

**National Immunization Survey-Child  
Error Profile for the 2024 NIS-Child**

**Centers for Disease Control and Prevention**

**National Center for Immunization  
and Respiratory Diseases**

**Presented by:**

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# Table of Contents

<b>1. Introduction</b> .....	<b>1</b>
<b>2. Part I: Comparisons of NIS-Child Data to External Sources</b> .....	<b>3</b>
2.1 Demographic Distributions: Comparison of NIS-Child Distributions to Population Distributions .....	3
2.2 Comparison of NIS-Child and IISAR Vaccination Coverage .....	6
What is IISAR?.....	6
Visual Comparison of the Vaccination Coverage Estimates .....	7
Child Participation Rate (CPR).....	8
Examination of the Difference Between NIS-Child and IISAR Vaccination Coverage Estimates.....	10
2.3 Comparison of Children by Type of Health Insurance Coverage .....	11
<b>3. Part II: Assessment of Total Survey Error for NIS-Child Vaccination Coverage Estimates</b> .....	<b>14</b>
3.1 Sampling-Frame Coverage Error.....	16
3.2 Nonresponse Error .....	20
Components of Nonresponse in NIS-Child.....	20
Weight Adjustment for Nonresponse Error .....	21
Assessment of Nonresponse Error.....	21
3.3 Measurement Error .....	24
3.4 Sampling Error .....	26
3.5 Total Survey Error Distribution.....	27
3.6 Assessment of the Change in Bias Using the Bridging Cohort Method .....	31
<b>4. Summary</b> .....	<b>34</b>
<b>References</b> .....	<b>38</b>

# List of Figures

- 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 at 24 Months: 56 Estimation Areas, Combined 2020-2021 Annual Birth Cohorts ..... 8
- Figure 2.2:** Scatterplot of Vaccination Coverage Estimates for Combined 7-Vaccine Series at 24 Months (in Percent) vs. Child Participation Rate (CPR, in Percent): Immunization Information Systems Annual Report (IISAR) Data for 56 Estimation Areas, Combined 2020-2021 Annual Birth Cohorts ..... 9
- Figure 2.3:** Scatterplot of the Difference in Vaccination Coverage Estimate (Percentage Points, National Immunization Survey-Child (NIS-Child) Minus Immunization Information Systems Annual Report (IISAR)) vs. Child Participation Rate (CPR, in Percent): 56 Estimation Areas, Combined 2020-2021 Annual Birth Cohorts ..... 11

# List of Tables

<b>Table 2.1:</b>	One-Way Demographic Distributions Among Children with Adequate Provider Data vs. Population Distributions: NIS-Child, 2024 .....	5
<b>Table 2.2:</b>	Comparison of Alternative Estimates of Health Insurance Coverage Among Children: NIS-Child, ACS, CPS ASEC, and NHIS for 2023 and NIS-Child, CPS ASEC and NHIS for 2024 .....	12
<b>Table 3.1:</b>	Percentage of Age-Eligible Children in the Population by Telephone Status by Year: NIS-Child, United States, 2012-2023 .....	17
<b>Table 3.2:</b>	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 .....	18
<b>Table 3.3:</b>	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 .....	19
<b>Table 3.4:</b>	Preliminary Assessment of Sampling-Frame Coverage Error and Mean True Vaccination Coverage (in Percent): NIS-Child, United States, 2024 ....	20
<b>Table 3.5:</b>	Estimates of NIS-Child Vaccination Coverage Estimate (%) Nonresponse Error, 2024, Derived from Estimates Based on 2023 and 2024 National Health Interview Survey (NHIS) Imputations .....	23
<b>Table 3.6:</b>	Estimated Under-Reporting Error by Vaccine Series: NIS-Child, United States, 2017 and 2019.....	26
<b>Table 3.7:</b>	Vaccination Coverage Estimates and Standard Errors Using Design Weights and Final Weights: NIS-Child, United States, 2024 .....	27
<b>Table 3.8:</b>	Total Survey Error Model Inputs by Stages: NIS-Child, United States, 2024	28
<b>Table 3.9:</b>	Mean and 95% Credible Interval for the Estimated TSE Distribution and Component Error Distributions: NIS-Child, United States, 2024.....	30
<b>Table 3.10:</b>	Difference Between the Estimates for the Bridging Birth Cohort by Age 19 Months: NIS-Child, United States, 2023 vs. 2024.....	32

# List of Abbreviations

<b>1+ Hep A:</b>	Hepatitis A vaccine, $\geq 1$ dose
<b>1+ MMR:</b>	Measles, mumps, and rubella vaccine, $\geq 1$ dose
<b>1+ VAR:</b>	Varicella vaccine, $\geq 1$ dose
<b>3+ Hep B:</b>	Hepatitis B vaccine, $\geq 3$ doses
<b>3+ Hib:</b>	<i>Haemophilus influenzae</i> type b conjugate vaccine, $\geq 3$ doses
<b>3+ Polio:</b>	Poliovirus vaccine, $\geq 3$ doses
<b>4+ DTaP:</b>	Diphtheria, tetanus, and acellular pertussis vaccine, $\geq 4$ doses
<b>4+ PCV:</b>	Pneumococcal conjugate vaccine, $\geq 4$ doses
<b>ACS:</b>	American Community Survey
<b>Combined 7-vaccine series:</b>	$\geq 4$ doses of DTaP, $\geq 3$ doses of poliovirus vaccine, $\geq 1$ dose of measles-containing vaccine, the full series of Hib, $\geq 3$ doses of Hep B, $\geq 1$ dose of varicella vaccine, and $\geq 4$ doses of PCV
<b>CPR:</b>	Child Participation Rate
<b>CPO:</b>	Cell-phone only
<b>CPS ASEC</b>	Current Population Survey Annual Social and Economic Supplement
<b>DTaP/DTP/DT:</b>	Diphtheria, tetanus, and acellular pertussis vaccine; diphtheria, tetanus, and pertussis vaccine; or diphtheria and tetanus vaccine
<b>Hep B birth dose:</b>	Hepatitis B dose within 3 days of birth
<b>Hib-FS:</b>	Full series of Hib, $\geq 3$ doses or $\geq 4$ doses depending on brand
<b>Hib-PS:</b>	Primary series of Hib, $\geq 2$ doses or $\geq 3$ doses depending on brand
<b>IHQ:</b>	Immunization History Questionnaire
<b>IIS:</b>	Immunization Information Systems
<b>IISAR:</b>	Immunization Information Systems Annual Report
<b>LLO:</b>	Landline only
<b>NHIS:</b>	National Health Interview Survey
<b>NIS-Child:</b>	National Immunization Survey-Child
<b>NIS-Teen:</b>	National Immunization Survey-Teen
<b>NVSS:</b>	National Vital Statistics System
<b>PRC:</b>	Provider Record Check
<b>PUF:</b>	Public Use File
<b>PUMS:</b>	Public Use Microdata Sample
<b>RDD:</b>	Random digit dial
<b>TSE:</b>	Total survey error

