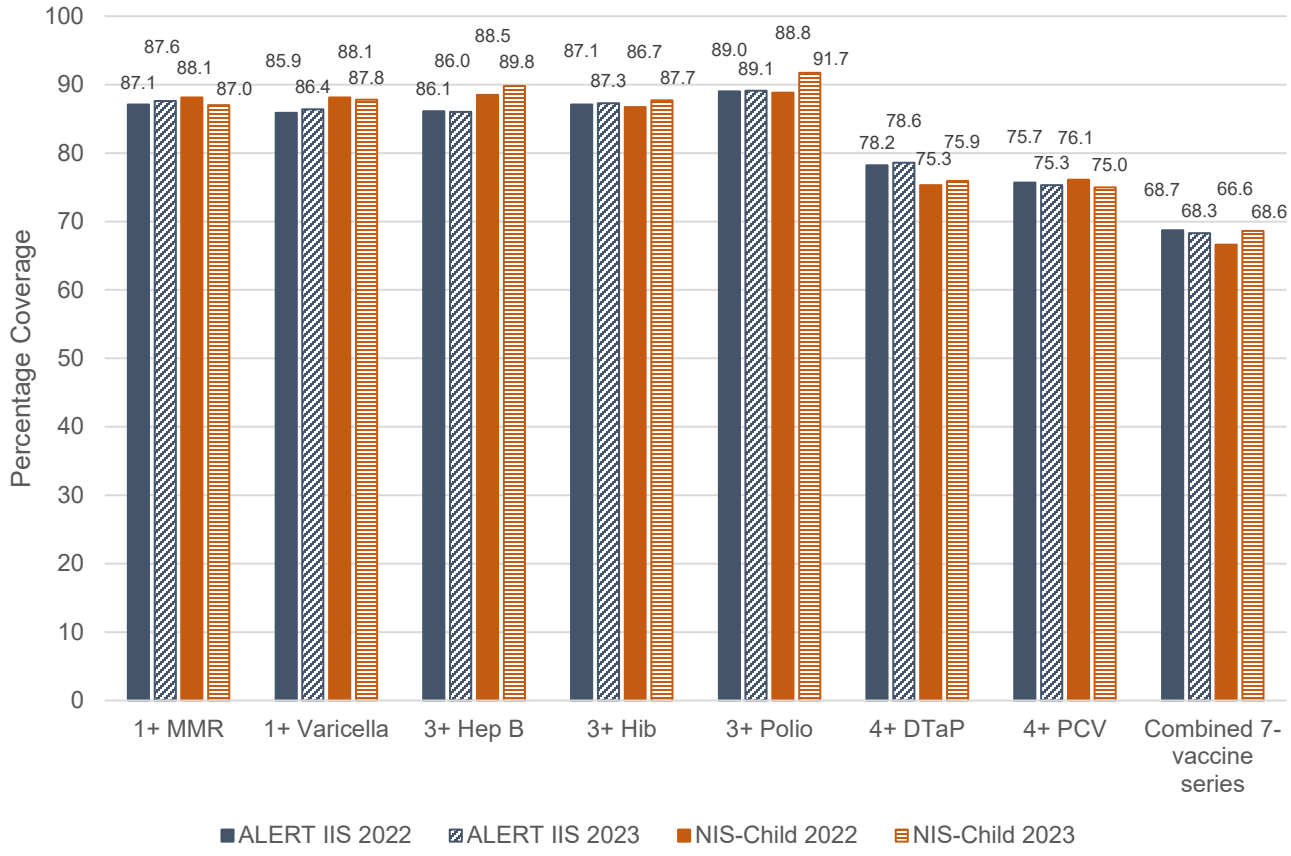


Figure 2.7 presents a comparison of the Oregon ALERT IIS and NIS-Child vaccination coverage estimates for children by age 24 months for 1+ MMR, 1+ Var, 3+ Hep B, 3+ Hib, 3+ Polio, 4+ DTaP, 4+ PCV, and the combined 7-vaccine series. We observe reasonably good agreement between the NIS-Child and ALERT IIS estimates.

Figure 2.7: Comparison of Vaccination Coverage Estimates for Children by Age 24 Months: ALERT Immunization Information System (IIS) vs. National Immunization Survey-Child (NIS-Child) in Oregon, 2022 and 2023



The Washington WAIIS and NIS-Child estimates are compared for children at age 19-35 months in Figure 2.8. Overall, we find a large discrepancy between the two sets of estimates, with the NIS-Child estimates being much higher than the corresponding WAIIS estimates for all vaccines examined.

Figure 2.9 presents a comparison of the Wisconsin WIR and NIS-Child vaccination coverage estimates for children by age 24 months. It shows the vaccination coverage estimates for 1+ MMR, 1+ Var, 3+ Hep B, 3+ Hib, 3+ Polio, 4+ DTaP, 4+ PCV and the combined 7-vaccine series. In comparing vaccination coverage estimates between NIS-Child and IIS in two states, we found smaller differences in estimates for 3+ Hib and 4+PCV in 2022 and 2023, and larger differences for 1+ MMR and the combined 7-vaccine series estimates in 2022 and 2023. Generally, NIS-Child estimates are larger than WIR in both years.

Figure 2.8: Comparison of Vaccination Coverage Estimates for Children Aged 19-35 Months: Washinton State Immunization Information System (WAIIS) vs. National Immunization Survey-Child (NIS-Child) in Washington, 2022 and 2023

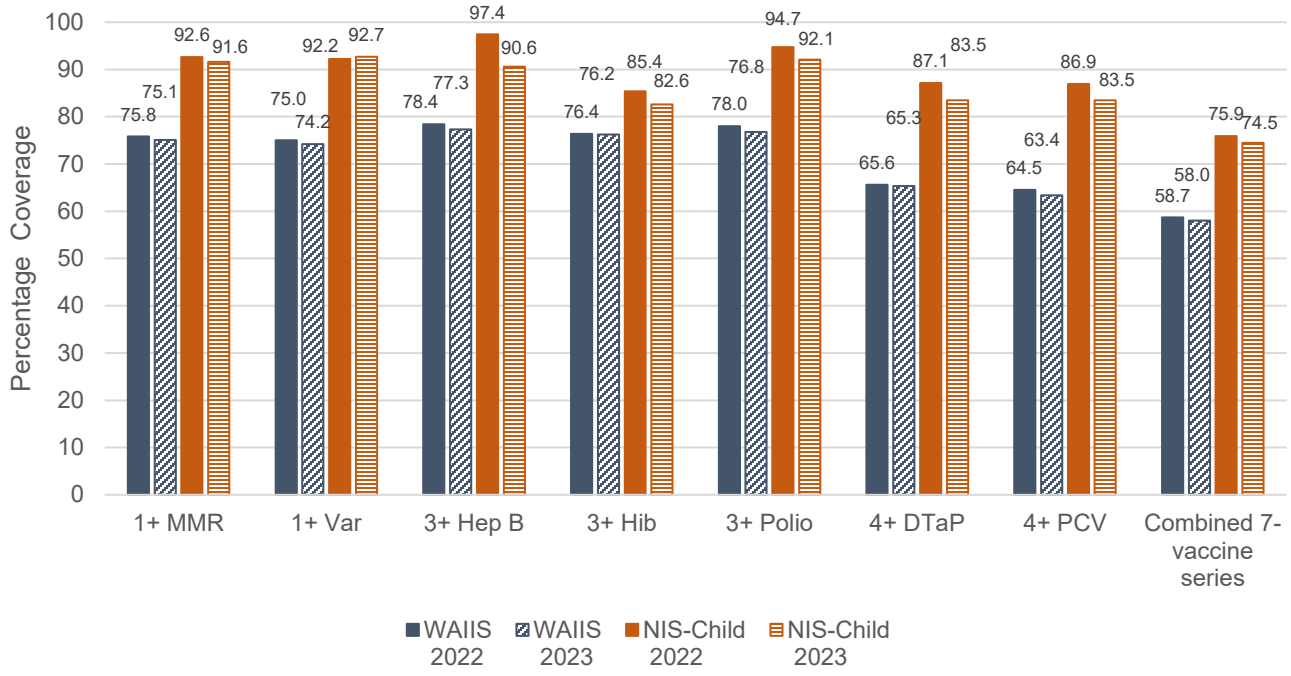
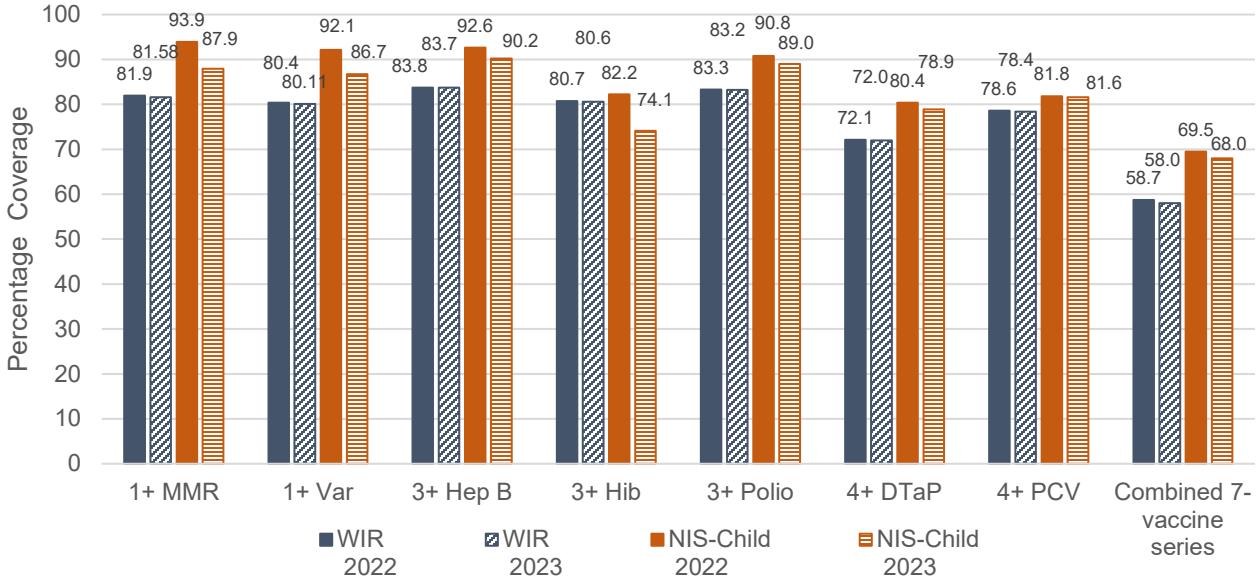


