National Immunization Survey-Teen

Error Profile for the 2022 NIS-Teen

Centers for Disease Control and Prevention

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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 2022 NIS-Teen estimated vaccination coverage at the national level. 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 2022 NIS-Teen and of the change in TSE between the 2021 and 2022 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 among the total age-eligible population, among females, and among males. Assessments are conducted at the national level (50 states plus District of Columbia).

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). Third, we compare health insurance distributions derived from the NIS-Teen Health Insurance Module (HIM) to corresponding benchmark distributions obtained from (i) the National Health Interview Survey (NHIS), (ii) the ACS, and (ii) the Current Population Survey Annual Social and Economic Supplement (CPS ASEC). Finally, we compare NIS-Teen vaccination coverage estimates to those available from state immunization surveys from Georgia and Kansas, and we discuss literature comparing NIS-Teen vaccination coverage estimates to independent estimates based on immunization information systems for Florida and Wisconsin.

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, higher quality sources. 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 to 17 in 2022, we began by obtaining PEP data for 2021 by the combination of state, single year of age (12 to 16 in 2021), sex, and race/ethnicity (These data are made available from the Census Bureau at approximately a one-year lag, and the 2021 estimates were the most recent available at this writing). 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 13-17 years was estimated using the combined 2019, 2020, and 2021 one-year ACS Public-Use Microdata Sample (PUMS); 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 2021 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, 2021) for the 2021 PEP counts and the midpoint of the reference year (July 1, 2022) for the 2022 NIS-Teen.

We produced 2022 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 2022 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 (57.3 percent in survey, 50.2 percent in population) and Hispanic adolescents (19.1 percent in survey, 25.7 percent in population). These differences are substantially smaller when final weights are used (25.6 percent survey estimate for Hispanic adolescents, 25.7 percent in population; 48.5 percent survey estimate for non-Hispanic White only adolescents, 50.2 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, and other (including non-Hispanic White) – and in some geographic areas categories for calibration may be collapsed due to small sample sizes.

Differences between survey estimates and population values are observed for mother's education. The survey over-represents adolescents whose mothers have a four-year college degree when the design weights are used (51.9 percent in survey, 37.4 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 (44.2 percent in survey, 37.4 percent in population) and under-represents adolescents whose mothers have some college (23.3 percent in survey, 30.3 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.)

Table 2.1: One-Way Demographic Distributions Among Adolescents with Adequate Provider Data vs. Population Control: NIS-Teen, United States, 2022

		Design Weighted		Final Weighted*	
Demographic	Population Percentage	Survey Estimate	Survey Estimate – Population Percentage	Survey Distribution	Survey Estimate – Population Percentage
Adolescent Age					
13 years	19.7	19.7 ± 1.1	0.1 ± 1.1	20.7 ± 1.3	1.0 ± 1.3
14 years	20.4	19.4 ± 1.1	-1.0 ± 1.1	19.4 ± 1.1	-1.0 ± 1.1
15 years	20.3	20.4 ± 1.1	0.1 ± 1.1	20.2 ± 1.2	-0.1 ± 1.2
16 years	19.9	21.5 ± 1.2	1.6 ± 1.2	20.6 ± 1.2	0.6 ± 1.2
17 years	19.7	18.9 ± 1.1	-0.7 ± 1.1	19.2 ± 1.1	-0.5 ± 1.1
Adolescent Sex					
Male	51.2	52.6 ± 1.4	1.4 ± 1.4	51.2 ± 1.5	0.0 ± 1.5
Female	48.8	47.4 ± 1.4	-1.4 ± 1.4	48.8 ± 1.5	0.0 ± 1.5
Adolescent Race/Ethnicity					
Hispanic	25.7	19.1 ± 1.1	-6.6 ± 1.1	25.6 ± 1.4	-0.1 ± 1.4
Non-Hispanic White only	50.2	57.3 ± 1.4	7.1 ± 1.4	48.5 ± 1.4	-1.7 ± 1.4
Non-Hispanic Black only	13.7	11.3 ± 1.0	-2.5 ± 1.0	13.6 ± 1.0	-0.1 ± 1.0
Other	10.4	12.4 ± 0.9	2.0 ± 0.9	12.3 ± 0.9	1.9 ± 0.9
Mother Education					
Less than high school	11.9	6.6 ± 0.7	-5.4 ± 0.7	11.5 ± 1.2	-0.4 ± 1.2
High school	20.4	15.7 ± 1.0	-4.7 ± 1.0	21.0 ± 1.3	0.6 ± 1.3
Some college	30.3	25.9 ± 1.2	-4.4 ± 1.2	23.3 ± 1.2	-7.1 ± 1.2
4-year college graduate	37.4	51.9 ± 1.4	14.5 ± 1.4	44.2 ± 1.4	6.9 ± 1.4
Mother Age					
< 35 years	7.6	5.3 ± 0.5	-2.3 ± 0.5	7.0 ± 0.8	-0.6 ± 0.8
35-44 years	46.8	43.5 ± 1.4	-3.4 ± 1.4	43.4 ± 1.4	-3.5 ± 1.4
>= 45 years	45.6	51.2 ± 1.4	5.7 ± 1.4	49.6 ± 1.5	4.1 ± 1.5

