National Immunization Survey-Teen

Error Profile for the 2023 NIS-Teen

Centers for Disease Control and Prevention

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List of Abbreviations

ACS: American Community Survey

APR: Adolescent Participation Rate

CPO: Cell-phone only

CPS ASEC: Current Population Survey Annual Social and Economic Supplement

HPV UTD: Up-to-date for HPV vaccine series: ≥3 doses, or ≥2 doses if 1st dose before age 15 and at least 5 months minus 4 days between 1st and 2nd doses

IIS: Immunization Information Systems

IISAR: Immunization Information Systems Annual Report

IRIS: Iowa Immunization Registry Information System

LLO: Landline only

NHIS: National Health Interview Survey

NIS-Child: National Immunization Survey-Child

NIS-Teen: National Immunization Survey-Teen

PEP: U.S. Census Bureau Population Estimate Program

PRC: Provider Record Check

PUMS: Public Use Microdata Sample

RDD: Random digit dial

TSE: 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 sample-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-Teen (NIS-Teen) estimated vaccination coverage at the national level. Prior reports discussed TSE for the 2022 National Immunization Survey-Child (NIS-Child) (NORC 2023a) and the 2022 NIS-Teen (NORC 2023b). The statistics and methodology of the NIS have been described by Smith, Hoaglin, Battaglia et al. (2005) and Wolter, Smith, Khare et al. (2017).

The report is written in two parts. The first part, which appears in Section 2, compares NIS-Teen 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-Teen statistic and its corresponding benchmark is likely a signal of error in the NIS-Teen or of definitional differences between NIS-Teen and benchmark concepts. A small difference may be a signal of good accuracy in the NIS-Teen or simply an indicator that the NIS-Teen statistic and its benchmark are consistent with one another. This part of the report examines demographic statistics, vaccination coverage estimates, and health insurance statistics.

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

The report closes in Section 4 with a summary of findings and limitations.

Throughout the report, we analyze total survey error for the following vaccines: 1+ Tdap; 1+ MenACWY; and up-to-date (UTD) status for HPV[1] among the total age-eligible population, among females, and among males. Assessments are conducted at the national level (50 states plus District of Columbia).

[1] ≥3 doses, or ≥2 doses if 1st dose before age 15 and at least 5 months minus 4 days between 1st and 2nd doses.

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

We begin by comparing NIS-Teen demographic distributions (adolescent age, adolescent sex, adolescent race/ethnicity, mother's education, and mother's age) to benchmark distributions derived from the Census Bureau's Population Estimates Program (PEP) and American Community Survey (ACS). Second, we compare NIS-Teen vaccination coverage estimates to estimates set forth in the Immunization Information Systems Annual Report (IISAR) for 1+ Tdap. Third, we compare health insurance distributions derived from the NIS-Teen Health Insurance Module to corresponding benchmark distributions obtained from (i) the National Health Interview Survey (NHIS), (ii) the ACS, and (iii) the Current Population Survey Annual Social and Economic Supplement (CPS ASEC). Finally, we compare NIS-Teen vaccination coverage estimates based on immunization information system (IIS) data published directly by Iowa and Oregon for multiple vaccine series.

2.1 Demographic Distributions: Comparison of NIS-Teen 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 vaccination coverage are not available, we can compare the survey estimates of demographic distributions to those derived from the PEP and ACS data.

To create benchmark demographic distributions for adolescents aged 13-17 years in 2023, we began by obtaining PEP data for 2022 by the combination of state, single year of age (12-16 years in 2022), sex, and race/ethnicity (These data are made available from the Census Bureau at approximately a one-year lag, and the 2022 estimates were the most recent estimates available at this writing).[2] An adjustment was then made within age groups to remove the institutionalized population because the NIS-Teen target population excludes institutionalized adolescents. The distribution of education level for mothers of adolescents aged 13-17 years was estimated using the combined 2020, 2021, and 2022 one-year ACS Public-Use Microdata Sample (PUMS)[3]; these mother's education distribution estimates were produced within the combination of state and adolescent age, sex, and race/ethnicity and then applied to the overall PEP estimates for each combination to estimate the total number of adolescents by mother's education for each combination. The distribution of mother's age was estimated from one-year

[2] https://www.census.gov/programs-surveys/popest.html

[3] US Census Bureau. 2022 ACS PUMS Data. Retrieved from https://www.census.gov/programs-surveys/acs/microdata.html

2022 ACS data and applied to the overall PEP estimates to estimate the total number of adolescents by mother's age. Finally, adjustments were made for mortality and foreign immigration; these steps account for changes in the adolescent population totals in the one-year period between the reference day (July 1, 2022) for the 2022 PEP counts and the midpoint of the reference year (July 1, 2023) for the 2023 NIS-Teen.

We produced 2023 NIS-Teen national-level demographic distribution estimates first using design weights and then using the 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 demographics used in this calibration.)

Table 2.1 compares 2023 NIS-Teen national-level survey estimates of demographic distributions for adolescents with adequate provider data to benchmark distributions for adolescent age, sex, race/ethnicity, mother's education, and mother's age. The survey distributions of adolescent age, adolescent sex, and mother's age are very close to the population distributions, even when using the design weights.

The design-weighted distribution of adolescent race/ethnicity differs from the population distribution, with larger differences for non-Hispanic White only adolescents (57.1 percent in survey, 49.7 percent in population) and Hispanic adolescents (20.0 percent in survey, 26.0 percent in population). These differences are substantially smaller when final weights are used (26.0 percent survey estimate for Hispanic adolescents, 26.0 percent in population; 48.6 percent survey estimate for non-Hispanic White only adolescents, 49.7 percent in population). Note that the final-weighted distribution does not exactly match the population distribution because final weights are calibrated to only three race/ethnicity categories – Hispanic, non-Hispanic Black only, and other (including non-Hispanic White only) – and in some geographic areas categories for calibration may be collapsed due to small sample sizes.

Differences between survey estimates and population values are also observed for mother's education. The survey over-represents adolescents whose mothers have a four-year college degree when the design weights are used (50.9 percent in survey, 37.9 percent in population) and under-represents adolescents whose mothers have no high school degree, only a high school degree, or some college. When the final weights are used, the survey still over-represents adolescents whose mothers have a four-year college degree (44.9 percent in survey, 37.9 percent in population) and under-represents adolescents whose mothers have some college (22.8 percent in survey, 30.1 percent in population). (Final survey weights are calibrated to population totals for less than high school, high school, and more than high school, but are not calibrated separately for some college vs. four-year degree.)

Comparisons of demographic distributions were made between survey estimates and population values for all two-way combinations of adolescent age, adolescent sex, adolescent race/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 cross-classifications involving adolescent age, sex, race/ethnicity, and mother's education regarding the categories in Table 3.1 are all less than 5.0 percentage points when final weights are used.

Table 2.1: One-Way Demographic Distributions Among Adolescents with Adequate Provider Data vs. Population Controls: NIS-Teen, United States, 2023

		Design Weighted		Final Weighted*	
Demographic	**Population Percentage**	**Survey Estimate**	**Survey Estimate - Population Percentage**	**Survey Distribution**	**Survey Estimate - Population Percentage**
Adolescent Age					
13 years	19.3	20.4 ± 1.1	1.0 ± 1.1	19.1 ± 1.2	-0.2 ± 1.2
14 years	19.7	20.1 ± 1.1	0.3 ± 1.1	20.0 ± 1.2	0.3 ± 1.2
15 years	20.5	20.3 ± 1.2	-0.2 ± 1.2	20.9 ± 1.4	0.4 ± 1.4
16 years	20.4	20.3 ± 1.1	-0.1 ± 1.1	20.3 ± 1.2	-0.1 ± 1.2
17 years	20.1	19.0 ± 1.1	-1.0 ± 1.1	19.7 ± 1.2	-0.3 ± 1.2
Adolescent Sex					
Male	51.2	52.8 ± 1.4	1.6 ± 1.4	51.2 ± 1.6	0.0 ± 1.6
Female	48.8	47.2 ± 1.4	-1.6 ± 1.4	48.8 ± 1.6	0.0 ± 1.6
Adolescent Race/Ethnicity					
Hispanic	26.0	20.0 ± 1.2	-5.9 ± 1.2	26.0 ± 1.6	0.1 ± 1.6
Non-Hispanic White only	49.7	57.1 ± 1.4	7.4 ± 1.4	48.6 ± 1.5	-1.1 ± 1.5
Non-Hispanic Black only	13.8	10.3 ± 0.9	-3.6 ± 0.9	13.5 ± 1.1	-0.3 ± 1.1
Other	10.6	12.7 ± 1.0	2.1 ± 1.0	11.9 ± 0.9	1.3 ± 0.9
Mother Education					
Less than high school	11.6	7.6 ± 0.8	-4.0 ± 0.8	11.4 ± 1.3	-0.2 ± 1.3
High school	20.4	16.1 ± 1.1	-4.3 ± 1.1	20.9 ± 1.3	0.5 ± 1.3
Some college	30.1	25.4 ± 1.3	-4.7 ± 1.3	22.8 ± 1.3	-7.3 ± 1.3
4-year college graduate	37.9	50.9 ± 1.4	13.0 ± 1.4	44.9 ± 1.5	7.0 ± 1.5
Mother Age					
< 35 years	7.5	5.3 ± 0.6	-2.2 ± 0.6	6.8 ± 0.9	-0.7 ± 0.9
35-44 years	47.5	44.5 ± 1.4	-3.0 ± 1.4	44.5 ± 1.6	-3.0 ± 1.6
>= 45 years	45.1	50.3 ± 1.4	5.2 ± 1.4	48.7 ± 1.6	3.6 ± 1.6

Note: Excludes U.S. territory samples in Guam, Puerto Rico, and U.S. Virgin Islands.
Note: The notation ± signifies 95% confidence intervals.
* Final provider-phase weights are calibrated within each geographic estimation area to marginal totals for adolescent age (13-14 years, 15-17 years), adolescent sex (male, female), adolescent race/ethnicity (Hispanic, non-Hispanic Black only, all other race/ethnicity groups), mother's education (less than high school, high school, more than high school), household telephone status (cell-phone-only, other), and quintile of the estimated propensity to have adequate provider data for the adolescent, given the household interview was completed for the adolescent. Some geographic areas categories for calibration may be collapsed due to small sample sizes.