Figure 2.9: Comparison of Vaccination Coverage Estimates for Children Aged 19-35 Months: Wisconsin Immunization Registry (WIR) vs. National Immunization Survey-Child (NIS-Child) in Wisconsin, 2022 and 2023



In summary, there is reasonable agreement in vaccination coverage estimates between NIS-Child and the Tennessee TIS for series other than the Hib full-series and the combined 7-vaccine series. NIS-Child vaccination coverage estimates are closely aligned with ALERT IIS estimates in Oregon, while NIS-Child estimates tend to be larger than estimates from the other four state IIS. Differences in estimates in these states could be due to missing vaccination data in the state IIS or error in NIS-Child estimates.

3. Part II: Assessment of Total Survey Error for NIS-Child Vaccination Coverage Estimates

In this second part of the report, we assess the total survey error in NIS-Child vaccination coverage estimates using the framework developed and implemented in Molinari et al. (2011) and Wolter et al. (2017). We decompose TSE into components of sampling and nonsampling error, and then assemble the best information available about the magnitude of each component error from specialized evaluation studies. We view each component error as a random variable subject to a conditional distribution, given the outcome of the NIS-Child. The mean of the conditional distribution is estimated from numerical evidence obtained in the corresponding evaluation study, and the variance of the distribution, reflecting both variability in the evaluation survey samples and other uncertainties in our knowledge about the component error, is estimated from internal evidence within the evaluation study and additional professional judgment when necessary. After assembling our best information about each of the component errors, we combine the information to produce a total survey error distribution, using a Monte Carlo method.

Before proceeding to consider the component errors, we introduce some notation that will be helpful in this section. Let μ_0 denote the true but unknown vaccination coverage rate in the age-eligible population of children and let $\hat{\mu}$ denote the NIS-Child estimate of the vaccination coverage. The TSE in vaccination coverage estimate is then given by

$$q_0 = \hat{\mu} - \mu_0 \ . \tag{1}$$

We use a three-stage model for TSE, where Stage 1 represents error due to the sampling frame's undercoverage of the population of age-eligible children, Stage 2 represents error due to nonresponse among sampled units, and Stage 3 represents measurement error among the responding units. The model for the first stage (sampling-frame coverage) is

$$\mu_0 = (1 - p_{1A})\mu_1 + p_{1A}\mu_{1A} \ , \tag{2}$$

where μ_1 is the true vaccination coverage for the age-eligible children covered by the sampling frame, μ_{1A} is the true vaccination coverage for the age-eligible children not covered by the sampling frame, and p_{1A} is the proportion of the age-eligible population not covered by the sampling frame. The model at the second stage (response) is

$$\boldsymbol{\mu_1 = (1 - p_{2A})\mu_2 + p_{2A}\mu_{2A}}\ , \tag{3}$$

where μ_2 is the true vaccination coverage for children who respond to NIS-Child, μ_{2A} is the true vaccination coverage for children who do not respond, and p_{2A} is the proportion of children who do not respond. Finally, the model at the third stage (measurement) is

$$\boldsymbol{\mu_2 = (1 - p_{3A})\mu_3 + p_{3A}\mu_{3A}}\ , \tag{4}$$

where μ_3 is the true vaccination coverage of children for whom accurate response is given to the survey, μ_{3A} is the true vaccination coverage of children for whom inaccurate response is given to the survey, and p_{3A} is the proportion of children for whom inaccurate response is given.

Combining all three stages together, the true vaccination coverage can be written as

$$\boldsymbol{\mu_0 = (1 - p_{1A})[(1 - p_{2A})\{(1 - p_{3A})\mu_3 + p_{3A}\mu_{3A}\} + p_{2A}\mu_{2A}] + p_{1A}\mu_{1A}}\ . \tag{5}$$

We can also write the TSE as

$$\boldsymbol{q_0 = q_1 + q_2 + q_3}\ , \tag{6}$$

where $q_1 = \mu_1 - \mu_0$ is the error due to noncoverage, $q_2 = \mu_2 - \mu_1$ is the error due to nonresponse, and $q_3 = \hat{\mu} - \mu_2$ is the error due to inaccurate reporting by survey respondents.

The seven parameters on the right side of (5) are $\boldsymbol{\phi} = (\mu_{1A}, \mu_{2A}, \mu_{3A}, \mu_3, p_{1A}, p_{2A}, p_{3A})'$. Estimates of the values of these seven parameters, based on the analyses to be presented in Sections 3.2 through 3.4, are denoted by $\widehat{\boldsymbol{\phi}} = (\hat{\mu}_{1A}, \hat{\mu}_{2A}, \hat{\mu}_{3A}, \hat{\mu}_3, \hat{p}_{1A}, \hat{p}_{2A}, \hat{p}_{3A})'$. Let $\widehat{\boldsymbol{\Sigma}}$ denote the estimated variance-covariance matrix of $\boldsymbol{\phi}$. We assume the seven parameters are independently distributed and that $\widehat{\boldsymbol{\Sigma}} = \text{diag}(\hat{\sigma}^2_{\mu 1A}, \hat{\sigma}^2_{\mu 2A}, \hat{\sigma}^2_{\mu 3A}, \hat{\sigma}^2_{\mu 3}, \hat{\sigma}^2_{p1A}, \hat{\sigma}^2_{p2A}, \hat{\sigma}^2_{p3A})'$, where each term on the diagonal is our estimate of the variance of the corresponding parameter.

We assume our knowledge about the true parameters, $\boldsymbol{\phi}$, can be acceptably represented by a probability distribution, with parameters $\widehat{\boldsymbol{\phi}}$ and $\widehat{\boldsymbol{\Sigma}}$. We assess TSE by making random draws of $\boldsymbol{\phi}$ from its distribution. For each draw, we use (5) to produce a draw from the distribution of true vaccination coverage in the overall age-eligible population (say, μ_0^*) and we compute $q^* = \hat{\mu} - \mu_0^*$ as a draw from the distribution of TSE. We obtain the distribution of TSE through 10,000 such draws.

Having established our model and notation, we now consider *sampling-frame coverage error* in the NIS-Child, which arises because the sampling frame omits direct representation of the phoneless and landline only (LLO) populations. Second, we consider *nonresponse error* in the NIS-Child, which comes about due to nonresponse in the random digit dial (RDD) telephone survey of households, failure of the parental respondent to give consent to contact the children's immunization providers, and missing vaccination histories in the Provider Record Check given consent. Third, we consider *response or measurement error* in the provider reporting of vaccination histories. This component of error has also been referred to as under-ascertainment of vaccination histories. Fourth, we consider error in the NIS-Child due to sampling, i.e., error because the survey observes only approximately 1 out of 300 children in the age-eligible population. Fifth, we combine the foregoing component error distributions, resulting in the TSE distribution of the vaccination coverage estimate for the 2023 NIS-Child. Finally, we close this part of the report by examining the change in the TSE from the 2022 NIS-Child to the 2023 NIS-Child using the bridging cohort method, developed and implemented by Yankey et al. (2015).

3.1 Sampling-Frame Coverage Error

Sampling-frame coverage errors arise in a survey when the sampling frame does not include the entire target population. In 2018, the NIS-Child began using a single-frame cell-phone RDD design, which omits direct representation of children in LLO and phoneless households. To account for the excluded population groups, the NIS-Child weighting methodology makes adjustment to the weights by raking the weights to select demographic characteristics of the population of children 19 to 35 months. The assumption embedded in this procedure is that, after controlling for these characteristics, the vaccination coverage in the population not represented on the sampling frame equals the coverage in the population represented on the frame. However, it is possible that estimated vaccination coverage of children in the omitted domains experience different vaccination coverage than the domains of children included in the survey, namely, cell-phone only (CPO) children and dual-user children, which may introduce bias into the estimator of vaccination coverage.