Note: Excludes U.S. territory samples.
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, 15-17), adolescent sex (male, female), adolescent race/ethnicity (Hispanic, non-Hispanic Black only, other), 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.

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, and race/ethnicity are all less than 5.0 percentage points when final weights are used.

2.2 Comparison of NIS-Teen and IISAR Vaccination Coverage Estimates

This section compares NIS-Teen vaccination coverage estimates to Immunization Information System Annual Report (IISAR) data in 2021.[1] The comparison is given for estimates for coverage of the 1+ Tdap vaccine using the data available from IISAR, recognizing that the findings may not apply to other vaccine series. 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 at least one or both sources are 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) [2] Adolescent Participation Rate (APR). Finally, we demonstrate through regression analysis that the difference between the 1+Tdap vaccination coverage estimates in NIS-Teen and IISAR is related to the APR.

What is IISAR?

The IISAR is an annual assessment of IIS activity among the 64 immunization program awardees, which include the 50 states, 6 cities (Chicago, District of Columbia, Houston, New York City, Philadelphia and San Antonio), and 8 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, 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.

[1] https://www.cdc.gov/vaccines/programs/iis/annual-report-iisar/overview.html

[2] State IIS are computer databases that aspire to contain information about all of the doses of all vaccines administered to all adolescent residents within the state. It is known that different state IIS vary in their completeness of both adolescents and the doses they received. https://www.cdc.gov/vaccines/programs/iis/about.html

NCIRD provides competitive supplemental funds to grantees that have achieved consistently high standards. During the period 2013-2017, six grantees were recognized as *sentinel sites*, including Michigan, Minnesota, North Dakota, New York City, Oregon, and Wisconsin.[3] Because of the higher standards they achieved regarding participation rates and other indicators of IIS quality, vaccination coverage estimates reported in IISAR by sentinel sites are thought to be relatively more accurate than vaccination estimates reported by non-sentinel sites. In this analysis, the sentinel sites are mentioned as *2013-2017 sentinel sites*.

In what follows, we compare 2021 NIS-Teen vaccination estimates to 2021 IISAR vaccination estimates. Because 2022 IISAR vaccination coverage estimates are not available as of this writing, the 2021 comparison will serve as the most current information available about the relative accuracy of the 2022 NIS-Teen.

Visual Comparison of Vaccination Coverage Estimates

Figures 2.1 and 2.2 display plots of the NIS-Teen vaccination coverage estimate versus the IISAR vaccination coverage estimate for 1+ Tdap for the year 2021. Figure 2.1 includes only 56 of the estimation areas used in the NIS-Teen; it does not include points corresponding to 8 U.S. territories. Figure 2.2 includes only the six 2013-2017 sentinel sites. Some of the areas are missing from some of the plots due to missing values in the IISAR. IISAR vaccination coverage estimates use 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, for example if adolescents in the IIS have moved away from the area.

In all plots, 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 plots reveal that in some areas the NIS-Teen vaccination coverage estimates are greater than the IISAR estimates and vice versa. There is reasonably good agreement between the two estimates in five of the six 2013-2017 sentinel sites; in New York City, the IISAR estimate is much greater than 100 percent, possibly because the IIS contains many adolescents not currently living in New York City. Generally, IISAR vaccination coverage estimates tend to be lower in non-sentinel areas. For IIS that achieve high standards, NIS-Teen and IISAR vaccination estimates are reasonably similar.