2.2 Comparison of NIS-Teen and IISAR Vaccination Coverage Estimates

This subsection compares NIS-Teen vaccination coverage estimates to Immunization Information System Annual Report (IISAR) data in 2022.[4] The comparison is given for estimates for coverage with 1+ Tdap vaccine using the data available from IISAR, recognizing that the findings may not apply to other vaccine series. Note that 1+ Tdap estimates are the only vaccination coverage estimates for the NIS-Teen age range provided by IISAR. Agreement between the vaccination coverage estimates signals consistency between the NIS-Teen and IISAR, and it may signal that both sources provide an accurate measurement of the true vaccination coverage in the age-eligible adolescent population (13- to 17-year-old adolescents). 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-Teen and IISAR visually using scatterplots. Third, we introduce the concept of the IIS (Immunization Information System) [5] Adolescent Participation Rate (APR) as a measure of IIS quality before demonstrating through regression analysis that higher quality IIS, as indicated by the APR, tend to have smaller differences between the 1+ Tdap vaccination coverage estimates in NIS-Teen and IISAR.

What is IISAR?

The 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-Teen vaccination estimates to 2022 IISAR vaccination estimates. Because 2023 IISAR vaccination coverage estimates are not available as of this writing, the 2022 comparison will serve as the most current information available about the relative accuracy of the 2023 NIS-Teen.

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

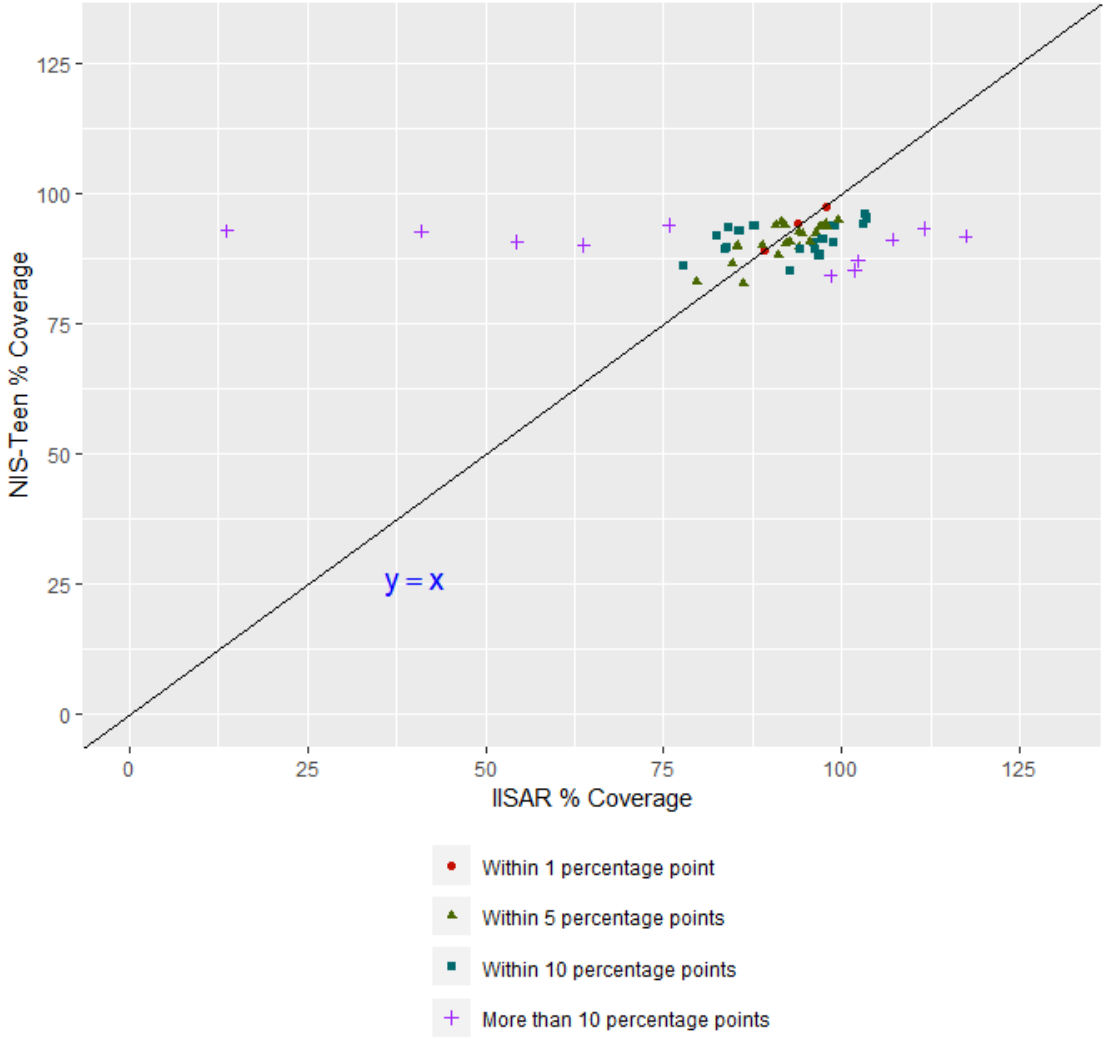
[5] IIS are computer databases that aspire to contain information about all of the doses of all vaccines administered to all adolescent residents within a jurisdiction. It is known that different IIS vary in their completeness of both adolescents and the doses they received. https://www.cdc.gov/iis/annual-report-iisar/?CDC_AAref_Val=https://www.cdc.gov/vaccines/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

Visual Comparison of Vaccination Coverage Estimates

Figure 2.1 displays a plot of the NIS-Teen vaccination coverage estimate versus the IISAR vaccination coverage estimate for 1+ Tdap for the year 2022. Figure 2.1 includes the 56 core estimation areas used in NIS-Teen; it does not include points corresponding to eight U.S. territories. IISAR vaccination coverage estimates use an IIS count of vaccinated adolescents as the numerator and a U.S. Census count of adolescents living in the area as the denominator; this can result in some IISAR vaccination rates being greater than 100 percent, for example if adolescents in the IIS catchment area have moved away from the area.

In Figure 2.1, the straight line through the origin reflects the $y = x$ line. Points above the line represent areas in which the NIS-Teen 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-Teen and IISAR rates. The plot shows a range of levels of agreement between NIS-Teen vaccination coverage and IISAR estimates across areas, including some areas where the NIS-Teen estimates are greater and some where the IISAR estimates are greater.

Figure 2.1: Scatterplot of National Immunization Survey-Teen (NIS-Teen, in %) vs. Immunization Information Systems (IISAR, in %) Vaccination Coverage Estimates for 1+ Tdap: 56 Estimation Areas, 2022



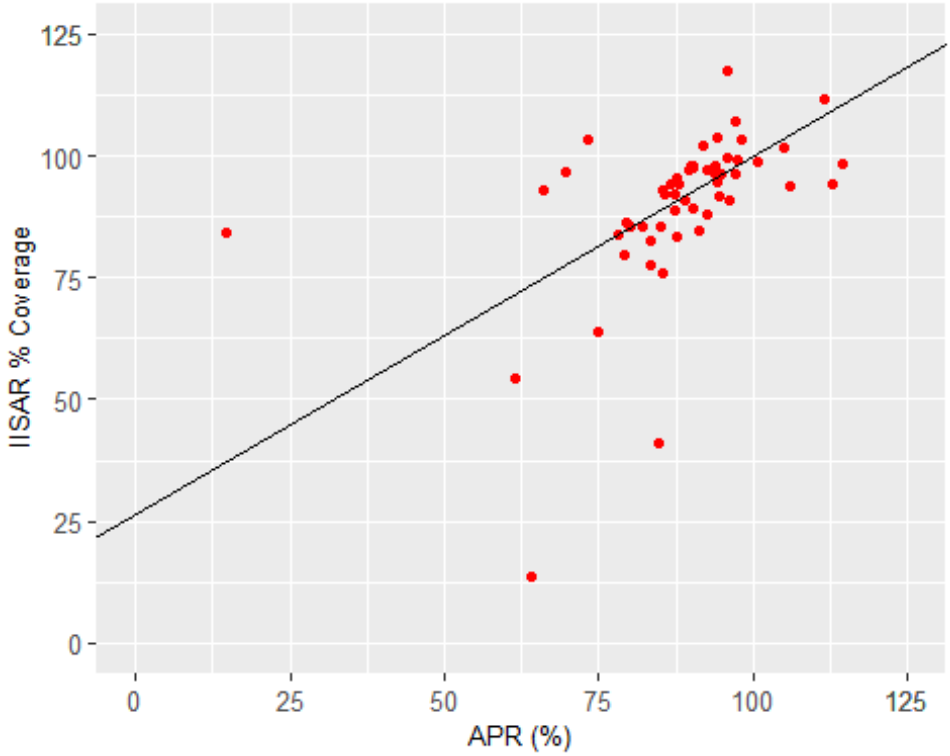
Adolescent Participation Rate (APR)

To test the hypothesis that increasing quality of an awardee's IIS data implies increasing agreement between the NIS-Teen and IISAR vaccination estimates, we introduce the adolescent participation rate (APR)[6] and evaluate it as a possible measure of the quality of the IIS. We then study the relationship between this measure of IIS quality and the difference between NIS-Teen and IIS estimates. In Figure 2.2, we plot the IISAR vaccination coverage

[6] Proportion of adolescents 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 adolescents living in the area. This can result in some APR values being greater than 100 percent, for example if adolescents in the IIS catchment area have moved away from the area.

estimate for 1+ Tdap versus the APR for the year 2022, including the 56 core estimation areas. Note that the IISAR APR uses an IIS count of vaccinated adolescents as the numerator but a U.S. Census count of adolescents living in the area as the denominator; this can result in some IISAR vaccination rates being greater than 100 percent.