# 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 2024 National Immunization Survey-Child (NIS-Child) estimated vaccination coverage at the national level.<sup>1</sup> Recent reports discussed TSE for the 2023 National Immunization Survey-Child (NIS-Child) (NORC, 2024) and the 2024 NIS-Teen (NORC, 2025). 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 2024 NIS-Child and of the change in TSE between the 2023 and 2024 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.

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<sup>1</sup> In 2024, sample was fielded in two U.S. territories – Guam and Puerto Rico. The assessment of error in this report excludes these U.S. territories.

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

- diphtheria, tetanus, and acellular pertussis vaccine (DTaP),  $\geq 4$  doses (4+ DTaP);
- poliovirus vaccine,  $\geq 3$  doses (3+ Polio);
- measles, mumps, and rubella vaccine (MMR),  $\geq 1$  dose (1+ MMR);
- the full series of *Haemophilus influenzae* type b conjugate vaccine (Hib),  $\geq 3$  doses or  $\geq 4$  doses depending on brand (Hib-FS);<sup>2</sup>
- hepatitis B vaccine (Hep B),  $\geq 3$  doses (3+ Hep B);
- hepatitis B dose within 3 days of birth (Hep B birth dose);
- varicella vaccine,  $\geq 1$  dose (1+ VAR);
- pneumococcal conjugate vaccine (PCV),  $\geq 4$  doses (4+ PCV); and
- the combined 7-vaccine series ( $\geq 4$  doses of DTaP,  $\geq 3$  doses of poliovirus vaccine,  $\geq 1$  dose of measles-containing vaccine, the full series of Hib,  $\geq 3$  doses of Hep B,  $\geq 1$  dose of varicella vaccine, and  $\geq 4$  doses of PCV).

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

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<sup>2</sup> At times in this report, we also refer to the Hib primary series (Hib-PS) which is  $\geq 2$  doses or  $\geq 3$  doses depending on brand. We refer to  $\geq 3$  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. Finally, 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).

### 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 2024, we began by obtaining the counts of live births from the 2021 and 2022 NVSS natality data<sup>3</sup> for children that would be 19 to 35 months old as of July 1, 2024, 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, 2024. 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, 2024. These adjustments were applied separately by race and ethnicity group to account for differences in mortality and immigration across these groups.

We produced 2024 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 nonresponse and are not

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<sup>3</sup> <https://www.cdc.gov/nchs/nvss/nvss-restricted-data.htm>

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 2024 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 sex is close to the population distribution, even when using the design weights. For child's age, the design-weighted distribution differs somewhat from the population distribution with the largest differences being for 19- to 23-month old children (33.2 percent in survey, 30.1 percent in population) and for 24- to 29-month old children (29.0 percent in survey, 33.6 percent in population). 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 also differs somewhat from the population distribution, with the largest differences being for non-Hispanic Black only mothers (9.0 percent in survey, 14.1 percent in population), and non-Hispanic White only mothers (54.8 percent in survey, 50.5 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 (47.2 percent in survey, 35.5 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 (42.3 percent in survey, 35.5 percent in population) and under-represents children whose mothers have some college but not a four-year degree (20.0 percent in survey, 26.7 percent in population). The survey also over-represents children whose mothers are age 30 or older when the final weights are used (69.1 percent in survey, 64.4 percent in population) and under-represents children whose mothers are age 20 to 29 (30.1 percent in survey, 34.7 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 4.0 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, 2024

Demographic Domain	Population Distribution (%)	Design-Weighted Estimates		Final-Weighted Estimates*	
		Survey Distribution (%)	Difference (Survey – Population)	Survey Distribution (%)	Difference (Survey – Population)
<b>Child's Age</b>					
19-23 months	30.1	33.2 ± 2.7	3.1 ± 2.7	30.1 ± 1.2	0.0 ± 1.2
24-29 months	33.6	29.0 ± 1.7	-4.6 ± 1.7	33.6 ± 1.3	0.0 ± 1.3
30-35 months	36.3	37.8 ± 2.0	1.5 ± 2.0	36.3 ± 1.2	0.0 ± 1.2
<b>Child's Sex</b>					
Male	51.1	52.5 ± 2.2	1.4 ± 2.2	51.1 ± 1.3	0.0 ± 1.3
Female	48.9	47.5 ± 2.2	-1.4 ± 2.2	48.9 ± 1.3	0.0 ± 1.3
<b>Mother's Race and Ethnicity</b>					
Hispanic	25.7	25.8 ± 1.7	0.1 ± 1.7	25.5 ± 1.2	-0.2 ± 1.2
Non-Hispanic White only	50.5	54.8 ± 2.2	4.3 ± 2.2	49.6 ± 1.3	-0.9 ± 1.3
Non-Hispanic Black only	14.1	9.0 ± 0.9	-5.2 ± 0.9	13.5 ± 1.0	-0.6 ± 1.0
Non-Hispanic All Other	9.7	10.4 ± 0.9	0.8 ± 0.9	11.4 ± 0.9	1.8 ± 0.9
<b>Mother's Education</b>					
Less than high school	11.2	9.7 ± 1.1	-1.6 ± 1.1	11.0 ± 0.9	-0.3 ± 0.9
High school	26.5	21.6 ± 3.0	-4.9 ± 3.0	26.8 ± 1.3	0.3 ± 1.3
Some college	26.7	21.5 ± 1.4	-5.2 ± 1.4	20.0 ± 1.0	-6.8 ± 1.0
4-year college graduate	35.5	47.2 ± 2.2	11.7 ± 2.2	42.3 ± 1.3	6.8 ± 1.3
<b>Mother's Age</b>					
< 20 years	0.9	0.6 ± 0.2	-0.3 ± 0.2	0.9 ± 0.2	0.0 ± 0.2
20-29 years	34.7	28.1 ± 1.7	-6.6 ± 1.7	30.1 ± 1.3	-4.6 ± 1.3
>= 30 years	64.4	71.4 ± 1.7	7.0 ± 1.7	69.1 ± 1.3	4.7 ± 1.3