[3] https://www.cdc.gov/vaccines/programs/iis/activities/sentinel-sites.html

Figure 2.1: Scatterplot of NIS-Teen (in %) v. IISAR (in %) Vaccination Coverage Estimates for 1+ Tdap: 56 Estimation Areas, 2021

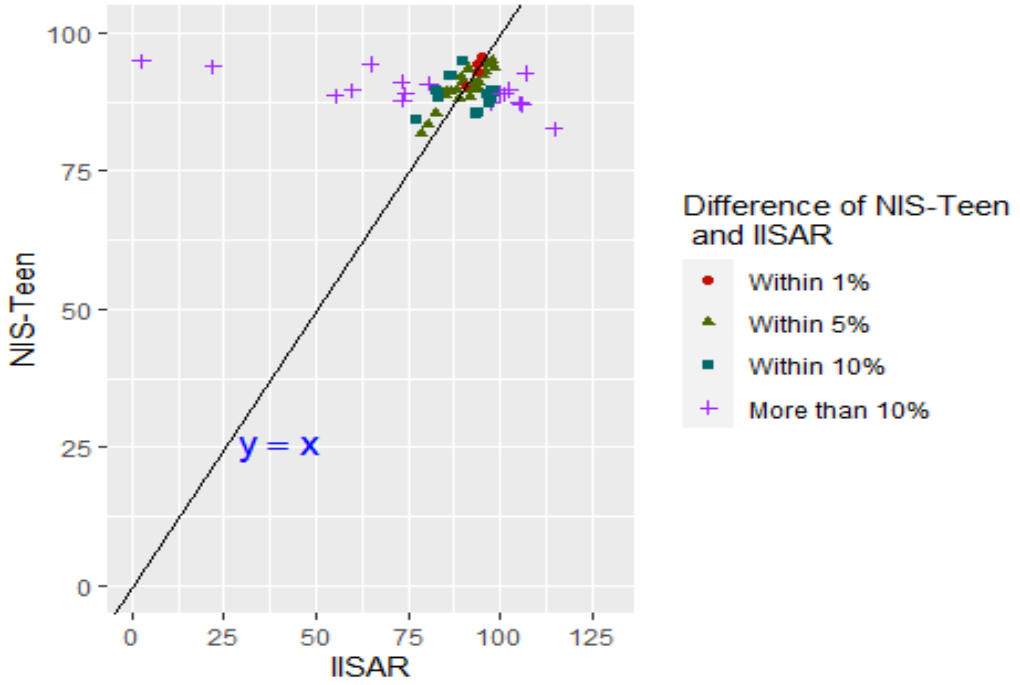
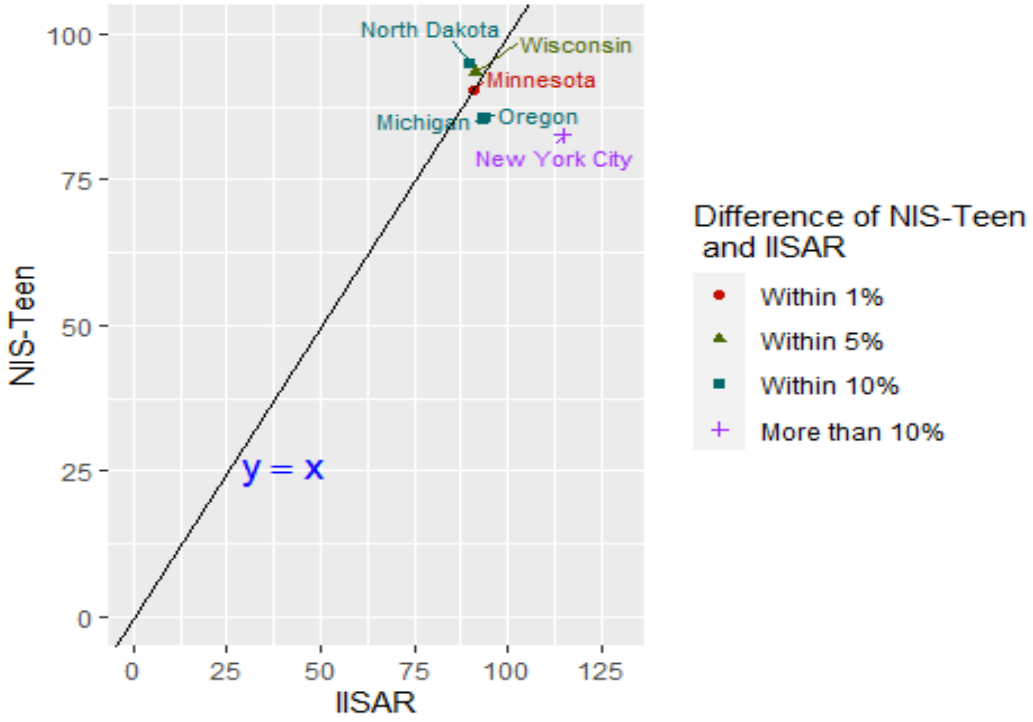