Figure 2.2: Scatterplot of Immunization Information Systems Annual Report (IISAR, in %) Vaccination Coverage Estimate for 1+ Tdap vs. Adolescent Participation Rate (APR, in %): 56 Estimation Areas, 2022



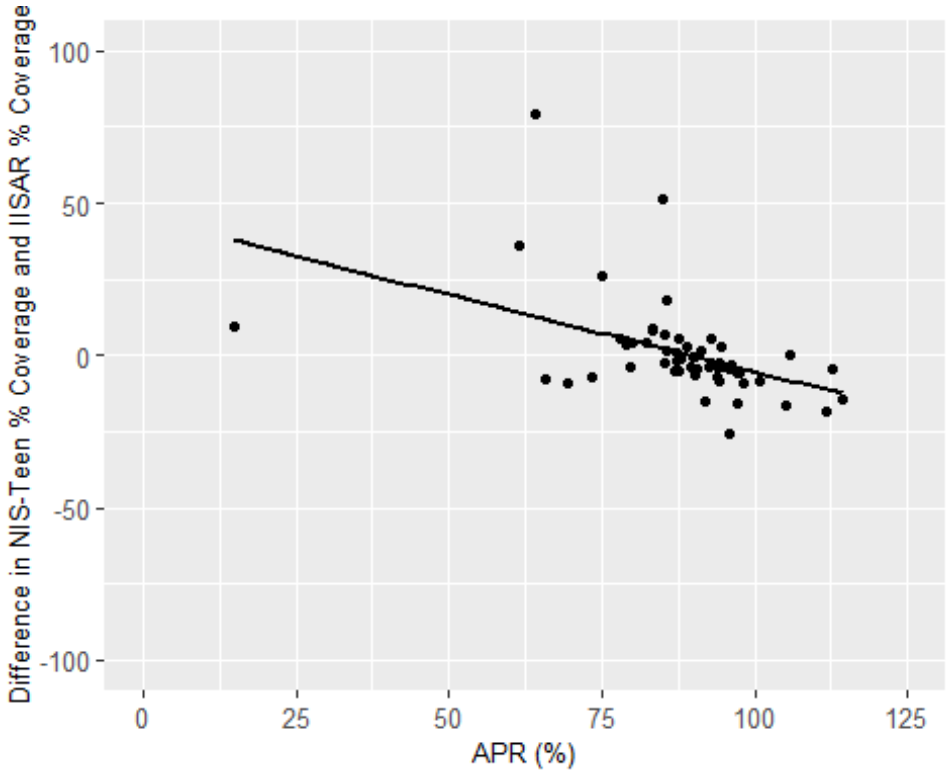
We fit a linear regression model to the points in Figure 2.2, and the corresponding fit is represented by the solid line depicted in the figure. The association of APR with the IISAR vaccination coverage estimate is positive and strongly statistically significant. The Pearson correlation is 0.590 with a 95% confidence interval of [0.388, 0.738]. We conclude that APR is positively associated with higher vaccination coverage estimates.

Negative Relationship Between Difference in Vaccination Coverage and APR

We conducted further evaluation of the hypothesis that increasing quality of state IIS data as indicated by the APR is associated with increasing agreement between the NIS-Teen and IISAR vaccination coverage estimates. Specifically, taking APR to be a measure of IIS quality, we calculated the difference between the 1+ Tdap coverage estimates in NIS-Teen and IISAR and fit a simple linear regression model relating the difference to the APR. Figure 2.3 presents the scatterplot of the difference versus the APR for the set of 56 core estimation areas in 2022, and the straight line depicted in the figure is the regression line. The APR has a strong and statistically significant relationship with the difference. The coefficient on the APR is negative

(-0.74 percentage points with a 95% confidence interval of [-1.02, -0.46]), which implies that the difference declines with increasing APR, or in other words, the difference between NIS-Teen and IISAR vaccination coverage estimates declines as IIS quality increases. As the APR, as an indicator of IIS data quality, increases, IISAR vaccination estimates tend to converge towards NIS-Teen vaccination estimates, thus supporting the correlation and accuracy of both estimates.

Figure 2.3: Scatterplot of the Difference in Vaccination Coverage Estimates (Percentage Points, National Immunization Survey-Teen (NIS-Teen) minus Immunization Information Systems Annual Report (IISAR)) vs. Adolescent Participation Rate (APR, in %) 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-Teen and IISAR vaccination coverage estimates on APR, dummy variables for year, and estimation area dummy variables. Similar to the 2022 results in Figure 2.3, the pooled results showed that APR has a statistically significant, negative relationship with the difference, with a regression slope coefficient of -0.31 percentage points with a 95% confidence interval of [-0.38, -0.23].

Summarizing, we have presented evidence in this subsection that APR is a reasonable, though not comprehensive, measure of the quality of IIS adolescent data. We have shown that as state IIS data quality indicators improve, the difference between the NIS-Teen and IISAR vaccination coverage estimates declines. IIS and NIS are independent data sources. Thus, as the accuracy of IIS vaccination coverage increases, NIS and IIS tend to provide mutual support for one another's accuracy.

2.3 Comparison of Adolescents by Type of Health Insurance Coverage

In this subsection, we compare NIS-Teen health insurance estimates to those from the ACS, the CPS ASEC, and the NHIS. We discuss the percentages of adolescents 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.

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 adolescent population aged 13-17 years 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 coverage 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 adolescents aged 13-17 years 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 for adolescents aged 13-17 years are shown in Table 2.2, as 2022 is the most recently available NHIS data. In the NHIS, health insurance status is assessed as of the time of the interview.

Table 2.2: Comparison of Alternative Estimates of Health Insurance Coverage Among Adolescents ages 13-17 years: NIS-Teen, ACS, CPS ASEC, and NHIS for 2022 and NIS-Teen and CPS ASEC for 2023

Type of Health Insurance Coverage	2022				2023	
	ACS	CPS ASEC	NHIS	NIS-Teen[a]	CPS ASEC	NIS-Teen[a]
Any private[b]	61.1%	63.1%	57.8%	62.8%	63.1%	61.7%
Any public[c]	39.2%	36.5%	39.2%	44.1%	35.8%	43.6%
Uninsured[d]	5.5%	5.5%	4.9%	3.4%	6.0%	3.8%

NIS-Teen: National Immunization Survey-Teen.
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-Teen estimates were produced among adolescents with adequate provider data using the final NIS-Teen 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: Adolescents 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.

In reviewing Table 2.2, we find NIS-Teen estimates, which are also based on health insurance status as of the date of the interview, to be larger than those from the ACS and NHIS for the privately-insured population for 2022 while the NIS-Teen estimate is smaller than the CPS ASEC estimate for 2022 and 2023. We find the estimates for public health insurance in NIS-Teen to be larger than the corresponding estimates from ACS, CPS ASEC, and NHIS in 2022 and also larger than the CPS ASEC estimate in 2023. Finally, we find NIS-Teen estimates of the size of the uninsured population are less than corresponding estimates from ACS, CPS ASEC, and NHIS in 2022 and also less than the CPS ASEC estimate for 2023. The differences in estimates between the NIS-Teen and the other three sources could be due to differential error in the NIS-Teen relative to the other sources (due to differential sample-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 NIS-Teen and State Immunization Information Systems Vaccination Coverage Estimates

In this subsection, we compare NIS-Teen vaccination coverage estimates to estimates based on IIS data that have been published for particular states. Whereas the comparison to IISAR estimates in subsection 2.2 could be made only for 1+ Tdap, comparisons in this subsection can be made for additional vaccines. Agreement between NIS-Teen and 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.

We identified two state IIS that in recent years have produced vaccination coverage estimates for resident adolescents for the NIS-Teen age range: Iowa and Oregon in 2022 and 2023. This subsection compares (a) NIS-Teen vaccination coverage estimates for Iowa to those from the Iowa Immunization Registry Information System (IRIS)[7], sponsored and conducted by the Iowa Department of Health and Human Services and (b) NIS-Teen vaccination coverage estimates for Oregon to those from Oregon's Immunization Information System, called ALERT IIS[8], conducted by the Oregon Health Authority.

IRIS and ALERT IIS are population-based computerized systems that contain immunization information for individuals of all ages residing in the states of Iowa and Oregon, respectively. The numerator of their estimates is the number of immunized individuals. IRIS uses county adolescent Census population data for the denominator, and ALERT IIS uses individuals in the ALERT IIS registry that had at least one immunization entry prior to their most recent birthday.

Figure 2.4 presents a comparison of IRIS and NIS-Teen vaccination coverage estimates for adolescents aged 13-15 years for the two most recently available data years: 2022 and 2023. We observe that both 1+ MenACWY and 1+ Tdap have small differences in estimates for both 2022 and 2023, with all differences under 3.5 percentage points. Other vaccine series have large differences in vaccination coverage estimates, including for HPV UTD, for which the NIS-Teen estimates are 15.8 percentage points higher in 2022 and 7.4 percentage points higher in 2023. For 2+ MMR and 2+ Varicella, the IRIS estimates are over 100% and thus higher than the NIS-Teen estimates.