NOTE: Excludes U.S. territory samples in Guam and Puerto Rico. 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) estimates for the combined 2020-2021 annual birth cohorts.<sup>4</sup> The comparison is given for estimates of coverage with the combined 7-vaccine series at 2 years of age 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.<sup>5</sup> 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 describe available indicators of IIS<sup>6</sup> quality, including the child participation rate (CPR). We conclude by providing evidence that higher quality IIS, as indicated by the CPR, tend to have smaller differences between the combined 7-vaccine series 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, the District of Columbia, five cities (Chicago, 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.

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<sup>4</sup> <https://www.cdc.gov/iis/about/>

<sup>5</sup> Agreement between the two sources does not necessarily mean both sources are accurate. If the two sources have similarly sized errors in the same direction, there can be agreement without accuracy.

<sup>6</sup> 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/>

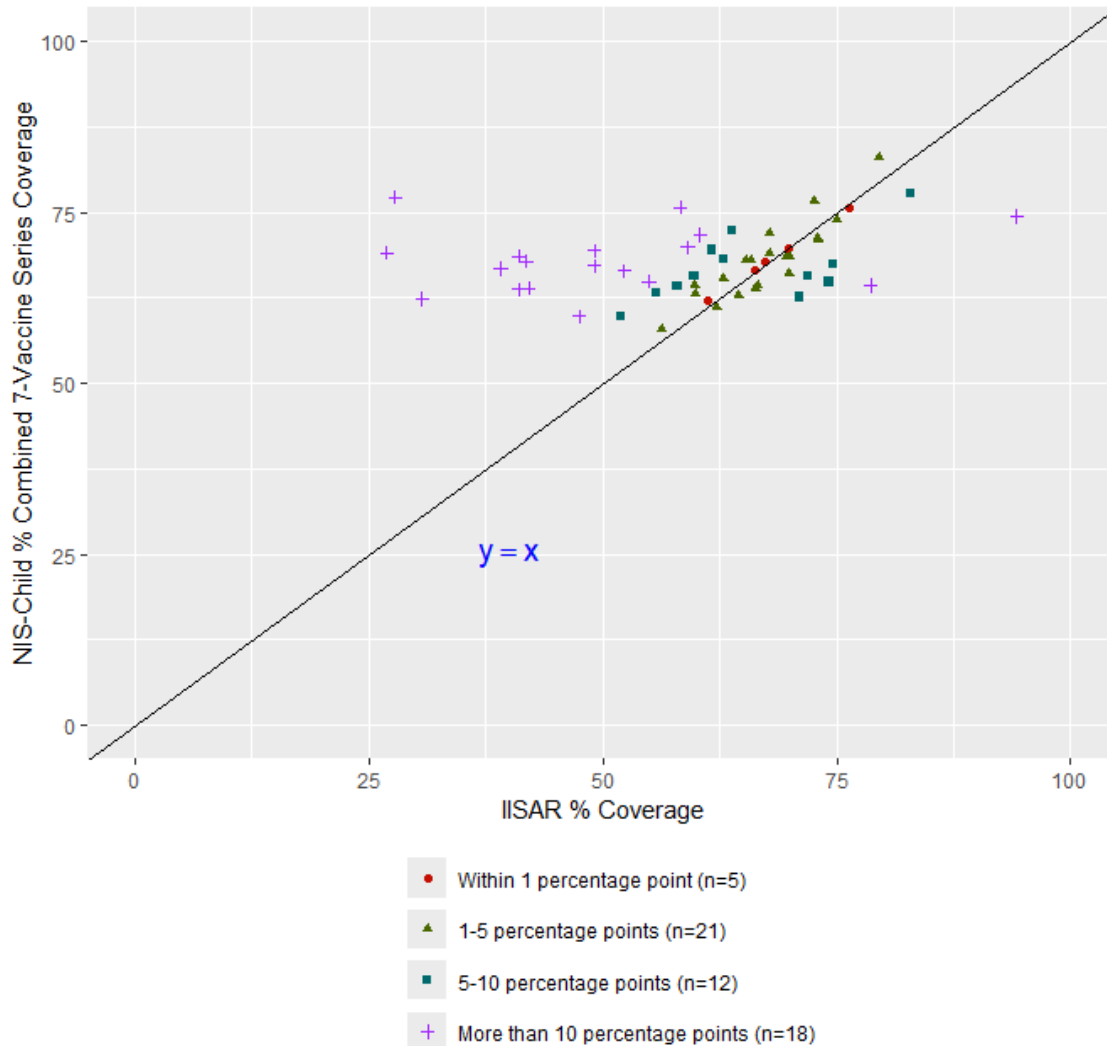
In what follows, we compare NIS-Child vaccination estimates to IISAR vaccination estimates for the combined 2020-2021 annual birth cohorts, which are the most recently available IISAR estimates to assess the relative accuracy of the 2024 NIS-Child.

## 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 series by age 24 months for the 2020-2021 annual birth cohorts. 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 but remain in the IIS, if there are duplicate children in the IIS, or if there are inaccuracies in the Census population count.