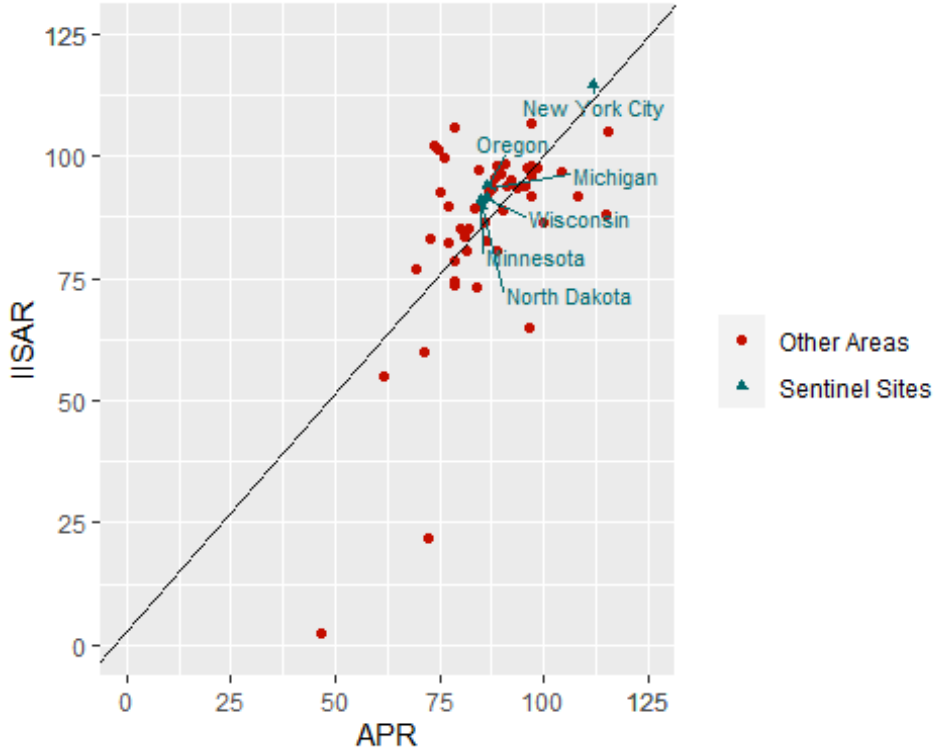
Figure 2.2: Scatterplot of NIS-Teen (in %) v. IISAR (in %) Vaccination Coverage Estimates for 1+ Tdap: Six 2013-2017 Sentinel Sites, 2021



Adolescent Participation Rate (APR)

To test the hypothesis that increasing quality of a state's IIS data implies increasing agreement between the NIS-Teen and IISAR vaccination estimates, we introduce the APR[4] and evaluate it as a possible measure of the quality of the IIS. In Figure 2.3, we plot the IISAR vaccination coverage estimate for 1+ Tdap versus the APR for the year 2021, including the 56 core estimation areas. Points for the six 2013-2017 sentinel sites are labeled, and these sites are generally located in the upper right corner of the plot, corresponding to higher values of APR and the IISAR vaccination estimate. Note that the IISAR APR use 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 2.3: Scatterplot of IISAR (in %) Vaccination Coverage Estimate for 1+ Tdap v. APR (in %): 56 Estimation Areas, 2021