[7] https://hhs.iowa.gov/public-health/data/health/immunization/adolescent-immunizations-data
[8] https://public.tableau.com/app/profile/oregon.immunization.program/viz/OregonAdolescentImmunizations/D-Landing

Figure 2.4: Comparison of Vaccination Coverage Estimates for Adolescents Aged 13-15 Years: Iowa Immunization Registry Information System (IRIS) vs. National Immunization Survey-Teen (NIS-Teen) in Iowa, 2022 and 2023

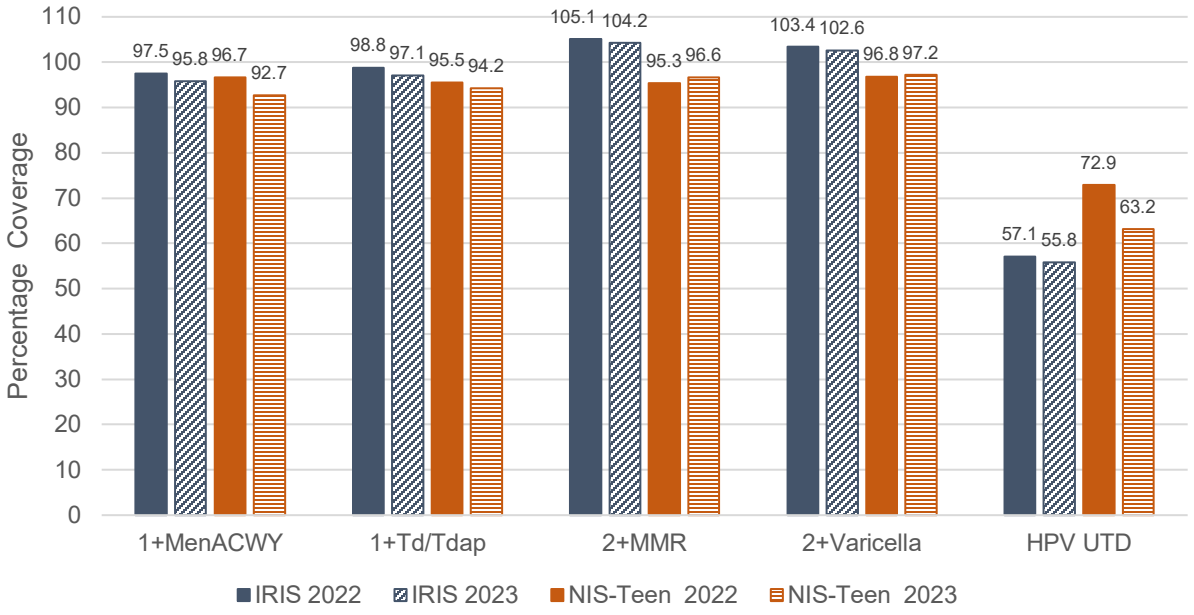
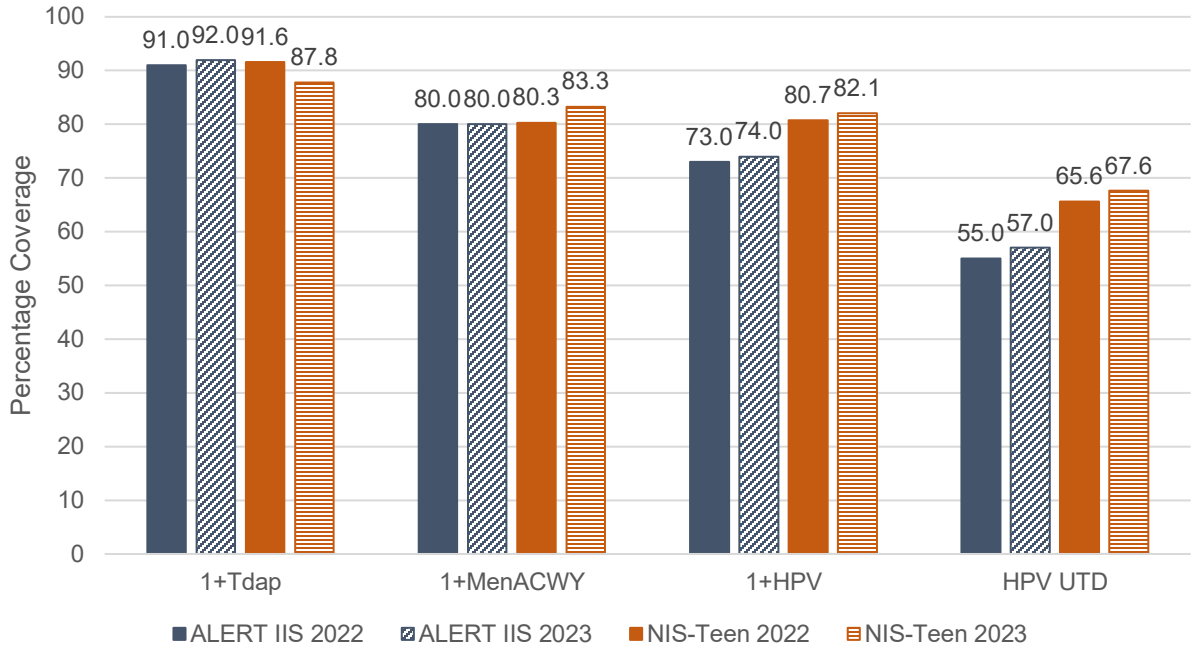


Figure 2.5 presents a comparison of ALERT IIS and NIS-Teen vaccination coverage estimates for adolescents aged 13-17 for the two most recently available data years: 2022 and 2023. It shows the vaccination coverage estimates for 1+ Tdap, 1+ MenACWY, 1+ HPV, and HPV UTD. The estimates for 1+ MenACWY show the smallest differences in estimates for both years: 0.3 percentage points in 2022 and 3.3 percentage points in 2023. However, the differences for HPV estimates are large. For HPV UTD, NIS-Teen estimates are 10.6 percentage points higher in 2022 and also 10.6 percentage points higher in 2023.

Figure 2.5: Comparison of Vaccination Coverage Estimates for Adolescents Aged 13-17 Years: ALERT Immunization Information System (IIS) vs. National Immunization Survey-Teen (NIS-Teen) in Oregon, 2022 and 2023



In comparing vaccination coverage estimates between NIS-Teen and IIS in two states, we found smaller differences in estimates for MenACWY and Tdap and larger differences for HPV estimates. The Iowa IRIS estimates for two series (2+ MMR and 2+ Varicella) are over 100%. Regarding differences in HPV coverage estimates for both states, differences may be due to missing HPV vaccination data in the state IIS but may also be due to nonresponse error in NIS-Teen estimates.

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

In this part of the report, we assess the total survey error in NIS-Teen vaccination coverage estimates using the framework developed and implemented in Molinari et al. (2011) and Wolter et al. (2017). We decompose the total survey error (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-Teen. The mean of the conditional distribution is estimated from numerical evidence obtained in the corresponding evaluation study. 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 possibly additional professional judgment. After assembling the best available 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 in the age-eligible population of adolescents, and let $\hat{\mu}$ denote the NIS-Teen estimate of vaccination coverage. The TSE in the vaccination coverage estimate is then given by

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

We use a three-stage model for TSE, where Stage 1 represents error due to the sampling-frame's under-coverage of the population of age-eligible adolescents, 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

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

where μ_1 is the true vaccination coverage for the age-eligible adolescents covered by the sampling frame, μ_{1A} is the true vaccination coverage for the age-eligible adolescents 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

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

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

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

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

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

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

We can also write the TSE as

$$\boldsymbol{q_0 = q_1 + q_2 + q_3}\ , \qquad (6)$$

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 below, are denoted by $\hat{\boldsymbol{\phi}} = (\hat{\mu}_{1A}, \hat{\mu}_{2A}, \hat{\mu}_{3A}, \hat{\mu}_3, \hat{p}_{1A}, \hat{p}_{2A}, \hat{p}_{3A})'$. Let $\widehat{\boldsymbol{\Sigma}}$ denote the estimated variance-covariance matrix of $\boldsymbol{\phi}$. We assume the seven parameters are independently distributed and that, $\widehat{\boldsymbol{\Sigma}} = \mathrm{diag}\left(\hat{\sigma}^2_{\mu 1A}, \hat{\sigma}^2_{\mu 2A}, \hat{\sigma}^2_{\mu 3A}, \hat{\sigma}^2_{\mu 3}, \hat{\sigma}^2_{p 1A}, \hat{\sigma}^2_{p 2A}, \hat{\sigma}^2_{p 3A}\right)$.

where each $\hat{\sigma}^2$ 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 $\hat{\boldsymbol{\phi}}$ and $\widehat{\boldsymbol{\Sigma}}$. We assess TSE by making random draws of $\boldsymbol{\phi}$ from its distribution. For each draw, we use equation (5) to produce a draw from the distribution of the 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 using 10,000 such draws.