In this subsection, we attempt to measure the bias in estimated vaccination coverage introduced by sampling-frame coverage error. Table 3.1 displays the proportion of 19- to 35-month-old children in the population by telephone status for 2012 to 2022 based on estimates from the NHIS. The proportion of children with CPO status is increasing throughout this period and the proportion of children with dual-user status is decreasing. The estimated proportion in cell-phone households (i.e., CPO and dual-user combined), was relatively steady until 2018, before increasing from 93.3% in 2018 to 98.2% in 2019. This estimate has remained at a similar level since that time (98.0% in 2022). LLO children have decreased in prevalence over time. Estimates of the phoneless population increased between 2012 and 2018 before lower estimates were found in 2019 and subsequent years.

Table 3.1: Percentage of Age-Eligible Children in the Population by Telephone Status by Year: NIS-Child, United States, 2012-2022

Year	Cell-Phone Only	Dual-User	Landline Only	Phoneless
2012	51.3	43.4	4.0	1.3
2013	57.6	36.8	3.0	2.6
2014	64.1	30.8	2.6	2.5
2015	68.9	26.5	2.2	2.4
2016	71.8	24.6	1.3	2.4
2017	73.3	20.9	2.5	3.3
2018	74.0	19.3	1.6	5.1
2019	80.9	17.3	1.1	0.7
2020	82.5	16.2	0.4	0.9
2021	87.2	10.6	1.0	1.2
2022	89.3	8.7	1.2	0.8

Source: Produced using the methods of Blumberg, Ganesh, Luke, and Gonzales (2013) applied to data from the 2012-2022 National Health Interview Survey sponsored by CDC's National Center for Health Statistics (https://www.cdc.gov/nchs/nhis/index.htm).

The 2023 NIS-Child did not directly measure LLO or phoneless children, and to assess vaccination coverage in these domains and determine whether they differ from estimates in the combined cell-phone domain, we must turn to other sources. Specifically, the 2012-2017 NIS-Child sampled and directly represented LLO children, thus permitting comparison of the vaccination coverage by telephone status. Table 3.2 displays the vaccination coverage estimates for 2017, the closest such year to 2023. We observe that vaccination coverage estimates are generally higher in the cell-phone domain than in the LLO domain, and four of the nine differences in estimates of vaccination coverage are statistically significant.

Since NIS-Child has never included direct sampling of phoneless children, we study vaccination coverage in the phoneless domain using estimates from the 2012 National Health Interview Survey-Provider Record Check (NHIS-PRC).[11] Table 3.3 shows the vaccination coverage estimates for select vaccines and vaccine series for children in the cell-phone domain compared with those in the phoneless domain. For most of the vaccines presented, we observe higher vaccination coverage estimates from the cell-phone domain compared to the phoneless domain; however, none of the differences are statistically significant, likely due to the small number of phoneless children in the NHIS.

[11] 2012 was the last, and therefore most recent, year for which the NHIS-PRC was conducted, and thus for which a direct measurement was obtained of the vaccination status of phoneless children.

Table 3.2: Vaccination Coverage Estimates and Standard Errors of Select Vaccines and Vaccine Series for the Cell-Phone and Landline Only Domains: NIS-Child, United States, 2017

	Cell-Phone Domain		Landline Only Domain		Difference		
Variance/Series	Estimate	Standard Error	Estimate	Standard Error	Estimate	Standard Error	
4+ DTaP	83.4	0.59	58.7	10.65	24.6	10.66	*
3+ Polio	92.9	0.39	67.6	11.28	25.3	11.28	*
1+ MMR	91.6	0.43	80.0	7.82	11.5	7.83	
Hib-FS	80.9	0.66	58.7	10.68	22.1	10.70	*
3+ Hep B	91.5	0.46	81.1	7.77	10.4	7.78	
Hep B Birth Dose	73.7	0.80	70.1	8.07	3.6	8.12	
1+ Var	91.2	0.44	72.6	8.64	18.6	8.66	*
4+ PCV	82.6	0.64	62.0	10.83	20.6	10.85	
Combined 7-Vaccine Series	70.6	0.75	54.0	10.23	16.6	10.26	

$*$ $p \leq 0.05$.

Note that 2012 NHIS-PRC estimates for Hep B birth dose are not available. To assess coverage error in the Hep B birth dose estimate, we used a conservatively high estimate of the difference between the vaccination coverage for the cell-phone and phoneless domains. We used this approach to demonstrate in subsequent analysis that coverage error is small even if the difference in vaccination coverage between the covered and non-covered domains is large. Specifically, for Hep B birth dose, we used the largest estimated difference available for the eight other vaccine series.

The foregoing tables can be translated into an assessment of sampling-frame coverage error in the 2023 NIS-Child estimated vaccination coverage. We can also write the true vaccination coverage as

$$\boldsymbol{\mu_0 = \mu_1 - B}\,, \tag{7}$$

where $B = p_{1A}(\mu_1 - \mu_{1A})$ equates to sampling-frame coverage error. To fully assess the distribution of total survey error in the NIS-Child, we will require estimates of the parameters, $\hat{p}_{1A}$, $\hat{\mu}_{1A}$, and $\hat{\mu}_1$, and their standard errors, which we present in Section 3.5. Here, we simply observe that $\hat{p}_{1A}$ is obtained from the landline only and phoneless columns on the right side of Table 3.1 for the most recent year available 2022, and $\hat{\mu}_{1A}$ is obtained from the results of the 2023 NIS-Child and the Difference columns on the right side of Tables 3.2 and 3.3. The estimate of vaccination coverage in the sampling-frame covered population, $\hat{\mu}_1$, is obtained from the results of the 2023 NIS-Child and from analyses presented in Sections 3.2 and 3.3 on nonresponse error and measurement error.

Table 3.3: Vaccination Coverage Estimates and Standard Errors of Select Vaccines and Vaccine Series for Children 19-35 Months in the Cell-Phone and Phoneless Domains: National Health Interview Survey-Provider Record Check, United States, 2012

	Cell-Phone Domain		Phoneless Domain		Difference	
Vaccine	**Estimate**	**Standard Error**	**Estimate**	**Standard Error**	**Estimate**	**Standard Error**
4+ DTaP	83.87	1.36	87.40	6.53	-3.53	6.67
3+ Polio	93.90	0.82	91.10	5.61	2.80	5.67
1+ MMR	92.24	1.08	92.70	4.44	-0.46	4.57
Hib-PS	94.72	0.89	91.10	5.61	3.62	5.68
3+ Hep B	91.06	1.03	85.30	7.81	5.76	7.87
Hep B Birth Dose					6.47[#]	5.68[#]
1+ Var	91.69	0.98	92.70	4.44	-1.01	4.55
4+ PCV	85.37	1.32	78.90	8.27	6.47	8.37
Combined 7-Vaccine Series	72.53	1.71	67.80	9.85	4.73	9.99

Notes: Estimates for the Hib full series (Hib-FS) are not available from the National Health Interview Survey-Provider Record Check (NHIS-PRC). Instead, we use the estimate for the Hib primary series (Hib-PS), which is ≥2 doses or ≥3 doses depending on brand. The estimates for the combined 7-vaccine series in this table are also based on Hib-PS rather than Hib-FS.

$*$ $p \leq 0.05$.

[#] Estimates for Hep B birth dose are not available from the NHIS-PRC Analysis Report. As inputs for estimating coverage error for the Hep B birth dose, we used the largest difference in vaccination coverage estimates between the cell-phone and phoneless domains available from the eight other vaccines. This approach was chosen to be conservative and overestimate the extent of potential coverage error. For the standard error of the difference, we used the same standard error as for the corresponding estimate for Hib-PS, as Hib-PS and Hep B birth dose have similar 2023 vaccination coverage estimates.

As a preliminary assessment of the effect of sampling-frame coverage error, we estimate the true vaccination coverage ignoring the effects of nonresponse and measurement error. In this circumstance, the NIS-Child vaccination coverage estimate is essentially μ_1. Then, Table 3.4 presents estimates of B and of the true vaccination coverage, μ_0. We find that sampling-frame coverage error is 0.3 percentage points or less and the estimated error is less than the standard error of μ_0.

Table 3.4: Preliminary Assessment of Sampling-Frame Coverage Error and Mean True Vaccination Coverage (in %): NIS-Child, United States, 2023

Vaccine	$\hat{\mu}_1$ (2023 NIS-Child Vaccination Coverage Estimate)	$\hat{B}$[a]	$\hat{\mu}_0$(Mean of μ_0, the True 2023 Vaccination Coverage)	Standard Error of μ_0
4+ DTaP	82.2	0.3	81.9	0.7
3+ Polio	91.9	0.3	91.5	0.5
1+ MMR	91.1	0.1	90.9	0.5
Hib-FS	78.2	0.3	78.0	0.7
3+ Hep B	91.3	0.2	91.2	0.5
Hep B Birth Dose	79.1	0.1	79.0	0.6
1+ Var	90.9	0.2	90.7	0.5
4+ PCV	81.4	0.3	81.1	0.7
Combined 7-Vaccine Series	69.5	0.2	69.3	0.7

[a] The estimated sampling-frame coverage error, $\hat{B}$, is obtained by combining information in Table 3.2 about the landline only population in 2017 with information in Table 3.3 about the phoneless population in 2012.