We fit a linear regression model to the points in Figure 2.3, 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 0.656 with a 95% confidence interval of [0.475, 0.784]. We conclude that APR is positively associated with the

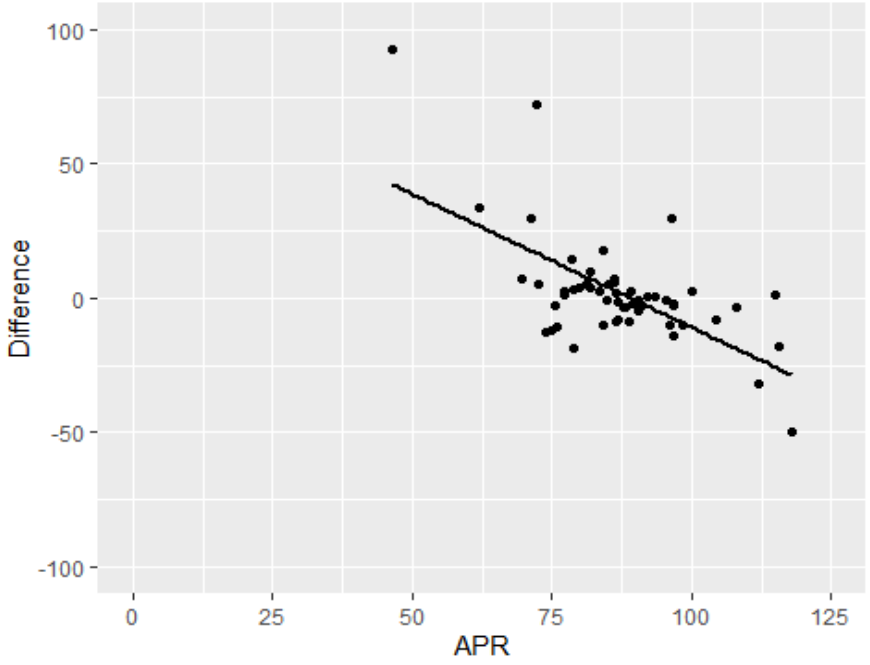
[4] Proportion of adolescents in the area who have two or more doses of any vaccine recorded in the IIS relative to a U.S. Census Bureau count of adolescents living in the area. This can result in some APR values being greater than 100 percent.

completeness of the vaccination histories of the adolescents. APR appears to be a reasonable, but not necessarily comprehensive, measure of the quality of data in the IIS databases.

Negative Relationship between Difference in Vaccination Coverage and APR

We conducted further evaluation of the hypothesis that increasing quality of state IIS data is associated with increasing agreement between the NIS-Teen and IISAR vaccination coverage estimates. Specifically, taking APR to be the 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 2.4 presents the scatter plot of the difference versus the APR for the set of 56 core estimation areas in 2021, 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 (-0.99 percentage points with a 95% confidence interval of [-1.32, -0.66]), 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 potentially supporting the accuracy of the NIS-Teen vaccination coverage estimates.

Figure 2.4: Scatterplot of the Difference (NIS-Teen minus IISAR) (in %) v. APR (in %) with Regression Line: 56 Estimation Areas, 2021



We conducted an additional analysis pooling the data over the period 2016 to 2021 to achieve greater precision and regressed the difference between NIS-Teen and IISAR vaccination coverage estimates on APR, dummy variables for year, and state dummy variables. Similar to the 2021 only results in Figure 2.4, the pooled results showed that APR has a statistically significant, negative relationship with the difference, with a regression slope coefficient of -0.90 percentage points with a 95% confidence interval of [-0.98, -0.82].

Summarizing, we have presented evidence in this section that APR is a reasonable, though not comprehensive, measure of the quality of IIS adolescent data. As state IIS data quality indicators improve, the difference between the NIS-Teen and IISAR vaccination coverage estimates declines. Because NIS-Teen uses a consistent methodology in all areas, it may be reasonable to extrapolate this finding and suggest that IISAR and NIS-Teen vaccination coverage estimates would tend to agree in all areas, if the IIS was of consistently high quality in all areas.