Having established our model and notation, we now consider *sampling-frame coverage error* in NIS-Teen, which arises because the sampling frame omits direct representation of the landline-only (LLO) and phoneless populations. Second, we consider *nonresponse error* in the NIS-Teen, which comes about due to nonresponse in the random digit dial (RDD) telephone survey of households, to failure of the parental respondent to give consent to contact the adolescent's

immunization providers, and to 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-Teen due to sampling, i.e., error because the survey observes only about 1 out of 1,260 adolescents 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-Teen. Finally, we close this section by examining the change in the TSE, from the 2022 NIS-Teen to the 2023 NIS-Teen, using the bridging cohort method, first described in Yankey, Hill, Elam-Evans 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-Teen began using a single-frame cell-phone RDD design, which omits direct representation of adolescents in LLO and phoneless households. To account for the excluded population groups, the NIS-Teen weighting methodology makes adjustments to the weights by raking the weights to select demographic characteristics of the population of adolescents aged 13-17 years. 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 adolescents in the omitted domains differs from the vaccination coverage of adolescents in the included domains, which may introduce bias into the estimator of the vaccination coverage.

In this subsection, we attempt to measure the bias in the estimated vaccination coverage introduced by sampling-frame coverage error. Table 3.1 displays the proportion of adolescents aged 13-17 years in the population by telephone status by year for 2012-2022 based on estimates from the NHIS, as 2022 is the most recently available year of NHIS data. The proportion of adolescents with cell-phone-only (CPO) status is increasing throughout this period, and the proportion 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 95.5% in 2018 to 98.1% in 2019 and 99.3% in 2022. As a result, the estimated proportion of uncovered households decreased from 4.5% in 2018 to 0.7% in 2022.

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

Year	Cell-Phone-Only	Dual-User	Landline-Only	Phoneless
2012	36.2	58.6	3.5	1.7
2013	40.5	55.3	2.4	1.8
2014	44.8	50.5	3.0	1.7
2015	49.3	47.0	2.1	1.7
2016	55.2	41.2	1.9	1.7
2017	55.7	40.4	1.7	2.2
2018	56.9	38.5	2.2	2.3
2019	63.2	34.8	0.8	1.1
2020	65.0	33.7	0.7	0.7
2021	72.3	27.0	0.1	0.6
2022	74.9	24.4	0.3	0.4

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-Teen did not directly measure LLO or phoneless adolescents, 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-Teen samples directly represented LLO adolescents and thus permit comparison of their vaccination coverage estimates to the corresponding estimates of adolescents in cell-phone households. 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, yet none of the differences are statistically significant.

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

	Cell-Phone Domain		Landline-Only Domain		Difference	
Variance/Series	**Estimate**	**Standard Error**	**Estimate**	**Standard Error**	**Estimate**	**Standard Error**
1+ Tdap	88.7	0.46	86.9	3.79	1.9	3.8
1+ MenACWY	85.3	0.48	73.4	6.69	11.8	6.7
HPV UTD^	48.7	0.66	40.3	7.29	8.5	7.3
HPV UTD among females	53.1	0.97	55.0	9.70	-1.9	9.8
HPV UTD among males	44.5	0.88	31.6	10.13	12.8	10.2

$*$ $p \leq 0.05$.
^ Up-to-date (UTD): ≥3 doses, or ≥2 doses if 1st dose before age 15 and at least 5 months minus 4 days between 1st and 2nd doses.

Since NIS-Teen has never included direct sampling of phoneless adolescents, we study vaccination coverage in the phoneless domain using estimates from the 2012 National Health Interview Survey-Provider Record Check (NHIS-PRC).[9] Table 3.3 shows the vaccination coverage estimates for select vaccines and vaccine series for adolescents from the cell-phone domain versus those who are in the phoneless domain. Caution must be taken due to the very small sample size in the phoneless domain, but estimated differences in vaccination coverage estimates between the cell-phone domain and the phoneless domain are small relative to the standard errors of the differences.

[9] 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 adolescents.

Table 3.3: Vaccination Coverage Estimates and Standard Errors of Select Vaccines and Vaccine Series for Adolescents 13-17 Years 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
1+ Tdap	80.5	0.84	80.9	10.92	-0.4	11.0
1+ MenACWY	71.8	0.98	77.5	10.10	-5.7	10.1
1+ HPV among females[a]	51.7	1.49	41.3	13.06	10.4	13.1

$* \ p \leq 0.05$.

[a] Estimates for HPV vaccination with respect to the current recommendations are not available from the National Health Interview Survey-Provider Record Check, and are not available for males or for the overall adolescent population; the estimates for HPV in table can be presented only for 1+ HPV vaccination among females.

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

$$\boldsymbol{\mu_0 = \mu_1 - q_1}\ , \qquad (7)$$

where $q_1 = p_{1A}(\mu_1 - \mu_{1A})$ equates to sampling-frame coverage error. To fully assess the distribution of total survey error in the NIS-Teen, we will require estimates of the parameters $\hat{p}_{1A}$, $\hat{\mu}_{1A}$, and $\hat{\mu}_1$, and their standard errors, which we will present in Section 3.5. Here we simply observe that $\hat{p}_{1A}$ will be obtained from the landline-only and phoneless columns on the right side of Table 3.1 for 2022 (the most recent year available), and $\hat{\mu}_{1A}$ will be obtained from the results of the 2023 NIS-Teen 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, $\hat{\mu}_1$, will be obtained from the results of the 2023 NIS-Teen and from Sections 3.2 and 3.3 on nonresponse error and measurement error.

As a preliminary assessment of the effect of sampling-frame coverage error, we can estimate the true vaccination coverage estimate ignoring the effects of nonresponse and measurement error. In this circumstance, the NIS-Child vaccination estimate is μ_1. Table 3.4 presents estimates of q_1 and of the true vaccination estimate, μ_0. For all five vaccination coverage estimates, we estimate that sampling-frame coverage error is 0.1 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 Estimate (in %): National Immunization Survey-Teen, United States, 2023

Vaccine	$\hat{\mu}_1$(2023 NIS-Teen % Vaccination Coverage Estimate)	$\hat{q}_1$[a]	$\hat{\mu}_0$(Mean of μ_0, the True 2023 % Vaccination Coverage)	Standard Error of μ_0
1+ Tdap	89.0	0.0	89.0	0.5
1+ MenACWY	88.4	0.0	88.4	0.5
HPV UTD*	61.4	0.1	61.4	0.8
HPV UTD among females	64.0	0.0	64.0	1.1
HPV UTD among males	59.0	0.1	58.9	1.2

* Up-to-date (UTD): ≥3 doses, or ≥2 doses if 1st dose before age 15 and at least 5 months minus 4 days between 1st and 2nd doses.

[a] The estimated sampling-frame coverage error, $\hat{q}_1$, 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-Teen, unit nonresponse error due to not obtaining responses (or completed interviews) for all adolescents sampled and item nonresponse error due to missing questionnaire items among survey respondents. We start this subsection focusing on survey error due to unit nonresponse. We conclude with a review of 2023 NIS-Teen item nonresponse rates. NIS-Teen 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-Teen

Unit nonresponse error in NIS-Teen estimates of vaccination coverage is the error arising because completed interviews and vaccination histories are not obtained for all adolescents sampled. Unit 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 an age-eligible adolescent, (3) failure to complete the telephone interview of an eligible household, and (4) failure to obtain consent to contact the adolescent's vaccination providers or failure to obtain sufficient information from providers to determine the adolescent's vaccination status, given consent. We do not observe the vaccination statuses of adolescents for whom either the household interview is missing or the provider record check is missing. This subsection assesses the extent of nonresponse error

in the 2023 NIS-Teen estimates of vaccination coverage for three different vaccines: 1+ Tdap, 1+ MenACWY, and HPV UTD, with HPV analyzed for the overall population of adolescents and separately for males and females.

Weight Adjustment for Nonresponse Error

NIS-Teen addresses error due to nonresponse by using weight adjustments that correct for known differences between adolescents in responding and nonresponding households based on observable characteristics. Specifically, weighting cells are defined based on sample frame information known for both respondents and nonrespondents, and weights are adjusted by a factor inversely proportional to the response rate 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-Teen weighting methodology is described in detail in Wolter, Smith, Khare 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 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 adolescents with adequate provider data among adolescents in households corresponding to the sampled telephone numbers is needed. The 2023 NIS-Teen realization rate[10] of adolescents with adequate provider data was 2.6 percent with a standard error of 0.02 percentage points. Dividing the realization rate by the sampling-frame coverage rate estimated in Section 3.1 yields an estimate of the proportion of adolescents with adequate provider data among those covered by the sampling frame of also 2.6 percent, or 97.4 percent without adequate provider data, with a standard error of 0.2 percentage points. These two numbers (97.4% with a standard error of 0.2 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-Teen in this instance, with those from leading reference surveys (Biemer, 2010). A reasonable benchmark for the 2023 NIS-Teen is data available from the 2022 NHIS, because it provides representation

[10] 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.

of the same population of adolescents as the NIS-Teen, is known to be a premier health survey of the general population in the United States, is conducted using face-to-face interviewing methods, and has a relatively high response rate, with the final response rate for the Sample Child component in 2022 being 45.8%.[11]

Comparing NIS-Teen estimates to those based on the 2022 NHIS enables estimation of nonresponse error. If nonresponse error is minimal in the NHIS, then the comparison to the NIS-Teen can be taken as a measure of nonresponse error in the NIS-Teen. To ensure comparability to the population covered by the NIS-Teen, we examine NHIS adolescents who are in the corresponding age range and have a working cell-phone in the family.

While the NHIS only includes household reports of vaccination for a small number of vaccine series, we can compare indirect vaccination coverage estimates derived from the NHIS to the direct vaccination coverage estimates derived from NIS-Teen provider reports.[12] We take advantage of the range of variables that are common to both the 2023 NIS-Teen and the 2022 NHIS and produce estimates of nonresponse error for the following vaccination series: 1+ Tdap, 1+ MenACWY, and HPV UTD. Specifically, we estimate logistic regression models for vaccination statuses in the NIS-Teen with variables common to both surveys as independent variables. We then use the fitted models to produce multiple imputations of vaccination statuses for the NHIS case set, using the 2022 NHIS Public Use File.[13] 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-Teen sampling frame and estimate nonresponse error in the NIS-Teen estimates by taking the difference between the NIS-Teen and the NHIS estimates.