3.2 Nonresponse Error

There are two types of nonresponse error impacting NIS-Child, unit nonresponse error due to not obtaining responses (or completed interviews) for all children sampled and item nonresponse error due to missing questionnaire items among survey respondents. This subsection focuses on assessing survey error due to unit nonresponse. We conclude with a review of 2023 NIS-Child item nonresponse rates. NIS-Child vaccination coverage estimates are based on provider-reported vaccination histories; incomplete (or missing vaccination) information on these histories is a form of measurement error or under-reporting error, which is assessed in Section 3.3.

Components of Nonresponse in NIS-Child

Unit nonresponse error in NIS-Child estimates of vaccination coverage is the error arising because completed interviews and vaccination histories are not obtained for all children sampled. Nonresponse arises at four steps in the survey process, as follows: (1) failure to resolve the selected telephone number as an occupied household or some other known entity, (2) failure to screen the household for the presence of one or more age-eligible children, (3) failure to complete the interview of an eligible household, and (4) failure to obtain consent to contact the child's vaccination providers or failure to obtain sufficient information from providers

to determine the child's vaccination status, given consent. We do not observe the vaccination statuses of children for whom the household interview or the Provider Record Check is missing. This subsection assesses the extent of nonresponse error in the 2023 NIS-Child estimates of vaccination coverage for four vaccines or vaccine series, 4+ DTaP, 1+ MMR, Hep B birth dose, and the combined 7-vaccine series.

Weight Adjustment for Nonresponse Error

NIS-Child addresses error due to nonresponse by using weight adjustments that correct for known differences between children in responding and nonresponding households based on observable characteristics. Specifically, weighting cells are defined based on sampling frame information known for both respondents and nonrespondents, and weights are adjusted by a factor inversely proportional to the response rates within each cell. Calibration of the weights to demographic population totals also serves to adjust for differences between the responding sample and the population. The NIS-Child weighting methodology is described in detail in Wolter et al. (2017).

The weighting adjustment method assumes that nonresponse is a *missing at random* process (Rubin 1976), or that the conditional distribution of vaccination coverage on the characteristics used to form the weighting cells and calibration dimensions is the same whether or not the data are missing. This assumption, while widely used for weighting nonresponse adjustments, is generally untestable since we do not observe vaccinations statuses for the nonrespondents. Thus, further methods are needed to assess the extent of nonresponse error after conducting weighting adjustments.

Assessment of Nonresponse Error

To inform our TSE models, an estimate of the proportion of children with adequate provider data among children in households corresponding to the sampled telephone numbers is needed. The 2023 NIS-Child realization rate[12] of children with adequate provider data was 2.4 percent with a standard error of 0.04 percentage points. Dividing the realization rate by the coverage rate of the sampling frames as estimated in Section 3.1 yields an estimate of the proportion of children with adequate provider data among those covered by the sampling frame of 2.4 percent, or 97.6 percent without adequate provider data, with a standard error of 0.4 percentage points. These two numbers (97.6% with a standard error of 0.4 percentage points) serve as model inputs $\hat{p}_{2A}$ and $\hat{\sigma}_{p2A}$ for the TSE analysis.

We now assess the extent of nonresponse error both before conducting nonresponse weighting adjustments as well as the residual error after accounting for such adjustments. It is common in TSE analyses to compare estimates derived from the survey under study, NIS-Child in this

[12] The realization rate (Skalland, 2011) is calculated as the ratio of the unadjusted survey estimate of the size of the target population to an external estimate of the true size of the target population and can be interpreted as the product of the coverage rate of the sampling frame and the response rate.

instance, with those from leading reference surveys (Biemer, 2010). A reasonable benchmark for the NIS-Child is the NHIS, because it provides representation of the same population of children as the NIS-Child and is known to be a premier health survey of the general population in the United States. The NHIS is conducted using face-to-face interviewing methods, and has a relatively high response rate, with the final response rates for the Sample Child component in 2022 and 2023 being 45.8% and 44.9%.[13, 14] We combined two years of NHIS data to improve the accuracy of estimates and increase the sample size for young children.

Comparing NIS-Child estimates to those based on the NHIS enables estimation of nonresponse error. If nonresponse error is minimal in the NHIS, then the comparison to the NIS-Child can be taken as a measure of nonresponse error in the NIS-Child. To ensure comparability with the population covered by the NIS-Child, we examine NHIS children who are in the corresponding age range and have a working cell-phone in the family.

While the NHIS does not collect vaccination data for children and thus does not produce direct estimates of vaccination coverage, we can compare indirect vaccination coverage estimates derived from the NHIS to the direct estimates of vaccination coverage derived from the NIS-Child. We take advantage of the range of variables that are common to both the 2023 NIS-Child and the 2022 and 2023 NHIS and produce estimates of nonresponse error for four vaccination coverage estimates: 4+ DTaP, 1+ MMR, Hep B birth dose, and the combined 7-vaccine series. Specifically, we estimate logistic regression models for vaccination statuses in the NIS-Child employing variables common to both surveys as independent variables and then use these models to produce multiple imputations of vaccination statuses for the NHIS case set, using the 2022 and 2023 NHIS Public Use Files (PUFs).[15] Then, we estimate vaccination coverage using the NHIS data after pooling the survey-weighted estimates across the multiply-imputed datasets. We treat the estimates based on imputations of the NHIS as the true vaccination coverage among the population covered by the NIS-Child sampling frame and estimate nonresponse error in the NIS-Child estimates by taking the difference between the NIS-Child and the pooled NHIS estimates.

We note that a common method for nonresponse bias analysis is to apply modeling, including logistic regression, to develop predictions or imputations of key variables among nonrespondents to develop full-response key estimates and compare to estimates based on respondents alone (U.S. Census Bureau, 2019). The method we employ in this study extends this concept to applying predictions or imputations to a reference survey. The 2009 report of the NCES/NISS Task Force on Nonresponse Bias Analysis recommends producing multiple imputations when employing such methods to account for imputation modeling variance in estimates of nonresponse bias.

[13] See p. 26 of https://ftp.cdc.gov/pub/Health_Statistics/NCHS/Dataset_Documentation/NHIS/2022/srvydesc-508.pdf
[14] See p. 29 of https://ftp.cdc.gov/pub/Health_Statistics/NCHS/Dataset_Documentation/NHIS/2023/srvydesc-508.pdf
[15] https://www.cdc.gov/nchs/nhis/data-questionnaires-documentation.htm

Table 3.5 compares the estimates of vaccination coverage based on the NHIS imputed data and NIS-Child provider-reported data. Two NIS-Child estimates are presented, one based on applying design weights and another based on applying the final weights that reflect adjustments for noncoverage and nonresponse. Presenting both sets of estimates shows how the NIS-Child estimates, before and after weighting adjustments that account for nonresponse, compare to the estimates based on NHIS imputations. The table further shows the percentage point difference between the NHIS-based estimate and the NIS-Child estimate based on design weights. It includes a t-statistic for testing the difference between the two vaccination coverage estimates, accounting for the uncertainty in both estimates.

Table 3.5: Estimates of NIS-Child Vaccination Coverage Estimate (%) Nonresponse Error, 2023, Derived from Estimates Based on 2022 and 2023 National Health Interview Survey (NHIS) Imputations

Estimates of Vaccination Coverage and Differences by Data Source and Weighting Method	4+ DTaP	1+ MMR	Hep B Birth Dose	Combined 7-Vaccine Series
(a) Estimate Based on NHIS Imputations	83.0	91.2	80.3	71.0
Standard Error	1.5	1.3	1.5	1.9
(b) NIS-Child Estimate (Design Weighted)	83.4	90.7	77.4	71.0
Standard Error	0.7	0.6	1.0	0.9
(c) NIS-Child Estimate (Final Weighted)	82.2	91.1	79.1	69.5
Standard Error	0.6	0.5	0.6	0.7
(d) Difference, (b) - (a)	0.4	-0.5	-2.8	-0.1
Standard Error of Difference	1.6	1.5	1.8	2.1
t-statistic	0.28	-0.35	-1.59	-0.03
p-value (2-sided)	0.78	0.72	0.11	0.97
(d) Difference, (c) - (a)	-0.7	-0.1	-1.1	-1.5
Standard Error of Difference	1.6	1.4	1.6	2.0
t-statistic	-0.46	-0.07	-0.72	-0.74
p-value (2-sided)	0.64	0.94	0.47	0.46

The NIS-Child estimates based on design weights are 0.4 percentage points higher than the estimate based on NHIS imputations for 4+ DTaP, 0.5 percentage points lower for 1+ MMR, 2.8 percentage points lower for Hep B birth dose, and 0.1 percentage point lower for the combined 7-vaccine series. While none of these differences are statistically significant, the Hep B birth dose difference is larger with a p-value of 0.11 for the test of difference being significantly different from 0. For the TSE model, we base our estimates of $\hat{\mu}_{2A}$ and $\hat{\sigma}_{2A}$ on these differences by taking (b) - (a) as the difference in estimates between a full-response dataset and the respondent set. We then use our estimate of $\hat{p}_{2A}$ above to derive $\hat{\mu}_{2A}$ as an estimate of the vaccination coverage among nonrespondents.