2.3 Comparison of Adolescent 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 of the table, we provide an overview of each data source.

Table 2.2: Comparison of Alternative Estimates of Health Insurance Coverage Among Adolescents: NIS-Teen, ACS, CPS ASEC, and NHIS for 2021 and NIS-Teen and CPS ASEC for 2022

Type of Health Insurance Coverage	2021				2022	
	ACS	CPS ASEC	NHIS	NIS-Teen[a]	CPS ASEC	NIS-Teen[a]
Any private[b]	61.3%	63.5%	56.0%	65.3%	63.1%	62.8%
Any public[c]	38.8%	34.8%	41.4%	41.0%	36.5%	44.1%
Uninsured[d]	5.8%	6.7%	4.8%	3.0%	5.5%	3.4%

[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, CHIP, Indian Health Service, TRICARE, CHAMPUS and CHAMP-VA.
[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.

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 by the adolescent population aged 13 to 17 years based on the 2021 ACS[5] 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 2021 and 2022 CPS ASEC[6], national-level estimates of the health insurance distribution in 2021 and 2022 among adolescents aged 13 to 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[7] national-level estimates of the health insurance distribution in 2021 for adolescents aged 13 to 17 years are shown in Table 2.2, as 2021 is the most recently available NHIS data. In the NHIS, health insurance status is assessed as of the time of the interview.

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, CPS ASEC, and NHIS for the privately-insured population for 2021 and similar to the CPS ASEC estimate for 2022. We find the estimates for public health insurance in NIS-Teen to be larger than the corresponding estimates from ACS and CPS ASEC in 2021, about the same as the NHIS for 2021, and larger than the CPS ASEC estimate for 2022. 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 2021 and also less than the CPS ASEC estimate for 2022. 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.

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[5] US Census Bureau. 2021 ACS PUMS Data. Retrieved from https://www.census.gov/programs-surveys/acs/microdata/access/2021.html

[6] US Census Bureau. 2021 and 2022 CPS ASEC dataset. Retrieved from https://www.census.gov/data/datasets/time-series/demo/cps/cps-asec.html

[7] NHIS - Data, Questionnaires and Related Documentation. Retrieved from https://www.cdc.gov/nchs/nhis/data-questionnaires-documentation.htm

2.4 Comparison of Vaccination Coverage Estimates: NIS-Teen v. State Immunization Surveys

In this subsection, we compare vaccination coverage estimates from NIS-Teen and state vaccination surveys. Agreement between the 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.

The objective here is to compare NIS-Teen to state-sponsored surveys that are independent of the corresponding IIS. We are aware of only two states that have conducted an immunization survey of its resident adolescents: Georgia (GA) and Kansas (KS). Thus, we now compare NIS-Teen vaccination coverage rates for Georgia to those from the Georgia Adolescent Immunization Study (henceforth abbreviated GIS), which is sponsored and conducted by Georgia Department of Public Health (Machado, 2017 and 2018), and NIS-Teen vaccination coverage rates for Kansas to those from an analysis of Kansas BRFSS (Behavioral Risk Factor Surveillance System) survey data (henceforth abbreviated KIS), conducted by Kansas Department of Health and Environment (Gillespie, 2018). This report focuses on the most recently available data from these surveys, 2011 to 2016 for GIS and 2017 to 2018 for KIS.

Each annual GIS is based on a two-stage sample of seventh grade students, with vaccination history information collected from the Georgia Registry of Immunization Transactions and Services. In the first stage, up to thirty middle schools (public and private) are selected from each of eighteen state health districts, while in the second stage, a random sample of students is selected from within each selected school. Each KIS is based on a dual-frame random digit dial (RDD) survey of noninstitutionalized adults, 18 years and older. Households are screened for the presence of children aged 17 or younger in the household, and one eligible child is randomly selected for households with multiple children. From 2011 to 2016, parents and guardians were asked about adolescent vaccinations and vaccination histories. Published estimates include children younger than 13, whereas NIS-Teen is based on adolescents aged 13 to 17 identified in an RDD telephone survey of Georgia and Kansas households, with provider reporting of vaccination histories. Table 2.3 gives the sample sizes for the surveys. KIS and especially GIS are much larger in sample size than NIS-Teen.