We note that a common method for nonresponse 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 final report of the NCES/NISS Task Force on Nonresponse Bias Analysis (National Institute of Statistical Sciences, 2009) recommends conducting multiple imputation when employing such methods to account for the uncertainty in estimates of nonresponse error due to missing data.

Table 3.5 compares the estimates of vaccination coverage based on the NHIS-imputed data and NIS-Teen provider-reported data. Two NIS-Teen 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

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[11] See p. 26 of https://ftp.cdc.gov/pub/Health_Statistics/NCHS/Dataset_Documentation/NHIS/2022/srvydesc-508.pdf

[12] In future NIS-Teen TSE reports, we plan to compare estimates based on household reports of ever being vaccinated for HPV between NIS-Teen and the NHIS.

[13] https://www.cdc.gov/nchs/nhis/data-questionnaires-documentation.htm

the NIS-Teen estimates, before and after weighting adjustments, compare to the estimates based on NHIS imputations. The table further shows the percentage point difference between the NHIS-based estimate and the NIS-Teen 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.

The NIS-Teen estimates based on design weights are 0.3 percentage points lower than the estimates based on NHIS imputations for 1+ Tdap, 0.1 percentage points lower for 1+ MenACWY, and 1.9 percentage points lower for HPV UTD. None of these differences are statistically significant (*p*-values of 0.80, 0.96, and 0.35 respectively), accounting for uncertainty in both the NHIS and NIS-Teen estimates. When examining HPV estimates by sex, the NIS-Teen estimates based on design weights are 1.8 percentage points lower for females (*p*-value 0.48) and 1.9 percentage points higher for males (*p*-value 0.51). For our TSE model, we estimate $\hat{\mu}_{2A}$ and $\hat{\sigma}_{2A}$ by first taking the difference in estimates between (b) the respondent set and (a) the full-response set and then using our estimate of $\hat{p}_{2A}$ above to derive $\hat{\mu}_{2A}$ as an estimate of the vaccination coverage among nonrespondents.

Table 3.5: Estimated Parameters of Nonresponse Error in Vaccination Coverage Estimates (in %) – Comparison of Estimates Derived from the 2023 NIS-Teen the 2022 NHIS

Estimates of Vaccination Coverage and Differences by Data Source and Weighting Method	1+ Tdap	1+ MenACWY	HPV UTD*	HPV UTD among Females	HPV UTD among Males
(a) Estimate Based on NHIS Imputations	89.1	88.6	64.2	65.7	62.8
Standard Error	1.1	1.0	1.9	2.4	2.7
(b) NIS-Teen Estimate (Design Weighted)	88.7	88.6	62.3	63.8	60.9
Standard Error	0.5	0.5	0.7	1.0	1.0
(c) NIS-Teen Estimate (Final Weighted)	89.0	88.4	61.4	64.0	59.0
Standard Error	0.5	0.56	0.8	1.1	1.2
(d) Difference, (b) - (a)	-0.3	-0.1	-1.9	-1.8	-1.9
Standard Error of Difference	1.2	1.1	2.1	2.6	2.9
t-statistic	-0.26	-0.05	-0.93	-0.71	-0.66
p-value (2-sided)	0.80	0.96	0.35	0.48	0.51
(e) Difference, (c) - (a)	-0.1	-0.2	-2.8	-1.7	-3.8
Standard Error of Difference	1.2	1.1	2.1	2.6	2.9
t-statistic	-0.44	-0.17	-1.33	-0.64	-1.30
p-value (2-sided)	0.96	0.87	0.18	0.52	0.19

* Up-to-date (UTD): ≥3 doses, or ≥2 doses if 1st dose before age 15 and at least 5 months minus 4 days between 1st and 2nd doses.

The NIS-Teen estimates based on final weights are 0.1 percentage points lower than the estimates based on NHIS imputations for 1+ Tdap, 0.2 percentage points lower for 1+ MenACWY, and 2.8 percentage points lower for HPV UTD. Examining HPV UTD estimates by sex, NIS-Teen estimates are 1.7 percentage points lower for females and 3.8 percentage points lower for males. While there are differences for HPV UTD estimates, they are not statistically significant at the 10% level. When viewing the estimates based on NHIS imputations (a) as the full-response estimate of vaccination coverage, we find modest evidence of nonresponse bias for HPV UTD, but not for 1+ Tdap nor 1+ MenACWY. For all estimates, the large standard errors and insignificant results from statistical tests reflect uncertainty in our knowledge about the extent of nonresponse error.

One caveat is that the findings depend on the fit of the models used for imputation and the assumption that the conditional distributions of the NHIS case and NIS-Teen 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 large standard errors for estimates based on NHIS imputations. This fact further illuminates the extent of uncertainty in our estimates of nonresponse error.

NIS-Teen Item Nonresponse Rates

Thus far, this subsection has focused on assessing error in vaccination coverage estimates due to unit nonresponse to NIS-Teen. 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. Most item nonresponse rates in this table are low and less than five percent. We also include exact family income, with a higher item nonresponse rate of 25.3%, although 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-Teen Household Interview, United States, 2023

Variable	2023 Item Nonresponse Rate (Percent)*
Sex of adolescent	0.6
Hispanic ethnicity of adolescent	0.4
Race of adolescent with multiple race category	4.7
Education of mother	1.5
Household phone status – landline-only, cell-phone-only, or landline- and cell-phone	0.8
Family income	25.3
Exact income not reported but income cascade completed	17.0
Exact income not reported and income cascade not completed	8.3

* 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 U.S. territories of Guam, Puerto Rico, and the U.S. Virgin Islands.

3.3 Measurement Error

In this subsection, we assess one source of measurement error in the NIS-Teen: provider under-reporting of the adolescent's vaccination status. Throughout, we assume if a provider reported a vaccination for a given adolescent, it was actually given. We consider an adolescent to have under-reported vaccination status if the adolescent is truly up-to-date for the vaccine but the adolescent is classified as not up-to-date based on the vaccination history reported by the adolescent's provider(s). That is, adolescents with under-reporting are up-to-date but are reported as not up-to-date; adolescents 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. All adolescents 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 NIS-Teen sample of adolescents in selected geographic

estimation areas was matched to the state or local IIS. For each of these projects, the NIS-Teen interview requested parental consent to contact both the adolescent's vaccination providers and the local IIS. Adolescents for whom consent was obtained were matched to their respective IIS databases. Then, for the set of matched adolescents, we compared each adolescent's vaccination status based on the provider report(s) to the adolescent'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 adolescent's true vaccination status, and we view the NIS-Teen 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 of the adolescent'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 of the nominated providers responded to the mailed Immunization History Questionnaire, or if respondent providers did not have or report complete vaccination records.

From the match studies, we estimated the proportion of adolescents with under-reported vaccination status. For each given vaccine, we determined the subset of matched adolescents 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-Teen provider-reported vaccination history alone. Then we made the reasonable assumption that equivalency of the measured vaccination statuses is a sign of accurate reporting in the NIS-Teen Provider Record Check. In other words, if the IIS did not add information about vaccination status beyond that already embodied within the NIS-Teen provider-reported data, then we took the NIS-Teen data to be accurate (not under-reported). If the adolescent was up-to-date based on the combined (provider and IIS) vaccination history but not up-to-date based on the NIS-Teen vaccination history alone, then we classified the adolescent as having an under-reported vaccination status in the NIS-Teen. Among the adolescents with adequate NIS-Teen provider data that were in the IIS and had two or more doses in the IIS, we estimated the NIS-Teen 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-Teen are the match projects completed in 2017 and 2019. In 2017, match projects were conducted in 20 jurisdictions: Arkansas, 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 eight jurisdictions: Arkansas, Kansas, Louisiana, Missouri, Nevada, New York City, Vermont, and Washington. Because only a subset of jurisdictions participated in match projects, we estimated the standard error of the estimated under-reporting rate by treating each selected IIS as a cluster sampled from the population of IIS in the United States.

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: NIS-Teen, United States, 2017 and 2019

Vaccine	Under-reporting Error	
	Estimate (percentage points)	Standard Error (percentage points)
1+ Tdap	4.7	0.33
1+ MenACWY	4.1	0.33
HPV UTD*	2.5	0.25
HPV UTD among females	2.3	0.33
HPV UTD among males	2.5	0.38

Note: National-level under-reporting in NIS-Teen provider-reported vaccination status was estimated using data from the 2017 and 2019 IIS-NIS Match Projects. Among adolescents 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-Teen vaccination history alone were considered to have under-reported NIS-Teen vaccination status.
* Up-to-date (UTD): ≥3 doses, or ≥2 doses if 1st dose before age 15 and at least 5 months - 4 days between 1st and 2nd doses

3.4 Sampling Error

Sampling error arises from the fact that we observe only a random sample of the adolescent population, not the entire population. Table 3.8 presents estimated vaccination coverage and corresponding standard errors for 2023 NIS-Teen at the national level. We calculated the standard errors using the Taylor series method, 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 noncoverage, nonresponse, nor calibration to population control totals. Final weights are the design weights, with adjustments for noncoverage, nonresponse, and calibration to population control totals.

The national-level standard errors for these five vaccination coverage estimates are small, ranging from approximately 0.5 to 1.2 percentage points.