When applying final weights, the NIS-Child estimates are 0.7 percentage points lower than the estimate based on NHIS imputations for 4+ DTaP, 0.1 percentage points lower for 1+ MMR, 1.1 percentage points lower for Hep B birth dose, and 1.5 percentage points lower for the combined 7-vaccine series. None of these differences are statistically significant, and using final weights reduces the difference for Hep B birth dose. Overall, when viewing the estimates based on NHIS imputations as the full-response estimate of vaccination coverage, these results indicate that nonresponse error in these four NIS-Child estimates is modest, although the standard errors reflect uncertainty in our knowledge about the extent of nonresponse error.

One caveat is that the results depend on the fit of the models used for imputation and the assumption that the conditional distributions of the NHIS case and NIS-Child case vaccination statuses on the model variables are the same. The goodness-of-fit for the imputation models is not particularly strong (pseudo-$R^2 \leq 0.10$), resulting in fairly large standard errors for estimates based on NHIS imputations. This fact further illuminates the extent of uncertainty in our estimates of nonresponse error.

NIS-Child Item Nonresponse Rates

Thus far, this subsection has focused on assessing error in vaccination coverage rates due to unit nonresponse to NIS-Child. Here, we present item nonresponse rates for the household interview portion of the survey in Table 3.6, focusing on socio-demographic variables used in raking procedures for survey weighting. The item nonresponse rates in this table for variables used in survey weighting are low and less than five percent. This indicates low risk for impact on vaccination coverage estimates. Table 3.6 also includes family income, which is not used in survey weighting. Exact family income has a higher item nonresponse rate of 22.4%, but the majority of exact-income nonrespondents completed the follow-up cascade of income questions, which establish tight income bounds.

Table 3.6: Item Nonresponse Rates, NIS-Child Household Interview, United States, 2023

Variable	2023 Item Nonresponse Rate (Percent)*
Sex of child	0.4
Hispanic ethnicity of child	0.5
Race of child	4.7
Education of mother	1.0
Household phone status – landline only, cell-phone only, or landline- and cell-phone	0.3
Family income	22.4
Exact income not reported but income cascade completed	14.8
Exact income not reported and income cascade not completed	7.6

* Unweighted percent of "don't know" or "refused" responses among respondents asked the question. For race of child, percent also includes "other" responses that could not be back-coded into one or more of the race categories presented in the questionnaire. Rates presented in this table exclude the U.S. territories, Guam, Puerto Rico, and U.S. Virgin Islands.

3.3 Measurement Error

In this subsection, we assess provider under-reporting of the child's vaccination status. Throughout, we assume that if a provider reported a vaccination, it was given. We consider a child to have under-reported vaccination status if the child is truly up-to-date for the vaccine but the child is classified as not up-to-date based on the vaccination history reported by the child's provider(s). That is, children with under-reporting are up-to-date but are reported as not up-to-date; children without under-reporting either are both truly up-to-date and reported as up-to-date; or are truly not up-to-date and are reported as not up-to-date. Note that all children with under-reporting are, by definition, truly up-to-date.

To assess under-reporting in provider-reported vaccination histories, we rely on projects sponsored by CDC in which the 2017 and 2019 NIS-Child samples of children in selected states were matched to the state or local IIS. For each of these projects, the NIS-Child interview requested parental consent to contact both the child's vaccination providers and the local IIS. Children for whom consent was obtained were matched to their respective IIS databases. Then, for the set of matched children, we compared each child's vaccination status based on the provider report(s) to the child's vaccination status when both the provider(s) and the IIS reports are included in a combined vaccination history.
We take the combined history to offer the best available information about the child's true vaccination status, and we view the NIS-Child provider-reported history to be possibly subject to an under-reporting mechanism. This mechanism, often called under-ascertainment, can arise if some but not all the child's providers were nominated by the household respondent, if the nominated provider's contact information was reported incorrectly by the household respondent, if not all nominated providers responded to mailed Immunization History Questionnaires (IHQs), or if respondent providers did not have or report complete vaccination records.

From these studies, we estimated the proportion of children with under-reported vaccination status. For each given vaccine, we determined the subset of matched children for whom measured vaccination status (i.e., up-to-date or not up-to-date) from the combined (provider and IIS) vaccination history was equivalent to the vaccination status from the NIS-Child provider-reported vaccination history alone. Then we made the reasonable assumption that equivalence of the measured vaccination statuses is a sign of accurate reporting in the NIS-Child Provider Record Check. In other words, if the IIS did not add information about vaccination status beyond that already embodied within the NIS-Child provider-reported data, then we took the NIS-Child data to be accurate (not under-reported). If the child was up-to-date based on the combined (provider and IIS) vaccination history but not up-to-date based on the NIS-Child vaccination history alone, then we classified the child as having their vaccination status under-reported in the NIS-Child. Of the children with adequate NIS-Child provider data that were located in the IIS and had two or more doses in the IIS, we estimated the NIS-Child under-reporting rate for the vaccine as the design-weighted proportion classified as having under-reported vaccination status for the vaccine.

Recent sources of information for assessing under-reporting in the NIS-Child are the match projects completed in 2017 and 2019. In 2017, match projects were conducted in 21 jurisdictions: Arkansas, Connecticut, Georgia, Idaho, Iowa, Louisiana, Maine, Michigan, Mississippi, Nevada, New Mexico, New York City, North Carolina, North Dakota, Oklahoma, Rhode Island, South Dakota, Vermont, Washington, Wisconsin, and Wyoming. In 2019, match projects were conducted in 7 jurisdictions: Arkansas, Kansas, Louisiana, Missouri, Nevada, New York City, and Vermont. Because only a subset of jurisdictions participated in match projects, we estimated the standard error of the under-reporting rate by treating each selected jurisdiction as a cluster sampled from the population of jurisdictions.

Table 3.7 presents the estimated under-reporting error for the vaccines and vaccine series under study.

Table 3.7: Estimated Under-Reporting Error by Vaccine Series: NIS-Child, United States, 2017 and 2019

Vaccine	Under-Reporting Error	
	Estimate (percentage points)	Standard Error (percentage points)
Combined 7-vaccine series	8.3	0.57
4+ DTaP	4.7	0.38
3+ Polio	2.1	0.25
1+ MMR	2.7	0.28
Hib-FS	5.0	0.46
3+ Hep B*	2.8	0.31
Hep B birth dose	3.3	0.31
1+ Var	2.5	0.27
4+ PCV	3.7	0.35

Note: National-level under-reporting in NIS-Child provider-reported vaccination status was estimated using data from the 2017 and 2019 IIS-NIS Match Projects. Among children with adequate provider data found in the IIS database with two or more IIS doses, those classified as up-to-date based on the combined IIS-NIS vaccination history but not up-to-date based on the NIS-Child vaccination history alone were considered to have under-reported NIS-Child vaccination status.
*Estimates for 3+ Hep B do not incorporate data from North Dakota, as data were not available.

3.4 Sampling Error

Sampling error is the error arising because we do not observe the entire population, only a random sample of the population. Table 3.8 presents estimated vaccination coverage and their standard errors for 2023 NIS-Child, using the Taylor series method. The standard errors are calculated first for the design-weighted vaccination coverage estimate and then for the final-weighted vaccination coverage estimate. The design weights reflect the sample design but do not include adjustments for sampling-frame noncoverage, nonresponse, or calibration to

population control totals. Final weights are the design weights adjusted for noncoverage, nonresponse, and calibration to population control totals.

The national-level standard errors are estimated to be small, ranging from approximately 0.4 to about 0.7 percentage points for final-weighted estimates.

Table 3.8: Vaccination Coverage Estimates and Standard Errors Using Design Weights and Final Weights: NIS-Child, United States, 2023

Vaccine	Design Weighted		Final Weighted	
	Estimate (%)	Standard Error (percentage points)	Estimate (%)	Standard Error (percentage points)
Combined 7-vaccine series	71.0	0.89	69.5	0.72
4+ DTaP	83.4	0.71	82.2	0.63
3+ Polio	91.5	0.61	91.9	0.44
1+ MMR	90.7	0.62	91.1	0.46
Hib-FS	78.7	0.84	78.2	0.64
3+ Hep B	90.6	0.63	91.3	0.47
Hep B birth dose	77.4	1.00	79.1	0.60
1+ Var	90.7	0.61	90.9	0.47
4+ PCV	83.2	0.71	81.4	0.66

Note: Excludes U.S. territory samples in Guam, Puerto Rico, and U.S. Virgin Islands.

3.5 Total Survey Error Distribution

This subsection consolidates the component assessments of sampling-frame coverage error (Section 3.1), nonresponse error (Section 3.2), measurement error (Section 3.3), and sampling error (Section 3.4), resulting in an assessment of the total survey error in the 2023 NIS-Child estimated vaccination coverage. We focus the overall assessment on four estimates of vaccination coverage corresponding to 4+ DTaP, 1+ MMR, Hep B birth dose, and the combined 7-vaccine series. The subsection culminates with the presentation of total survey error distributions, constructed using the methodology described in Molinari, Wolter, Skalland, et al. (2011) and Wolter, Pineau, Skalland, et al. (2017). For each estimate, we review the distribution of total survey error across 10,000 Monte Carlo simulations, treating the mean of the distribution as the point estimate of total error and the interval between the 2.5th percentile and the 97.5th percentile as the 95% credible interval of total error.