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 signify 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 at 24 Months: 56 Estimation Areas, Combined 2020-2021 Annual Birth Cohorts

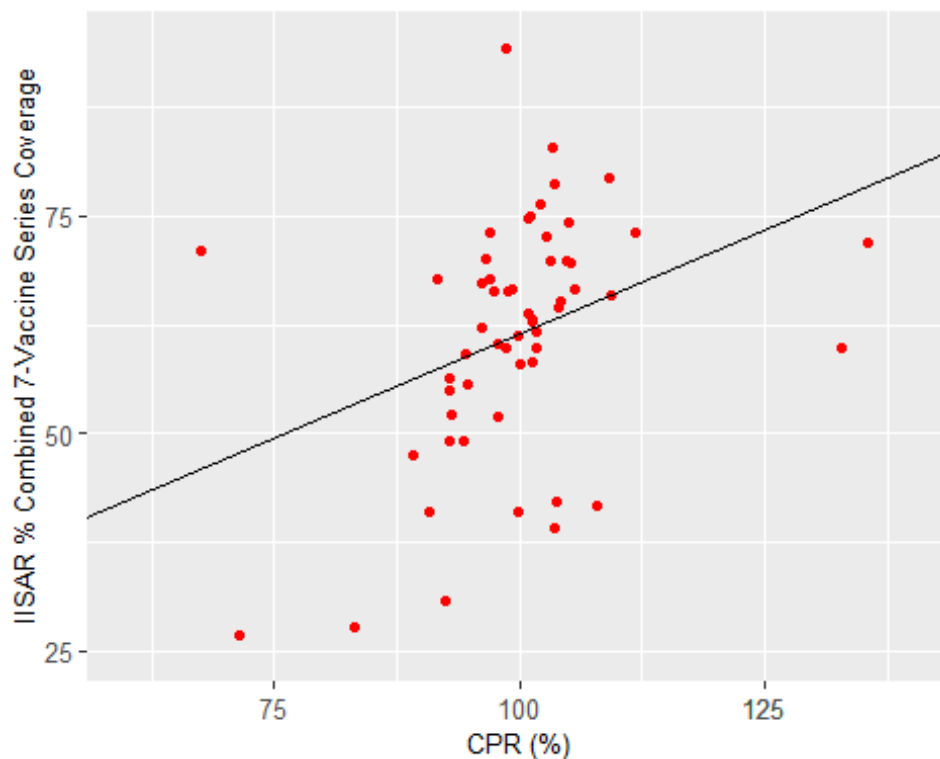


## Child Participation Rate (CPR)

To examine the hypothesis that for higher quality IIS data there is greater agreement between NIS-Child and IISAR vaccination estimates, we introduce the child participation rate (CPR) and evaluate it as a possible measure of the quality of the IIS. The CPR is defined as the proportion of children 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. We hypothesize that a higher CPR signals higher quality of the IIS. Note that many CPR values are greater than 100 percent; this can occur if children in the IIS catchment area have moved away from the area but remain in the IIS, if there are duplicate children in the IIS, or if there are inaccuracies in the Census population count.

In Figure 2.2, we plot the IISAR vaccination coverage estimates for the combined 7-vaccine series by age 24 months for the 2020-2021 annual birth cohorts versus the CPR from the 2023 IISAR file, including the 56 core estimation areas. By studying the relationship, we investigate the hypothesis that a higher CPR rate is associated with more complete vaccination histories for children in the IIS and therefore tends to indicate a higher quality IIS vaccination coverage estimate. Note that the IISAR vaccination coverage estimate uses an IIS count of vaccinated children as the numerator but a U.S. Census count of children living in the area as the denominator.

**Figure 2.2:** Scatterplot of Vaccination Coverage Estimates for Combined 7-Vaccine Series at 24 Months (in Percent) vs. Child Participation Rate (CPR, in Percent): Immunization Information Systems Annual Report (IISAR) Data for 56 Estimation Areas, Combined 2020-2021 Annual Birth Cohorts

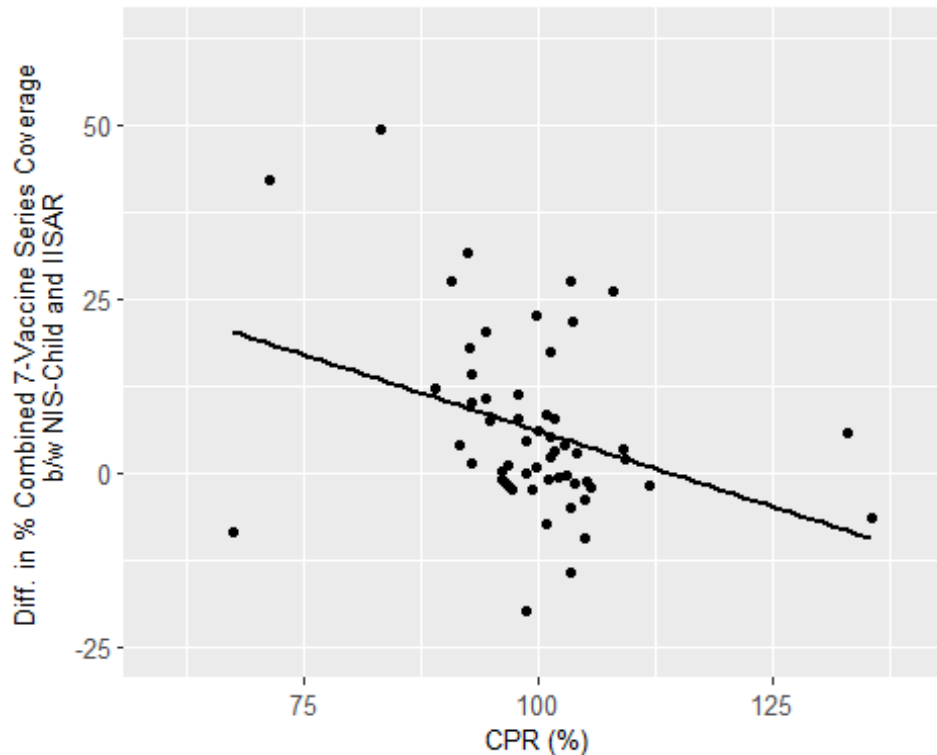


We fit a linear regression model to the points in Figure 2.2, and the corresponding fit is represented by the solid line depicted in the figure. The association of CPR with the IISAR vaccination coverage estimate is positive and strongly statistically significant. The Pearson correlation is 0.360 with a 95% confidence interval of [0.107, 0.569]. We conclude that CPR is positively associated with IISAR vaccination coverage estimates, which may suggest that a higher CPR tends to reflect a higher quality IIS.