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

	Design Weight		Final Weight	
Vaccine	**Estimate (%)**	**Standard Error (percentage points)**	**Estimate (%)**	**Standard Error (percentage points)**
1+ Tdap	88.7	0.5	89.0	0.5
1+ MenACWY	88.6	0.5	88.4	0.5
HPV UTD*	62.3	0.7	61.4	0.8
HPV UTD among females	63.8	1.0	64.0	1.1
HPV UTD among males	60.9	1.0	59.0	1.2

Note: Excludes U.S. territory samples in Guam, Puerto Rico, and the U.S. Virgin Islands.
* Up-to-date (UTD): ≥3 doses, or ≥2 doses if 1st dose before age 15 and at least 5 months minus 4 days between 1st and 2nd doses

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) to develop our estimates of TSE for estimated vaccination coverage corresponding to 1+ Tdap, 1+ MenACWY, and HPV UTD, both overall and separately for males and females. 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-Teen. These values arise from the analyses described in Sections 3.2 through 3.4 above.[14] We assume the logit transformations of the inputs are normally distributed and independent (i.e., no covariance between inputs).

[14] $\hat{\mu}_{1A}$ and $\hat{\mu}_{2A}$, which were estimated based on the NHIS-PRC and models built from NIS-Teen 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 3.9: Total Survey Error Model Inputs by Stages: NIS-Teen, United States, 2023

Parameter	1+ Tdap	1+ MenACWY	HPV UTD*	HPV UTD among Females	HPV UTD among Males
Stage 1: Sampling-Frame Coverage Error					
$\hat{p}_{1A}$	0.7%	0.7%	0.7%	0.7%	0.7%
$\hat{\sigma}_{p1A}$	0.2%	0.2%	0.2%	0.2%	0.2%
$\hat{\mu}_{1A}$	93.1%	90.7%	54.3%	61.2%	50.2%
$\hat{\sigma}_{\mu 1A}$	6.7%	7.0%	8.3%	9.0%	9.0%
Stage 2: Nonresponse Error					
$\hat{p}_{2A}$	97.4%	97.4%	97.4%	97.4%	97.4%
$\hat{\sigma}_{p2A}$	0.2%	0.2%	0.2%	0.2%	0.2%
$\hat{\mu}_{2A}$	93.8%	92.7%	66.7%	68.0%	65.5%
$\hat{\sigma}_{\mu 2A}$	1.2%	1.1%	2.0%	2.5%	2.8%
Stage 3: Measurement Error					
$\hat{p}_{3A}$	4.7%	4.1%	2.5%	2.3%	2.6%
$\hat{\sigma}_{p3A}$	0.3%	0.3%	0.3%	0.3%	0.4%
$\hat{\mu}_{3A}$	100.0%	100.0%	100.0%	100.0%	100.0%
$\hat{\sigma}_{\mu 3A}$	0.0%	0.0%	0.0%	0.0%	0.0%
$\hat{\mu}_{3}$	93.1%	92.4%	63.9%	65.3%	62.6%
$\hat{\sigma}_{\mu 3}$	0.6%	0.6%	0.7%	1.1%	1.0%

* Up-to-date (UTD): ≥3 doses, or ≥2 doses if 1st dose before age 15 and at least 5 months minus 4 days between 1st and 2nd doses.

Table 3.10 presents the means and 95% credible intervals of total survey error distributions and component error distributions based on 10,000 Monte Carlo draws from the input (or component) error distributions and application of the TSE model set forth in equations (1) - (6). The means of the estimated TSE distributions are -4.6 percentage points for 1+ Tdap, -4.2 percentage points for 1+ MenACWY, -5.2 percentage points for HPV UTD, -3.9 percentage points for HPV UTD among females, and -6.2 percentage points for HPV UTD among males. The 95% credible interval for HPV UTD among females total error includes 0. These results suggest that the 2023 NIS-Teen may have somewhat underestimated the true vaccination

coverage for 1+ Tdap, 1+ MenACWY, HPV UTD, and HPV UTD among males. The largest estimated component of error in absolute value for all four series is measurement error, i.e., provider under-reporting error. Nonresponse error estimates are also moderate in absolute value for the HPV UTD estimates, though the 95% credible intervals for nonresponse error include 0 for all series.

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

Vaccine or Series	Component	Mean TSE (percentage points)	95% Credible Interval (percentage points)
1+ Tdap	TSE (final weighted)	-4.6	(-6.7, -2.0)*
	TSE (design weighted)	-4.9	(-6.9, -2.2)*
	Noncoverage error	0.0	(0.0, 0.2)
	Nonresponse error	-0.2	(-2.6, 2.6)
	Measurement error	-4.7	(-5.8, -3.5)*
	Sampling error	0.0	(-1.2, 1.4)
1+ MenACWY	TSE (final weighted)	-4.2	(-6.1, -1.9)*
	TSE (design weighted)	-4.1	(-6.0, -1.8)*
	Noncoverage error	0.0	(0.0, 0.2)
	Nonresponse error	-0.0	(-2.2, 2.5)
	Measurement error	-4.1	(-5.2, -2.9)*
	Sampling error	0.0	(-1.2, 1.3)
HPV UTD^	TSE (final weighted)	-5.2	(-8.8, -1.3)*
	TSE (design weighted)	-4.3	(-7.9, -0.4)*
	Noncoverage error	0.1	(0.0, 0.2)
	Nonresponse error	-1.9	(-5.9, 2.2)
	Measurement error	-2.5	(-3.9, -1.0)*
	Sampling error	0.0	(-1.4, 1.5)
HPV UTD among females	TSE (final weighted)	-3.9	(-8.3, 0.9)
	TSE (design weighted)	-4.0	(-8.4, 0.7)
	Noncoverage error	0.1	(-0.1, 0.2)
	Nonresponse error	-1.8	(-6.7, 3.3)
	Measurement error	-2.3	(-4.3, -0.2)*
	Sampling error	0.0	(-2.0, 2.1)
HPV UTD among males	TSE (final weighted)	-6.2	(-11.3, -0.8)*
	TSE (design weighted)	-4.3	(-9.4, 1.2)
	Noncoverage error	0.1	(0.0, 0.3)
	Nonresponse error	-1.8	(-7.4, 4.0)
	Measurement error	-2.6	(-4.6, -0.5)*
	Sampling error	0.0	(-2.1, 2.1)

* 95% credible interval does not include 0.
^ Up-to-date (UTD): ≥3 doses, or ≥2 doses if 1st dose before age 15 and at least 5 months minus 4 days between 1st and 2nd doses.

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

In the previous subsection, we assessed TSE in the 2023 NIS-Teen estimated vaccination coverage, while in the current subsection, we assess the change in TSE between vaccination coverage estimates produced from the 2022 and 2023 NIS-Teen samples. Change is measured using the bridging cohort method first described in Yankey, Hill, Elam-Evans et al. (2015).

Each survey quarter includes adolescents born within 21 quarterly birth cohorts. Every pair of adjacent survey quarters spans 22 quarterly birth cohorts, of which 20 are in common and 2 are not in common. In turn, every survey year includes adolescents born within 24 quarterly birth cohorts. Every pair of adjacent survey years spans 28 quarterly birth cohorts, of which 20 are in common and 8 are not in common. We shall call the common quarters the *bridging cohort*, and for 2022 and 2023, the bridging cohort extends from adolescents born in Q1 2005 through adolescents born in Q4 2009.

Consider a vaccination series with coverage estimated from the bridging cohort as of a given adolescent age, such as 13 years. Two estimates are possible, one using the sample of adolescents in the bridging cohort within the 2022 NIS-Teen sample and the second using the corresponding sample of adolescents within the 2023 NIS-Teen sample. Ideally, the two estimators should exhibit the same mean value. A large difference between the two estimates may signal a change in the expectation of the estimator 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 estimated vaccination estimates for adolescents as of 13 years of age for the 2022-2023 bridging cohort. 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.

Summarizing, we find evidence of a change in mean TSE between 2022 and 2023. The estimates for all five vaccine series are between 1.6 and 2.9 percentage points lower for the 2023 bridging birth cohort than for 2022. The differences for 1+ Tdap and 1+ MenACWY are statistically significant at the 5% level with *p*-values of 0.002 and 0.023 respectively. In addition, the overall difference for HPV UTD is statistically significant at the 10% level with a *p*-value of 0.067.

Table 3.11: Difference between the Estimates* for the Bridging Birth Cohort: NIS-Teen, United States, 2022 vs. 2023

	2022		2023		Difference		
Description	**Estimate**	**Standard Error**	**Estimate**	**Standard Error**	**Estimate**	**Standard Error**	***p*-value for Test of No Difference**
1+ Tdap by 13 years	85.8	0.62	82.9	0.70	-2.9	0.94	0.002
1+ MenACWY by 13 years	83.6	0.75	81.2	0.72	-2.4	1.04	0.023
HPV UTD[&] by 13 years	38.3	0.90	36.1	0.81	-2.2	1.21	0.067
HPV UTD by 13 years among females	39.8	1.26	38.2	1.17	-1.6	1.72	0.340
HPV UTD by 13 years among males	36.8	1.29	34.0	1.11	-2.8	1.70	0.106

* Estimates were computed among adolescents with adequate provider data, excluding U.S. territories. The bridging birth cohort used for this analysis includes adolescents born between January 2005 and December 2009. Final provider-phase weights for 2022 were ratio-adjusted within each monthly birth cohort such that their sum within monthly birth cohort equals the sum of the final provider-phase weights for 2023 within the corresponding monthly birth cohort.