Table 2.3: Sample Sizes of Adolescents in Georgia and Kansas

Year	State Vaccination Surveys	NIS-Teen in State, Adolescents with Adequate Provider Data
	Georgia	
2017	6,191	299
2018	7,057	345
	Kansas	
2011	971	359
2012	568	297
2013	1,280	205
2014	641	234
2015	1,073	228
2016	670	207

Sources:
https://dph.georgia.gov/sites/dph.georgia.gov/files/Adolescent%20Immunization%20Study%202017%20Final%20Report_Georgia.pdf
https://dph.georgia.gov/sites/dph.georgia.gov/files/Immunizations/2018%20GAIS%20final_web.pdf
https://www.kansaspharmacyfoundation.org/pdf/vaccines/vaccination-rates-Adolescent-Coverage-2016.pdf

Figures 2.5a and 2.5b present a comparison of GIS and NIS-Teen vaccination coverage estimates for the two most recently available years: 2017 and 2018. Differences for 1+ Tdap are small to moderate, with the difference for 2017 statistically significant ($p = 0.05$). The differences for 1+ MenACWY are small, 1.1 percentage points and 0.7 percentage points in 2017 and 2018, respectively. The largest differences are for 1+ HPV and UTD for HPV. For males and females combined, NIS-Teen estimates for 1+ HPV are 16.4 and 17.5 percentage points greater than GIS estimates, in 2017 and 2018, respectively. Similarly, for males and females analyzed separately, NIS-Teen estimates for 1+ HPV are much larger than GIS estimates. All differences for 1+ HPV are highly statistically significant. Differences may be due to the inclusion of 12-year-olds for the GIS who are less likely to have had their first dose of HPV vaccine.

Figure 2.5a: Comparison of Vaccination Coverage Estimates (in %): GIS v. NIS-Teen in GA, 2017 and 2018