At the beginning of Part II of this report, we presented our TSE model and its seven parameters. Table 3.9 contains the values of these seven parameters and their standard errors we used in the model for TSE in the 2023 NIS-Child. These values arise from the analyses described in

Sections 3.2 through 3.4 above.[16] We assume the logit transformations of the inputs are normally distributed and independent (i.e., no covariance between inputs).

Table 3.9: Total Survey Error Model Inputs by Stages: NIS-Child, United States, 2023

Parameter	4+ DTaP	1+ MMR	Hep B Birth Dose	Combined 7-Vaccine Series
Stage 1: Sampling-Frame Coverage Error (LLO and Phoneless Households)				
$\hat{p}_{1A}$	2.0%	2.0%	2.0%	2.0%
$\hat{\sigma}_{p1A}$	0.4%	0.4%	0.4%	0.4%
$\hat{\mu}_{1A}$	73.5%	87.0%	77.6%	66.0%
$\hat{\sigma}_{\mu 1A}$	7.5%	5.2%	5.5%	7.6%
Stage 2: Nonresponse Error				
$\hat{p}_{2A}$	97.6%	97.6%	97.6%	97.6%
$\hat{\sigma}_{p2A}$	0.4%	0.4%	0.4%	0.4%
$\hat{\mu}_{2A}$	87.6%	93.3%	83.6%	79.3%
$\hat{\sigma}_{\mu 2A}$	1.5%	1.4%	1.5%	2.0%
Stage 3: Measurement Error				
$\hat{p}_{3A}$	4.7%	2.7%	3.3%	8.3%
$\hat{\sigma}_{p3A}$	0.4%	0.3%	0.3%	0.6%
$\hat{\mu}_{3A}$	100.0%	100.0%	100.0%	100.0%
$\hat{\sigma}_{\mu 3A}$	0.0%	0.0%	0.0%	0.0%
$\hat{\mu}_{3}$	87.5%	93.1%	80.1%	77.4%
$\hat{\sigma}_{\mu 3}$	0.8%	0.7%	1.1%	1.1%

Table 3.10 presents the total survey error distribution and component error distributions based on 10,000 Monte Carlo draws from the input parameter distributions and application of the TSE model. The means of the estimated TSE distributions are -5.1, -2.0, -4.3, and -9.4 percentage points for 4+ DTaP, 1+ MMR, Hep B birth dose, and the combined 7-vaccine series, respectively, suggesting that the 2023 NIS-Child may have underestimated the true vaccination coverage. The largest estimated component of error in absolute value for all four vaccine series is measurement error, i.e., provider under-reporting error. Hep B birth dose has a modest estimate of mean nonresponse error of -2.8 percentage points, but the estimate is uncertain as reflected by the 95% credible interval.

[16] $\hat{\mu}_{1A}$ and $\hat{\mu}_{2A}$, which were estimated based on the NHIS-PRC and models built from NIS-Child vaccination data, respectively, have been adjusted upwards to account for provider under-reporting error in those surveys, assuming the same level of under-reporting error as was estimated in Section 3.4.

Table 3.10: Mean and 95% Credible Interval for the Estimated TSE Distribution and Component Error Distributions: NIS-Child, United States, 2023

Vaccine or Series	Component	Mean TSE (percentage points)	95% Credible Interval (percentage points)
4+ DTaP	TSE (final weighted)	-5.1	(-7.7, -1.9)*
	TSE (design weighted)	-3.9	(-6.5, -0.8)*
	Noncoverage error	0.3	(0.0, 0.7)
	Nonresponse error	0.5	(-2.7, 4.0)
	Measurement error	-4.7	(-6.1, -3.1)*
	Sampling error	0.1	(-1.6, 1.8)
1+ MMR	TSE (final weighted)	-2.0	(-4.3, 1.1)
	TSE (design weighted)	-2.4	(-4.7, 0.7)
	Noncoverage error	0.1	(0.0, 0.4)
	Nonresponse error	0.1	(-2.7, 3.4)
	Measurement error	-2.6	(-3.8, -1.2)*
	Sampling error	0.0	(-1.3, 1.6)
Hep B Birth Dose	TSE (final weighted)	-4.3	(-6.9, -1.2)*
	TSE (design weighted)	-5.9	(-8.6, -2.8)*
	Noncoverage error	0.1	(-0.1, 0.4)
	Nonresponse error	-2.8	(-6.2, 0.9)
	Measurement error	-3.3	(-5.2, -1.2)*
	Sampling error	0.0	(-2.0, 2.1)
Combined 7-Vaccine Series	TSE (final weighted)	-9.4	(-13.0, -5.4)*
	TSE (design weighted)	-8.0	(-11.6, -4.0)*
	Noncoverage error	0.3	(0.0, 0.7)
	Nonresponse error	-0.0	(-4.2, 4.5)
	Measurement error	-8.3	(-10.1, -6.2)*
	Sampling error	0.0	(-2.0, 2.3)

* 95% credible interval does not include 0.

3.6 Assessment of the Change in Bias Using the Bridging Cohort Method

The previous subsection assessed TSE in 2023 NIS-Child estimated vaccination coverage, while the current subsection assesses the change in TSE between 2022 and 2023. Change is measured using the bridging cohort method introduced by Yankey et al. (2015). Each survey quarter includes children born in 20 monthly birth cohorts. Every pair of adjacent survey quarters spans 23 monthly birth cohorts, of which 17 are in common and 6 are not in common. In turn, every survey year represents 29 monthly birth cohorts. Every pair of adjacent survey years spans 39 monthly birth cohorts, of which 17 are in common and 22 are not in common. We call the 17 common months the *bridging cohort*, and for 2022 and 2023, the bridging cohort extends from children born in January 2020 through children born in May 2021.

Consider a vaccination coverage estimate for the bridging cohort as of a given child age, such as 19 months or 24 months. Two estimates are possible, one using the sample of children in the bridging cohort within the 2022 NIS-Child sample and the second using the corresponding sample of children within the 2023 NIS-Child sample. Ideally, the two estimators should exhibit the same expected value. A large difference between the two estimates may signal a change in the expectation from one survey year to the next, which could result from a change in the distribution of sampling-frame coverage error, nonresponse error, or measurement error. Differences may also result simply from the effects of random sampling error.

Table 3.11 presents the two estimates of vaccination coverage for children as of 19 months of age for the 2022-2023 bridging cohort. Estimates and standard errors are presented for several vaccines and vaccine series and for the proportion of unvaccinated children in the population. The columns on the right side of the table reveal the differences between the 2023 and 2022 estimates for the bridging cohort, the estimated standard errors of the differences, and the *p*-values associated with statistical tests of the hypothesis that the expectations of the two estimators are the same. For example, for the 3+ DTaP vaccination coverage estimate by 19 months, the difference is -2.2 percentage points with a standard error of 0.8; given the *p*-value of 0.005, the hypothesis of no change in expectation is rejected.

Nearly all the vaccine series examined show that for the 2022-2023 bridging cohort, the 2023 sample has significantly lower vaccination coverage estimates than 2022. Out of eighteen vaccine series studied, five have statistically significant differences at the 1% level. An additional five have statistically significant differences at the 5% level. These findings suggest a change in expectation of total survey error between 2022 and 2023.

Table 3.11: Difference between the Estimates* for the Bridging Birth Cohort† by Age 19 Months: NIS-Child, United States, 2022 vs. 2023

	2022		2023		Difference		
Description	Est	Std Error	Est	Std Error	Est	Std Error	p-value for Test of No Difference
3+ DTaP/DTP/DT by 19 months	92.9	0.48	90.7	0.63	-2.2	0.79	0.005
4+ DTaP/DTP/DT by 19 months	71.7	0.93	71.0	0.92	-0.7	1.31	0.616
3+ Polio by 19 months	92.2	0.50	90.2	0.63	-2.0	0.81	0.014
1+ MMR by 19 months	88.9	0.60	86.9	0.75	-2.0	0.96	0.036
3+ Hib by 19 months	89.9	0.55	88.0	0.67	-1.9	0.87	0.032
Hib-PS by 19 months	92.2	0.50	89.9	0.65	-2.3	0.82	0.005
Hib-FS by 19 months	73.1	0.88	72.3	0.87	-0.9	1.24	0.479
1+ Var by 19 months, excluding shots before 12 months	88.4	0.59	85.6	0.77	-2.8	0.97	0.004
3+ Hep B by 19 months	91.2	0.56	89.0	0.71	-2.2	0.91	0.015
3+ PCV by 19 months	91.9	0.56	89.5	0.65	-2.4	0.86	0.005
4+ PCV by 19 months	78.6	0.84	77.0	0.88	-1.6	1.21	0.185
1+ Hepatitis A by 19 months	84.9	0.67	81.9	0.81	-3.0	1.05	0.005
2+ Hepatitis A by 19 months	29.0	0.84	27.6	0.89	-1.4	1.23	0.258
2+ or 3+ Rotavirus depending on type by 19 months	77.9	0.83	74.7	0.92	-3.1	1.24	0.011
Combined 7-vaccine series by 19 months	60.7	0.97	60.9	0.98	0.2	1.38	0.894
Hep B birth dose	80.5	0.79	79.5	0.77	-1.0	1.11	0.348
Unvaccinated children	0.9	0.11	1.1	0.14	0.2	0.18	0.274
2+ Flu by 19 months, doses at least 24 days apart	56.5	0.97	54.8	0.99	-1.6	1.39	0.236

* National-level estimates computed among children with adequate provider data, excluding children from U.S. territories, Guam, Puerto Rico, and U.S. Virgin Islands.