[&] Up-to-date (UTD): ≥3 doses, or ≥2 doses if 1st dose before age 15 and at least 5 months minus 4 days between 1st and 2nd doses

NIS-Teen vaccination coverage estimates are based on vaccination histories reported in the Provider Record Check (PRC). The lower vaccination coverage estimates for the bridging birth cohort from the 2023 sample versus the 2022 sample may have stemmed, in part, from a shortened data collection period for the NIS-Teen PRC in 2023 compared to 2022. Data collection for the NIS-Teen PRC was closed a month earlier for the 2023 sample than for the 2022 sample. This led to lower a PRC return rate[15] and a higher proportion of adolescents with adequate provider data having partial provider data[16] in 2023 than in 2022, as shown in Table 3.12.

The higher proportion of adolescents with partial provider data may have resulted in a higher proportion having incomplete vaccination histories in 2023 compared with 2022. This would be an increase in measurement error as described in Section 3.3 above. If an adolescent has an

[15] The PRC return rate is the number of adolescent-provider pairs for which a PRC Immunization History Questionnaire (IHQ) was mailed divided by the number for which PRC data were returned.

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

incomplete vaccination history reported in the PRC, then that adolescent could be classified as not vaccinated for a particular vaccine or vaccine series even if the adolescent is truly vaccinated.

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

Measure	2022	2023
PRC return rate*	88%	85%
Percent of adolescents with adequate provider data who have partial provider data†	33%	37%

* The PRC return rate is the number of adolescent-provider pairs for which an Immunization History Questionnaire (IHQ) was mailed divided by the number for which PRC data were returned.
† An adolescent with adequate provider data has partial provider data if the number of providers that returned vaccination data for the adolescent is less than the number of vaccination providers nominated for the adolescent by the respondent in the household interview.

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 adolescents with “complete” provider data, i.e., on adolescents for whom all providers nominated during the household interview returned vaccination data in the PRC. When limiting to adolescents with complete provider data, the differences in vaccination coverage estimates for the bridging birth cohort between the 2022 and 2023 samples are generally reduced, and no differences are statistically significant at the 5% level. This suggests that at least a portion of the change in mean TSE between the 2022 and 2023 samples as measured using the bridging birth cohort method is due to the higher rate of adolescents with partial provider data in the 2023 sample.

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

	2022		2023		Difference		
Description	**Estimate**	**Standard Error**	**Estimate**	**Standard Error**	**Estimate**	**Standard Error**	***p*-value for Test of No Difference**
1+ Tdap by 13 years	87.7	0.73	85.6	0.82	-2.1	1.10	0.057
1+ MenACWY by 13 years	85.4	0.95	83.9	0.86	-1.4	1.28	0.259
HPV UTD& by 13 years	39.7	1.09	37.8	1.04	-1.9	1.51	0.217
HPV UTD by 13 years among females	41.9	1.58	40.2	1.52	-1.7	2.19	0.446
HPV UTD by 13 years among males	37.5	1.51	35.5	1.40	-2.0	2.06	0.335

* Estimates were computed among adolescents with adequate provider data, excluding U.S. territories. The bridging birth cohort used for this analysis includes adolescents born between January 2005 and December 2009. Final provider-phase weights for 2022 were ratio-adjusted within each monthly birth cohort such that their sum within monthly birth cohort equals the sum of the final provider-phase weights for 2023 within the corresponding monthly birth cohort.

† An adolescent has complete provider data if the number of providers that returned vaccination data for the adolescent equals the number of vaccination providers nominated for the adolescent by the respondent in the household interview.

& Up-to-date (UTD): ≥3 doses, or ≥2 doses if 1st dose before age 15 and at least 5 months minus 4 days between 1st and 2nd doses.

4. Summary

We profiled the sources of error in 2023 NIS-Teen statistics at the national level (excluding U.S. territories of Guam, Puerto Rico, and U.S. Virgin Islands) for the total age-eligible population of adolescents. We compared NIS-Teen 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-Teen. 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-Teen.

In Part I, we compared NIS-Teen demographic distributions (age, sex, race/ethnicity, mother's education, mother's age) to values that have been established as benchmarks derived from the U.S. Census Bureau's PEP and ACS data. When using design weights that have not been calibrated to external population totals, demographic distributions as estimated by the survey are generally close to the benchmark distributions. Before calibration, the NIS-Teen somewhat over-represented non-Hispanic White-only adolescents, under-represented Hispanic adolescents, and over-represented adolescents whose mothers are college graduates. When using final weights that have been calibrated to external population totals, the differences between survey estimates and population values narrowed, but the 2023 NIS-Teen still over-represented adolescents whose mothers are college graduates and under-represented adolescents whose mothers have some college but not a four-year degree.

We compared NIS-Teen vaccination coverage estimates to IISAR vaccination coverage estimates and found that there is variation in the level of agreement between NIS-Teen and IISAR vaccination coverage estimates. Further, we determined that the adolescent participation rate is a reasonable indicator of the quality of the corresponding IIS database. We learned that the difference between NIS-Teen and IISAR vaccination coverage estimates declines as the adolescent participation rate increases (i.e., as the quality of the IIS increases). The findings are consistent with the view that IIS vaccination coverage estimates converge towards NIS-Teen vaccination estimates as the quality of the IIS increases. Differences may be due to missing data from state IIS and/or under-ascertainment by state IIS, but may also be due to differential error for NIS-Teen estimates.

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

Finally, we compared NIS-Teen vaccination coverage estimates to comparable statistics from two state IIS: Iowa and Oregon. For both states, NIS-Teen coverage estimates were higher than the IIS estimates for HPV.

In Part II of the report, we evaluated NIS-Teen vaccination coverage estimates with respect to sample-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.

The NIS-Teen cell-phone RDD sampling frame fails to include the LLO and phoneless populations, and we assessed vaccination coverage estimates in the former using data collected in the 2017 NIS-Teen and in the latter using data collected in the 2012 NHIS PRC. The vaccination coverage estimates in the LLO population tended to be less than the vaccination coverage estimates in the population included in the sampling-frame, and the results were somewhat mixed with regard to the phoneless 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 0.1 percentage points or less for each of the vaccine series examined.

We compared the 2022 NHIS and 2023 NIS-Teen to assess nonresponse error in the 2023 NIS-Teen. The NHIS does not offer direct estimates of vaccination coverage. Instead, we used a model-based technique to impute NHIS vaccination status and then compared the resulting NHIS vaccination coverage estimates (treated as vaccination coverage estimates void of nonresponse error) to NIS-Teen vaccination coverage estimates, with the difference treated as nonresponse error in the NIS-Teen. 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 age-eligible sample of households, the household failed to respond to the NIS-Teen, the household responded but did not grant consent to obtain vaccination data from the adolescent's vaccination providers, or consent was granted but an adequate provider-reported vaccination history for the adolescent was not obtained. We estimated mean nonresponse error in vaccination coverage estimates to be near zero for 1+ Tdap and 1+ MenACWY and -2 percentage points (design-weighted) for HPV. However, results were not statistically significant for any of the vaccine series examined.

We used 20 IIS-NIS match studies conducted in 2017 and eight additional match studies conducted in 2019 to assess measurement error, or under-ascertainment, in the NIS-Teen vaccination coverage estimates. In this work, the standard of truth for a given child is taken to be the synthesis of the NIS-Teen and IIS vaccination histories. We found measurement error was by far the largest component of error in NIS-Teen vaccination coverage estimates. We found measurement error depressed observed vaccination coverage estimates by about two to five percentage points, and these findings were statistically significant. Under-ascertainment of adolescent vaccination history may arise due to the failure of the household respondent to nominate all of the adolescent'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 adolescent has received.

We combined all the component errors and assessed the distribution of total survey error in the NIS-Teen vaccination coverage estimates, using a Monte Carlo technique. For the 1+ Tdap vaccination coverage estimate, we found the mean of the TSE distribution to be -4.6 percentage points with a 95% credible interval of (-6.7, -2.0) percentage points. That is, the NIS-Teen vaccination coverage estimate was on average about 4.6 percentage points too low. For the 1+ MenACWY vaccination coverage estimate, we found the mean of the TSE distribution to be -4.2 percentage points with a 95% credible interval of (-6.1, -1.9) percentage points, and for the HPV UTD vaccination coverage estimate, we found the mean of the TSE distribution to be -5.2 percentage points with a credible interval of (-8.8, -1.3) percentage points. Again, under-ascertainment of the provider-reported vaccination history dominated total survey error. Estimates of nonresponse error have wider 95% credible intervals reflecting that those estimates have larger uncertainty than other error components.

Finally, using the bridging cohort method, we assessed a change in bias between 2022 and 2023 NIS-Teen by comparing vaccination coverage estimates for adolescents born between the first quarter of 2005 and the fourth quarter of 2009 available from both survey years. In conducting comparisons for five key vaccination coverage estimates, we found evidence of a change of bias with a change in vaccination coverage estimates of -2.9 percentage points for 1+ Tdap by 13 years (p-value 0.002), -2.4 percentage points for 1+ MenACWY by 13 years (p-value 0.023), and -2.2 percentage points for HPV UTD by 13 years (p-value 0.067). We describe evidence suggesting that some of the change in these estimates is due to a higher proportion of adolescents having partial provider data in 2023.

Our results for the 2023 NIS-Teen 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-Teen. Our comparison of NIS-Teen and IISAR vaccination coverage estimates is limited to 1+ Tdap, 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 the information on components errors are the NHIS and state or local IIS. The NHIS is based on a smaller sample size than the NIS-Teen, 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-Teen Provider Record Check, and it is subject to its own nonresponse and sampling-frame coverage errors. To study nonresponse error in the NIS-Teen, 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., to 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 only 22 areas across 28 studies. 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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