## Examination of the Difference Between NIS-Child and IISAR Vaccination Coverage Estimates

We examined the level of agreement between NIS-Child and IISAR vaccination coverage estimates first by looking at the relationship between the CPR and difference in vaccination coverage estimates across all 56 estimation areas. Under 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, we calculated the difference between the combined 7-vaccine series by age 24 months coverage estimates in NIS-Child and IISAR for the 2020-2021 annual birth cohorts 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 all 56 estimation areas for the 2020-2021 annual birth cohorts, 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 (-0.436 percentage points with a 95% confidence interval of [-0.761, -0.111]), which implies that the difference declines with increasing CPR. As the CPR, an indicator of IIS data quality, increases from below 70 percent towards 100 percent, IISAR vaccination coverage estimates tend to converge towards NIS-Child vaccination coverage estimates, thus supporting the correlation and accuracy of both estimates.

**Figure 2.3:** Scatterplot of the Difference in Vaccination Coverage Estimate (Percentage Points, National Immunization Survey-Child (NIS-Child) Minus Immunization Information Systems Annual Report (IISAR)) vs. Child Participation Rate (CPR, in Percent): 56 Estimation Areas, Combined 2020-2021 Annual Birth Cohorts



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. Note that there are some children who have both private and public health insurance. Thus, the any private and any public insurance groups in the table are not mutually exclusive.

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 2023 and NIS-Child, CPS ASEC and NHIS for 2024

Type of Health Insurance Coverage	2023				2024		
	ACS	CPS ASEC	NHIS	NIS-Child <sup>a</sup>	CPS ASEC	NHIS	NIS-Child <sup>a</sup>
Any private <sup>b</sup>	57.1% (0.28%)	59.5% (0.96%)	53.2% (2.01%)	53.1% (0.75%)	58.7% (1.08%)	56.6% (1.99%)	52.0% (0.66%)
Any public <sup>c</sup>	44.4% (0.28%)	40.6% (0.96%)	45.4% (2.02%)	57.7% (0.77%)	40.37% (1.08%)	41.6% (2.03%)	57.7% (0.68%)
Uninsured <sup>d</sup>	4.2% (0.11%)	4.4% (0.41%)	3.2% (0.76%)	3.0% (0.30%)	6.5% (0.60%)	4.0% (0.81%)	3.4% (0.27%)

Standard errors in parentheses.

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>

<sup>a</sup> 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.

<sup>b</sup> 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.

<sup>c</sup> 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.

<sup>d</sup> 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 2023 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 2023 and 2024 CPS ASEC, national-level estimates of the health insurance distribution in 2023 and 2024 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, which 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 2023 and 2024 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 2023 and also less than the CPS ASEC and NHIS estimates in 2024. The NIS-Child estimate is about the same as the NHIS estimate for 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 2023 and also larger than the CPS ASEC and NHIS estimates in 2024. Finally, we find NIS-Child estimates of the size of the uninsured population are less than corresponding estimates from ACS and CPS ASEC in 2023 and less than the CPS ASEC estimate for 2024. 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.

### 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  $\mu_0$  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

$$q_0 = \hat{\mu} - \mu_0 . \quad (1)$$

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

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

where  $\mu_1$  is the true vaccination coverage for the age-eligible children covered by the sampling frame,  $\mu_{1A}$  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

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

where  $\mu_2$  is the true vaccination coverage for children who respond to NIS-Child,  $\mu_{2A}$  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

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

where  $\mu_3$  is the true vaccination coverage of children for whom accurate response is given to the survey,  $\mu_{3A}$  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

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

We can also write the TSE as

$$q_0 = q_1 + q_2 + q_3 , \quad (6)$$

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  $\phi = (\mu_{1A}, \mu_{2A}, \mu_{3A}, \mu_3, p_{1A}, p_{2A}, p_{3A})'$ . 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  $\hat{\phi} = (\hat{\mu}_{1A}, \hat{\mu}_{2A}, \hat{\mu}_{3A}, \hat{\mu}_3, \hat{p}_{1A}, \hat{p}_{2A}, \hat{p}_{3A})'$ . Let  $\hat{\Sigma}$  denote the estimated variance-covariance matrix of  $\phi$ . We assume the logit transformations of the seven parameters are independently and normally distributed and that  $\hat{\Sigma} = \text{diag}(\hat{\sigma}_{\mu_{1A}}^2, \hat{\sigma}_{\mu_{2A}}^2, \hat{\sigma}_{\mu_{3A}}^2, \hat{\sigma}_{\mu_3}^2, \hat{\sigma}_{p_{1A}}^2, \hat{\sigma}_{p_{2A}}^2, \hat{\sigma}_{p_{3A}}^2)'$ , where each term on the diagonal is our estimate of the variance of the corresponding parameter.

We assume our knowledge about the true parameters,  $\phi$ , can be acceptably represented by a probability distribution, with parameters  $\hat{\phi}$  and  $\hat{\Sigma}$ . We assess TSE by making random draws of  $\phi$  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,  $\mu_0^*$ ) 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 330 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 2024 NIS-Child. Finally, we close this part of the report by examining the change in the TSE from the 2023 NIS-Child to the 2024 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 2023 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 (98.6% in 2023). 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, 2012-2023

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
2023	91.2	7.5	0.2	1.2

Source: Produced using the methods of Blumberg, Ganesh, Luke, and Gonzales (2013) applied to data from the 2012-2023 National Health Interview Survey sponsored by CDC's National Center for Health Statistics (<https://www.cdc.gov/nchs/nhis/index.htm>).

The 2024 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 2024. 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).<sup>7</sup> 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.

<sup>7</sup> 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

Variance/Series	Cell-Phone Domain		Landline Only Domain		Difference		
	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 the 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 the 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 2024 NIS-Child estimated vaccination coverage. We can also write the true vaccination coverage as

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

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 2023, and  $\hat{\mu}_{1A}$  is obtained from the results of the 2024 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 2024 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

Vaccine	Cell-Phone Domain		Phoneless Domain		Difference	
	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 <sup>#</sup>	5.68 <sup>#</sup>
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  $\geq 2$  doses or  $\geq 3$  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.