† The bridging birth cohort used for this analysis of the 2022 and 2023 NIS-Child includes children born between January 2020 and May 2021.

To investigate the decline in vaccination coverage estimates for the bridging birth cohort between the 2022 and 2023 samples, we considered the impact of three differences between the 2022 and 2023 NIS-Child: (1) the early close of the Provider Record Check (PRC) data collection for the 2023 sample, (2) a change beginning in Q3/2022 to the format of the IHQ used by providers to report vaccinations in the PRC, and (3) a small change to weighting procedures implemented in 2023.

Impact of Early Close of the PRC

NIS-Child vaccination coverage estimates are based on vaccination histories reported in the PRC. Data collection for the NIS-Child PRC was closed two months earlier for the 2023 sample than for the 2022 sample. This resulted in a lower PRC return rate[17] and a higher proportion of children with adequate provider data having partial provider data[18] in 2023 than in 2022, as shown in Table 3.12.

Table 3.12: Provider Record Check (PRC) Return Rates and Percent of Children with Partial Provider Data: NIS-Child, United States, 2022 vs. 2023

Measure	2022	2023
PRC return rate*	91%	85%
Percent of children with adequate provider data who have partial provider data†	13%	16%

* The PRC return rate is the number of child-provider pairs for which an Immunization History Questionnaire (IHQ) was mailed divided by the number for which PRC data were returned.

† A child with adequate provider data has partial provider data if the number of providers that returned vaccination data for the child is less than the number of vaccination providers nominated for the child by the respondent in the household interview.

If a child with adequate provider data has an incomplete vaccination history reported in the PRC due to only partial provider data being returned, then that child could be classified as not vaccinated for a particular vaccine or vaccine series even if the child is truly vaccinated. Table 3.13 presents the same vaccination coverage estimates for the bridging birth cohort as were presented in Table 3.11, but with the estimates in Table 3.13 based only on children with "complete" provider data, i.e., on children for whom all providers nominated during the household interview returned vaccination data in the PRC. Even when limiting the analysis to children with complete provider data, the differences in vaccination coverage estimates for the bridging birth cohort between the 2022 and 2023 samples are still present, and the magnitudes of the differences are similar to when all children, including those with partial provider data, are included. This suggests that the change in mean TSE between the 2022 and 2023 samples as measured using the bridging birth cohort method is likely not due to the higher rate of children with partial provider data in the 2023 sample.

[17] The PRC return rate is the number of child-provider pairs for which a PRC IHQ was mailed divided by the number for which PRC data were returned.

[18] A child with adequate provider data has partial provider data if the number of providers that returned vaccination data for the child is less than the number of vaccination providers nominated for the child by the respondent in the household interview.

Table 3.13: Difference between Vaccination Coverage Estimates* for the Bridging Birth Cohort for Children with Complete Provider Data†: NIS-Child, United States, 2022 vs. 2023

	2022		2023		Difference		
Description	Est	Std Error	Est	Std Error	Est	Std Error	p-value for Test of No Difference
3+ DTaP/DTP/DT by 19 months	94.7	0.44	92.5	0.60	-2.2	0.74	0.003
4+ DTaP/DTP/DT by 19 months	73.7	0.98	72.5	0.95	-1.2	1.37	0.388
3+ Polio by 19 months	93.9	0.47	92.0	0.61	-1.9	0.77	0.012
1+ MMR by 19 months	90.9	0.59	88.6	0.71	-2.3	0.92	0.012
3+ Hib by 19 months	91.6	0.53	89.4	0.70	-2.2	0.88	0.012
Hib-PS by 19 months	94.1	0.46	91.4	0.68	-2.7	0.82	0.001
Hib-FS by 19 months	74.8	0.94	73.8	0.93	-1.0	1.32	0.461
1+ Var by 19 months, excluding shots before 12 months	90.3	0.58	87.3	0.75	-3.0	0.95	0.002
3+ Hep B by 19 months	93.0	0.55	91.0	0.63	-2.0	0.84	0.016
3+ PCV by 19 months	93.5	0.56	90.9	0.67	-2.6	0.87	0.003
4+ PCV by 19 months	80.2	0.89	79.1	0.88	-1.1	1.25	0.387
1+ Hepatitis A by 19 months	87.0	0.66	83.8	0.78	-3.2	1.02	0.002
2+ Hepatitis A by 19 months	29.9	0.92	28.0	0.95	-1.9	1.33	0.159
2+ or 3+ Rotavirus depending on type by 19 months	79.8	0.88	76.4	0.95	-3.4	1.29	0.009
Combined 7-vaccine series by 19 months	62.6	1.05	62.5	1.03	0.0	1.47	0.976
Hep B birth dose	81.0	0.86	80.4	0.82	-0.6	1.19	0.628
Unvaccinated children	0.5	0.10	0.8	0.11	0.2	0.15	0.129
2+ Flu by 19 months, doses at least 24 days apart	57.6	1.05	55.2	1.06	-2.4	1.49	0.103

* Estimates were computed among children with complete provider data, excluding U.S. territories Guam, Puerto Rico, and U.S. Virgin Islands.

† The bridging birth cohort used for this analysis of the 2022 and 2023 NIS-Child includes children born between January 2020 and May 2021. A child has complete provider data if the number of providers that returned vaccination data for the child equals the number of vaccination providers nominated for the child by the respondent in the household interview.

Impact of Change in IHQ Format

Most vaccination providers report vaccination histories for the child either by returning a completed IHQ form or by returning the portion of a child's medical record showing the vaccinations the child has received. The IHQ form contains a "shot grid" listing each of the vaccines and asking the provider to report the dates and types of vaccinations the child has received. Prior to Q3/2022, the shot grid was presented on a single page of the IHQ but beginning in Q3/2022 when the COVID vaccine was added, the shot grid was split across two pages of the IHQ, with the DTaP, Polio, Hib, and Hepatitis B vaccines on one page and the remainder of the vaccines on a second page.[19] This change resulted in a small number of

[19] The shot grid version presented on a single page is available from https://www.cdc.gov/vaccines/imz-managers/nis/downloads/NIS-Child-IHQ-QI2021.pdf. The shot grid version with two pages is available from https://www.cdc.gov/vaccines/imz-managers/nis/downloads/NIS-Child-IHQ-Q2-2024.pdf.

providers neglecting to complete the first page of the shot grid when filling out the IHQ, which led to some children's vaccination histories missing DTaP, Polio, Hib, and Hepatitis B doses. However, because the missingness was limited to providers returning IHQs (not medical records), and because the number of providers failing to complete the first page of the shot grid was small, the impact of the missing doses on vaccination coverage rate estimates was limited. Moreover, because the change to the IHQ was made in Q3/2022, the change impacted both the 2022 and the 2023 estimates, not just the 2023 estimates. We estimate that this change can explain at most 0.5 percentage points of the decline in vaccination coverage rate estimates between the 2022 and 2023 samples for DTaP, Polio, Hib, and Hepatitis B. This change would not have impacted estimates for the other vaccines.

Impact of Change to NIS-Child Weighting Procedures

As described in the NIS-Child Data User's Guide (CDC, 2023), NIS-Child weights are calibrated to external demographic population control totals within each geographic estimation area. One of the demographic dimensions in the calibration is mother's education. Prior to 2023, NIS-Child weights were calibrated to control totals for two categories of mother's education: (1) High school or less and (2) More than high school. To better align the NIS-Child and NIS-Teen weighting procedures, beginning in 2023 NIS-Child weights are calibrated to control totals for three categories of mother's education: (1) Less than high school, (2) High school, and (3) More than high school. To evaluate the impact of this change, an alternative set of NIS-Child weights was produced for the 2023 sample that utilized the pre-2023 methodology, i.e., that used only the (1) High school or less and (2) More than high school categories when calibrating weights to control totals for mother's education. The difference in vaccination coverage estimates between the two weighting approaches is negligible, with the largest difference for national-level estimates being 0.1 percentage points. Therefore, the change in weighting procedure cannot account for the differences in estimates between the 2022 and 2023 samples for the bridging birth cohort.

In conclusion, the bridging birth cohort analysis suggests that the NIS-Child may have experienced a change in mean TSE between 2022 and 2023, with 2023 estimates being lower than 2022 estimates for the same bridging birth cohort. Subsequent investigations found that this change cannot be fully explained by known changes in NIS-Child methodology: the early close of the NIS-Child PRC data collection, the change in IHQ design, or the change in weighting procedures. We found no additional evidence of error or change in methodological procedures that might explain the bridging birth cohort results.