\*  $p \leq 0.05$ .

<sup>#</sup> Estimates for the 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 the Hep B birth dose have similar 2024 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  $\mu_1$ . Then, Table 3.4 presents estimates of  $B$  and of the true vaccination coverage,  $\mu_0$ . We find that sampling-frame coverage error is 0.1 percentage points or less and the estimated error is less than the standard error of  $\mu_0$ .

**Table 3.4:** Preliminary Assessment of Sampling-Frame Coverage Error and Mean True Vaccination Coverage (in Percent): NIS-Child, United States, 2024

Vaccine	$\hat{\mu}_1$ (2024 NIS-Child Vaccination Coverage Estimate)	$\hat{B}^a$	$\hat{\mu}_0$ (Mean of $\mu_0$ , the True 2024 Vaccination Coverage)	Standard Error of $\mu_0$
4+ DTaP	84.3	0.0	84.3	0.5
3+ Polio	92.9	0.1	92.8	0.4
1+ MMR	92.3	0.0	92.3	0.4
Hib-FS	79.7	0.1	79.6	0.6
3+ Hep B	92.6	0.1	92.5	0.4
Hep B Birth Dose	79.9	0.1	79.9	0.6
1+ VAR	91.5	0.0	91.4	0.4
4+ PCV	81.8	0.1	81.7	0.6
Combined 7-Vaccine Series	71.0	0.1	70.9	0.6

<sup>a</sup> 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.

### 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 2024 NIS-Child estimates of

vaccination coverage for four vaccines or vaccine series, 4+ DTaP, 1+ MMR, the 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 weight 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 2024 NIS-Child realization rate<sup>8</sup> of children with adequate provider data was 2.7 percent with a standard error of 0.06 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 2.8 percent, or 97.2 percent without adequate provider data, with a standard error of 0.3 percentage points. These two numbers (97.2% with a standard error of 0.3 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 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

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<sup>8</sup> 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.

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 2023 and 2024 being 44.9% and 45.8%.<sup>9,10</sup> 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 2024 NIS-Child and the 2023 and 2024 NHIS and produce estimates of nonresponse error for four vaccination coverage estimates: 4+ DTaP, 1+ MMR, the 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 2023 and 2024 NHIS Public Use Files (PUFs).<sup>11</sup> 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.

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<sup>9</sup> See p. 29 of [https://ftp.cdc.gov/pub/Health\\_Statistics/NCHS/Dataset\\_Documentation/NHIS/2023/srvydesc-508.pdf](https://ftp.cdc.gov/pub/Health_Statistics/NCHS/Dataset_Documentation/NHIS/2023/srvydesc-508.pdf)

<sup>10</sup> See p. 28 of [https://ftp.cdc.gov/pub/Health\\_Statistics/NCHS/Dataset\\_Documentation/NHIS/2024/srvydesc-508.pdf](https://ftp.cdc.gov/pub/Health_Statistics/NCHS/Dataset_Documentation/NHIS/2024/srvydesc-508.pdf)

<sup>11</sup> <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, 2024, Derived from Estimates Based on 2023 and 2024 National Health Interview Survey (NHIS) Imputations

<b>Estimates of Vaccination Coverage and Differences by Data Source and Weighting Method</b>	<b>4+ DTaP</b>	<b>1+ MMR</b>	<b>Hep B Birth Dose</b>	<b>Combined 7-Vaccine Series</b>
(a) Estimate Based on NHIS Imputations	83.7	91.7	80.8	72.1
Standard Error	1.6	1.3	1.9	1.8
(b) NIS-Child Estimate (Design Weighted)	82.3	91.9	77.8	70.0
Standard Error	1.6	0.4	1.5	1.4
(c) NIS-Child Estimate (Final Weighted)	84.3	92.3	79.9	71.0
Standard Error	0.5	0.4	0.6	0.6
(d) Difference, (b) - (a)	-1.4	0.2	-3.0	-2.1
Standard Error of Difference	2.3	1.4	2.5	2.3
<i>t</i> -statistic	-0.61	0.15	-1.24	-0.89
<i>p</i> -value (2-sided)	0.54	0.88	0.22	0.37
(d) Difference, (c) - (a)	0.6	0.6	-0.9	-1.1
Standard Error of Difference	1.7	1.3	2.0	1.9
<i>t</i> -statistic	0.35	0.46	-0.44	-0.56
<i>p</i> -value (2-sided)	0.72	0.65	0.66	0.58

The NIS-Child estimates based on design weights are 1.4 percentage points lower than the estimate based on NHIS imputations for 4+ DTaP, 0.2 percentage points higher for 1+ MMR, 3.0 percentage points lower for the Hep B birth dose, and 2.1 percentage points lower for the combined 7-vaccine series. None of these differences is statistically significant. 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 0.6 percentage points higher than the estimate based on NHIS imputations for 4+ DTaP, 0.6 percentage points higher for 1+ MMR, 0.9 percentage points lower for the Hep B birth dose, and 1.1 percentage points lower for the combined 7-vaccine series. None of these differences is statistically significant, and using final weights reduces the difference for the Hep B birth dose and the combined 7-vaccine series. 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.

### 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 3.6 presents the estimated under-reporting error for the vaccines and vaccine series under study.

**Table 3.6:** 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 3.7 presents estimated vaccination coverage and their standard errors for 2024 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 0.38 to about 0.63 percentage points for final-weighted estimates.

**Table 3.7:** Vaccination Coverage Estimates and Standard Errors Using Design Weights and Final Weights: NIS-Child, United States, 2024

Vaccine	Design Weighted		Final Weighted	
	Estimate (%)	Standard Error (percentage points)	Estimate (%)	Standard Error (percentage points)
Combined 7-vaccine series	70.0	1.42	71.0	0.63
4+ DTaP	82.3	1.57	84.3	0.51
3+ Polio	92.3	0.43	92.9	0.38
1+ MMR	91.9	0.45	92.3	0.38
Hib-FS	78.1	1.52	79.7	0.56
3+ Hep B	90.1	1.66	92.6	0.38
Hep B birth dose	77.8	1.55	79.9	0.56
1+ VAR	91.0	0.47	91.5	0.40
4+ PCV	80.5	1.55	81.8	0.55

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

### 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 2024 NIS-Child estimated vaccination coverage. We focus the overall assessment on four estimates of vaccination coverage corresponding to 4+ DTaP, 1+ MMR, the 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 2.5<sup>th</sup> percentile and the 97.5<sup>th</sup> 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 3.8 contains the values of these seven parameters and their standard errors we used in the model for TSE in the 2024 NIS-Child. These values arise from the analyses described in

Sections 3.2 through 3.4 above.<sup>12</sup> We assume the logit transformations of the inputs are normally distributed and independent (i.e., no covariance between inputs).

**Table 3.8:** Total Survey Error Model Inputs by Stages: NIS-Child, United States, 2024

Parameter	4+ DTaP	1+ MMR	Hep B Birth Dose	Combined 7-Vaccine Series
<b>Stage 1: Sampling-Frame Coverage Error (LLO and Phoneless Households)</b>				
$\hat{p}_{1A}$	1.4%	1.4%	1.4%	1.4%
$\hat{\sigma}_{p1A}$	0.3%	0.3%	0.3%	0.3%
$\hat{\mu}_{1A}$	89.2%	94.1%	77.1%	73.2%
$\hat{\sigma}_{\mu1A}$	6.2%	4.2%	5.0%	8.7%
<b>Stage 2: Nonresponse Error</b>				
$\hat{p}_{2A}$	97.2%	97.2%	97.2%	97.2%
$\hat{\sigma}_{p2A}$	0.3%	0.3%	0.3%	0.3%
$\hat{\mu}_{2A}$	88.4%	94.6%	84.2%	80.4%
$\hat{\sigma}_{\mu2A}$	1.7%	1.3%	2.0%	2.0%
<b>Stage 3: Measurement Error</b>				
$\hat{p}_{3A}$	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%
$\hat{\sigma}_{\mu3A}$	0.0%	0.0%	0.0%	0.0%
$\hat{\mu}_3$	86.4%	94.4%	80.4%	76.4%
$\hat{\sigma}_{\mu3}$	1.7%	0.5%	1.6%	1.6%

Table 3.9 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 -4.0, -2.1, -4.0, and -9.2 percentage points for 4+ DTaP, 1+ MMR, the Hep B birth dose, and the combined 7-vaccine series, respectively, suggesting that the 2024 NIS-Child may have underestimated the true vaccination coverage. The largest estimated component of error in absolute value for all four vaccine series

<sup>12</sup>  $\hat{\mu}_{1A}$  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.

is measurement error, i.e., provider under-reporting error. The Hep B birth dose also has a modest estimate of mean nonresponse error of -3.0 percentage points, but the estimate is uncertain as reflected by the 95% credible interval.

**Table 3.9:** Mean and 95% Credible Interval for the Estimated TSE Distribution and Component Error Distributions: NIS-Child, United States, 2024

Vaccine or Series	Component	Mean TSE (percentage points)	95% Credible Interval (percentage points)
4+ DTaP	TSE (final weighted)	-4.0	(-6.9, -0.4)*
	TSE (design weighted)	-6.0	(-8.9, -2.4)*
	Noncoverage error	0.0	(-0.1, 0.3)
	Nonresponse error	-1.4	(-5.8, 3.2)
	Measurement error	-4.6	(-7.5, -1.2)*
	Sampling error	0.1	(-2.8, 3.5)
1+ MMR	TSE (final weighted)	-2.1	(-4.3, 1.0)
	TSE (design weighted)	-2.5	(-4.7, 0.6)
	Noncoverage error	0.0	(-0.1, 0.2)
	Nonresponse error	0.1	(-2.4, 3.4)
	Measurement error	-2.6	(-3.6, -1.5)*
	Sampling error	0.0	(-1.1, 1.3)
Hep B Birth Dose	TSE (final weighted)	-4.0	(-7.4, 0.1)
	TSE (design weighted)	-6.1	(-9.6, -2.1)*
	Noncoverage error	0.1	(0.0, 0.3)
	Nonresponse error	-3.0	(-7.7, 2.0)
	Measurement error	-3.2	(-6.2, 0.1)
	Sampling error	0.1	(-2.9, 3.4)
Combined 7-Vaccine Series	TSE (final weighted)	-9.2	(-12.6, -5.3)*
	TSE (design weighted)	-10.2	(-13.6, -6.3)*
	Noncoverage error	0.1	(-0.1, 0.4)
	Nonresponse error	-2.0	(-6.6, 2.7)
	Measurement error	-8.2	(-11.1, -5.2)*
	Sampling error	0.1	(-2.9, 3.1)

\* 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 2024 NIS-Child estimated vaccination coverage, while the current subsection assesses the change in TSE between 2023 and 2024. 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 2023 and 2024, the bridging cohort extends from children born in January 2021 through May 2022.

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 2023 NIS-Child sample and the second using the corresponding sample of children within the 2024 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 3.10 presents the two estimates of vaccination coverage for children as of 19 months of age for the 2023-2024 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 2024 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 +1.9 percentage points with a standard error of 0.9; given the  $p$ -value of 0.024, the hypothesis of no change in expectation is rejected.

We find some evidence of a change in bias between the 2023 and 2024 NIS-Child. Out of eighteen vaccine series studied, three have statistically significant increases between the 2023 and 2024 bridging birth cohorts at the 5% level. An additional two have statistically significant differences at the 10% level. The other differences are not statistically significant, but most show increases in vaccination coverage estimates between the 2023 and 2024 samples for the bridging cohort.