4. Summary

We profiled the sources of error in 2023 NIS-Child statistics at the national level (excluding U.S. territories Guam, Puerto Rico, and U.S. Virgin Islands) for children aged 19 to 35 months. We compared NIS-Child statistics to corresponding values from benchmark surveys and other external sources (Part I) and assessed component and total error in vaccination coverage estimates through a series of specialized evaluation studies (Part II). Wherever possible, we used 2023 sources and studies to assess error in the 2023 NIS-Child. Where 2023 sources were not available, we reported information from prior year sources as the best information available for understanding error in the 2023 NIS-Child.

In Part I, we compared NIS-Child demographic distributions (child's age, child's sex, mother's race and ethnicity, mother's education, mother's age) to benchmark values derived from natality data supplied by the National Vital Statistics System. When using design weights that have not been calibrated to external population totals, demographic distributions as estimated in the survey are generally close to the population distributions. Before calibration of the weights to external population totals, the NIS-Child somewhat over-represented children whose mothers are college graduates, non-Hispanic White, or age 30 or greater. The survey somewhat under-represented children whose mothers are not college graduates, are Hispanic or non-Hispanic Black only, or age 20 to 29. When using the final weights that have been calibrated to external population totals, the differences between survey and population narrowed, but the 2023 NIS-Child still over-represented children whose mothers are college graduates or are age 30 or older.

We compared NIS-Child vaccination coverage estimates to IISAR vaccination coverage estimates and found that there is variation in the level of agreement between NIS-Child and IISAR vaccination coverage estimates. Further, we determined that the CPR is a reasonable correlate of the quality of the corresponding IIS database. We learned that the difference between NIS-Child and IISAR vaccination coverage estimates tends to decline as the CPR increases (i.e., as the quality of the IIS increases). The findings are consistent with the view that IIS and NIS vaccination coverage estimates are more closely aligned as the quality of the IIS increases. Differences may be due to missing data from state IIS and/or under-ascertainment by state IIS, or error in NIS-Child estimates.

We compared NIS-Child health insurance distributions to similar distributions produced by the ACS, CPS, and NHIS. The three surveys use somewhat different definitions of insurance status and different age ranges of children. Nevertheless, we found the three distributions to be broadly similar, but with some differences. The NIS-Child estimate of percent of children with any public insurance was higher than the corresponding estimates from ACS, CPS, and NHIS, and the NIS-Child estimate of the percent of children uninsured was lower than the estimates from the benchmark surveys.

We compared NIS-Child vaccination coverage estimates at the state level to corresponding estimates obtained from five state IIS in Iowa, Michigan, Oregon, Washington, and Wisconsin and one state immunization survey in Tennessee. We find reasonable levels of agreement for the comparisons in Oregon and in Tennessee, except for the Hib full-series and the combined 7-vaccine series estimates in Tennessee. NIS-Child vaccination coverage estimates tend be higher than IIS estimates from the other four state IIS.

In Part II of the report, we assessed NIS-Child with respect to sampling-frame coverage error, nonresponse error, measurement error, sampling error, and total survey error. We also assessed the change in total survey error from 2022 to 2023.

As the NIS-Child cell-phone RDD sampling frame fails to include the landline only and phoneless populations, we assessed vaccination coverage estimates in the former using data collected in the 2017 NIS-Child and in the latter using data collected in the 2012 NHIS-Provider Record Check. The vaccination coverage estimates in the population covered by the sampling frame were found to be higher than the vaccination coverage estimates in the uncovered population. Because the sampling-frame uncovered population is so small relative to the covered population, however, we found mean sampling-frame coverage error to be minimal, namely 0.3 percentage points or less, for all nine vaccines series studied.

We used the 2022 and 2023 NHIS in assessing nonresponse error in the 2023 NIS-Child. The NHIS does not offer direct estimates of vaccination coverage. Instead, we used a model-based technique to multiply impute NHIS vaccination status, and then compared the resulting NHIS vaccination coverage estimates (treated as estimates void of nonresponse error) to NIS-Child vaccination coverage estimates, with the difference treated as nonresponse error in the NIS-Child. Incorporating all sources of missing data, including (1) nonresolution of telephone numbers, (2) nonresponse to the screener, (3) failure to complete the interview, (4) non-consent to contact providers, and (5) nonresponse from providers, we estimated that for over 95% of the sample, the household failed to respond to the NIS-Child, the household responded but did not grant consent to obtain vaccination data from the child's vaccination providers, or consent was granted but an adequate provider-reported vaccination history for the child was not obtained. Despite this large percentage, we found mean nonresponse error in vaccination coverage estimates to be modest (2.8 percentage points in magnitude for Hep B birth dose and 0.5 percentage points or less for the other three vaccine series) and not statistically significant for any of the vaccine series examined.

We used 28 IIS-NIS match studies from 2017 and 2019 to assess measurement error, or under-ascertainment, in NIS-Child vaccination coverage estimates. In this work, the standard of truth for a given child is taken to be the synthesis of the NIS-Child and IIS vaccination histories. We found measurement error depressed observed vaccination coverage estimates by about two to eight percentage points. Under-ascertainment of a child's vaccination history may arise due to

the failure of the household respondent to nominate all of the child's vaccination providers, failure of the nominated vaccination providers to respond, or failure of the responding providers to report all of the vaccinations that the child has received.

We combined all the component errors and assessed the distribution of total error in the NIS-Child vaccination coverage estimates using a Monte Carlo technique. For the 4+ DTaP vaccination coverage estimate, we found the mean of the total survey error distribution to be -5.1 percentage points with a 95% credible interval of (-7.7, -1.9) percentage points. That is, the NIS-Child vaccination coverage estimate was on average about 5.1 percentage points too low. For the 1+ MMR vaccination coverage estimate, we found the mean of the TSE distribution to be -2.0 percentage points with a 95% credible interval of (-4.3, 1.1) percentage points that includes 0. For the estimate of Hep B birth dose vaccination coverage, the mean of the TSE distribution was -4.3 percentage points with a 95% credible interval of (-6.9, -1.2). Finally, for the combined 7-vaccine series, we found the mean of the TSE distribution to be -9.4 percentage points with a 95% credible interval of (-13.0, -5.4) percentage points. Again, under-ascertainment of the provider-reported vaccination history dominated total survey error, although the estimate of mean nonresponse error for Hep B birth dose was modest and not statistically different from 0. In general, estimates of nonresponse error have wider 95% credible intervals because those estimates have greater uncertainty than estimates of other error components.

Finally, we conducted a bridging cohort analysis to assess the possibility of a change in expected value between the 2022 and 2023 NIS-Child by comparing vaccination coverage estimates between the two survey years for children born during a 17-month period included for both survey years. In conducting comparisons for eighteen key vaccination coverage estimates, we found evidence of a change in bias with five estimates have statistically significant decreases at the 1% level between the 2022 and 2023 bridging birth cohorts and an additional five having statistically significant decreases at the 5% level. We reviewed evidence regarding the impact of three known factors on the changes in the bridging birth cohort estimates: (a) the early close of the NIS-Child PRC data collection in 2023, (b) the change in IHQ design, and (c) the change in weighting procedures. We found that none of these possibilities can fully explain the change in bias. While the change in the IHQ design explains some of the difference for specific vaccine series, but we have not been successful in identifying other methodological or environmental changes that would explain the residual difference.

Our results for the 2023 NIS-Child are subject to various limitations. The comparisons to benchmark distributions in Part I are flawed because the benchmark source usually uses somewhat different concepts or definitions than the NIS-Child. Our comparison of NIS-Child and IISAR vaccination coverage estimates is limited to the combined 7-vaccine series, and the findings may not apply to other vaccine series. Additionally, comparisons of NIS-Child estimates to vaccination coverage estimates from individual state surveys and state IIS could be impacted by missing vaccination data from the state data sources and/or differences in how vaccination

coverage was measured among data sources. In Part II, the results are based on input distributions for the component errors as estimated using our best available information from external sources and studies, but these inputs may not be accurate. While large-sample theory motivates our choice of the normal family of distributions, we have not validated this choice. Two key external sources of the information on component errors are the NHIS and state IIS. The NHIS is based on a smaller sample size than the NIS-Child, and its NHIS-Provider Record Check (used in the study of sampling-frame coverage error) is likely subject to many of the same measurement issues as the NIS-Child Provider Record Check. Further, the NHIS-Provider Record Check is subject to its own nonresponse and sampling-frame coverage errors. To study nonresponse error in the NIS-Child, we utilized imputed vaccination statuses in the NHIS rather than provider-reported statuses, because the NHIS-Provider Record Check was terminated in 2013. IIS may underestimate vaccination coverage to some extent (e.g., miss some resident children and some vaccine doses within included children), and completeness may vary substantially from one state or local area to the next. Our results are based on work with IIS in a subset of states that have conducted IIS-NIS match projects. Our results are also based on an assumption of independence of the component errors and this assumption might not be accurate. We conducted the TSE analysis for selected national-level vaccination coverage estimates, and the results do not necessarily extend to other vaccines, states or estimation areas, or socio-demographic domains.

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