**Table 3.10:** Difference Between the Estimates<sup>#</sup> for the Bridging Birth Cohort<sup>†</sup> by Age 19 Months: NIS-Child, United States, 2023 vs. 2024

Description	2023		2024		Difference		
	Est	Std Error	Est	Std Error	Est	Std Error	<i>p</i> -value for Test of No Difference
3+ DTaP/DTP/DT by 19 months	90.3	0.71	92.3	0.48	1.9	0.86	0.024
4+ DTaP/DTP/DT by 19 months	69.3	1.02	72.1	0.83	2.8	1.31	0.030
3+ Polio by 19 months	89.6	0.73	90.9	0.55	1.3	0.91	0.156
1+ MMR by 19 months	87.0	0.73	88.1	0.60	1.1	0.95	0.256
3+ Hib by 19 months	87.5	0.77	89.0	0.57	1.5	0.96	0.107
Hib-PS by 19 months	89.7	0.72	90.9	0.54	1.2	0.90	0.175
Hib-FS by 19 months	69.9	1.01	72.8	0.82	2.9	1.30	0.025
1+ VAR by 19 months, excluding shots before 12 months	86.8	0.72	86.6	0.61	-0.3	0.94	0.779
3+ Hep B by 19 months	89.5	0.71	90.8	0.54	1.3	0.90	0.143
3+ PCV by 19 months	89.6	0.72	90.5	0.53	0.9	0.90	0.314
4+ PCV by 19 months	75.6	0.99	77.2	0.77	1.5	1.26	0.218
1+ Hepatitis A by 19 months	81.2	0.87	83.2	0.67	2.0	1.10	0.074
2+ Hepatitis A by 19 months	28.0	0.94	29.2	0.82	1.2	1.25	0.335
2+ or 3+ Rotavirus depending on type by 19 months	74.2	0.96	75.1	0.82	0.8	1.26	0.504
Combined 7-vaccine series by 19 months	58.7	1.05	61.0	0.89	2.3	1.37	0.088
Hep B birth dose	79.3	0.85	80.5	0.70	1.2	1.11	0.297
Unvaccinated children	1.0	0.13	1.1	0.16	0.1	0.20	0.625
2+ Flu by 19 months, doses at least 24 days apart	50.2	1.04	52.4	0.89	2.2	1.37	0.106

\*\*  $p \leq 0.05$  \*  $p \leq 0.10$

# National-level estimates computed among children with adequate provider data, excluding children from U.S. territories fielded in 2023 or 2024 – Guam, Puerto Rico, and U.S. Virgin Islands.

† The bridging birth cohort used for this analysis of the 2023 and 2024 NIS-Child includes children born between January 2021 and May 2022.

We hypothesize that the resumption of the usual schedule for the Provider Record Check (PRC) for 2024 NIS-Child after an early closure for the PRC for 2023 NIS-Child is a contributor to these findings. In the corresponding bridging birth cohort analysis in the Error Profile report for the 2023 NIS-Child (NORC, 2024), we found strong evidence of decreases in vaccination coverage estimates between the 2022 and 2023 samples for the 2022-2023 bridging birth cohort in that

study, covering birth months between January 2020 and May 2021. In that report, we discussed the closure of the 2023 NIS-Child PRC two months earlier than for prior years as a possible cause of the bridging birth cohort analysis findings. The early close of the PRC for 2023 NIS-Child resulted in a lower provider response rate in the PRC and consequently a lower rate of children having provider-reported vaccination data available from all of the child's providers nominated by the household respondent. This may have resulted in increased provider under-reporting error for the 2023 sample relative to prior samples. For 2024 NIS-Child, the NIS PRC resumed its usual schedule with the usual, full field period for the PRC data collection and thus was not subject to the effects of the early PRC close in 2023. Higher vaccination coverage estimates for the 2023-2024 bridging birth cohort for the 2024 sample relative to the 2023 sample would be consistent with the hypothesis that the 2023 early PRC close may have reduced vaccination coverage estimates for that survey year. Thus, we hypothesize that the return of the PRC to its usual schedule for 2024 NIS-Child is a likely cause of the findings of this 2023-2024 bridging birth cohort analysis.

## 4. Summary

We profiled the sources of error in 2024 NIS-Child statistics at the national level (excluding the U.S. territories fielded in 2024 – Guam and Puerto Rico) 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 2024 sources and studies to assess error in the 2024 NIS-Child. Where 2024 sources were not available, we reported information from prior year sources as the best information available for understanding error in the 2024 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 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 2024 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 great variation in the level of agreement. We first determined that the child participation rate (CPR) is a reasonable indicator of the quality of the corresponding IIS database. We learned that the difference between NIS-Child and IISAR vaccination coverage estimates declines as the CPR rate increases towards 100 percent (i.e., as the quality of the IIS increases).

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 the 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.

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 2023 to 2024.

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 0.0 to 0.1 percentage points for all nine vaccines series studied.

We used the 2023 and 2024 NHIS in assessing nonresponse error in the 2024 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 (3.0 percentage points in magnitude for the Hep B birth dose, and 2.0 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 2 to 8 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 -4.0 percentage points with a 95% credible interval of (-6.9, -0.4) percentage points. That is, the NIS-Child vaccination coverage estimate was on average about 4.0 percentage points too low. For the 1+ MMR vaccination coverage estimate, we found the mean of the TSE distribution to be -2.1 percentage points with a 95% credible interval of (-4.3, 1.0) percentage points that includes 0. For the estimate of Hep B birth dose vaccination coverage, the mean of the TSE

distribution was -4.0 percentage points with a 95% credible interval of (-7.4, 0.1) that also includes 0. Finally, for the combined 7-vaccine series, we found the mean of the TSE distribution to be -9.2 percentage points with a 95% credible interval of (-12.6, -5.3) percentage points. Again, under-ascertainment of the provider-reported vaccination history dominated total survey error, although the estimate of mean nonresponse error for the 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 2023 and 2024 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 three estimates have statistically significant increases at the 5% level between the 2023 and 2024 bridging birth cohorts and an additional two having statistically significant increases at the 10% level. The report for the error profile of the 2023 NIS-Child found a decrease in estimates between the 2022 and 2023 bridging birth cohorts that were examined in that report. That report considered the early PRC close for 2023 NIS-Child as a potential cause of the decrease in bridging birth cohort estimates. Thus, we hypothesize that the resumption of the usual PRC schedule for the 2024 NIS-Child may explain the findings regarding the increase in bridging birth cohort estimates between 2023 and 2024.

Our results for the 2024 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. 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 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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