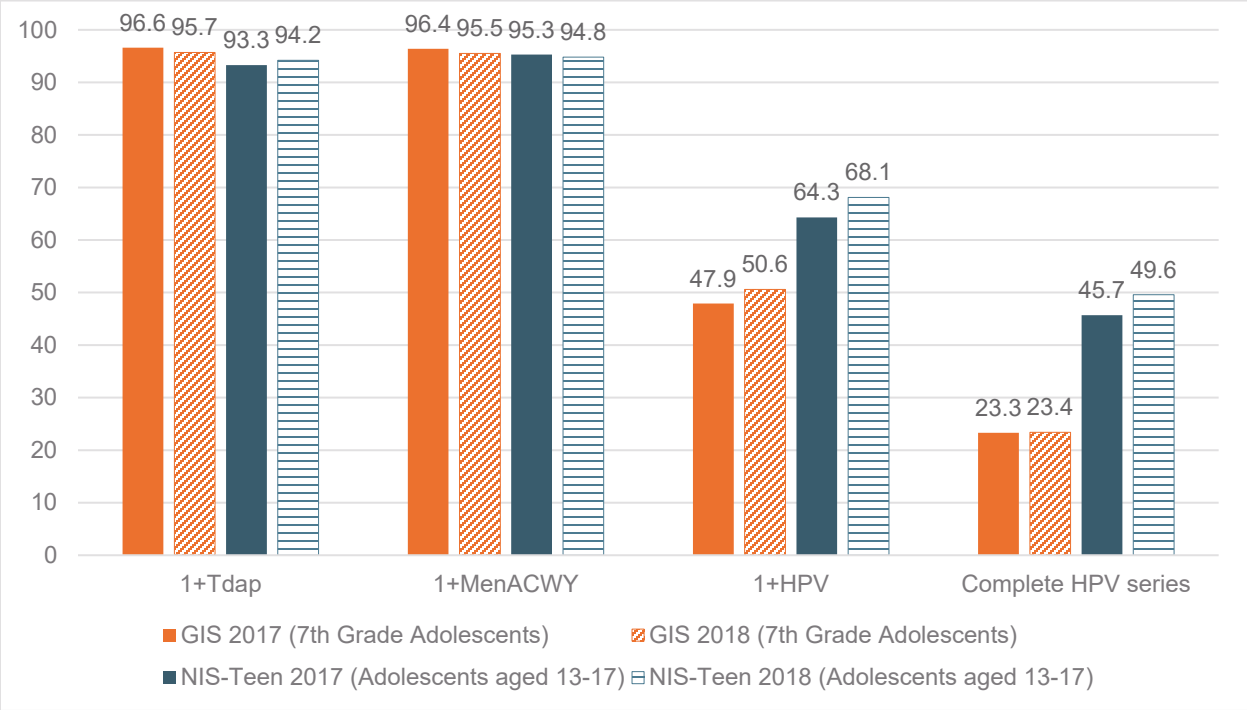
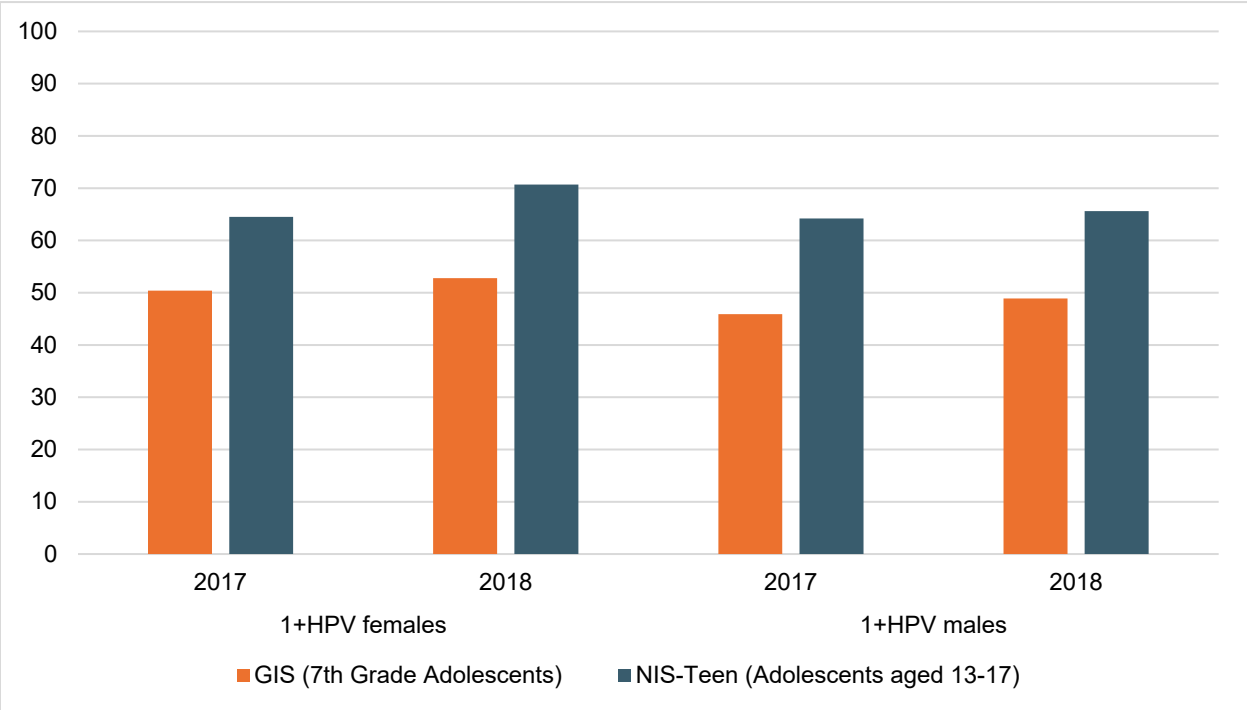


Figure 2.5b: Comparison of 1+HPV Coverage Estimates (in %) by Sex: GIS v. NIS-Teen in GA, 2017 and 2018



The comparison of NIS-Teen and KIS involves multiple years. The KIS assessed Tdap vaccination coverage in 2011 and 2014, 1+ MenACWY coverage in 2012 and 2015, and HPV coverage in 2013 and 2016. In Figures 2.6a and 2.6b, we compare KIS and NIS-Teen vaccination coverage estimates for these specific years. The smallest differences are 1.1 and 1.2 percentage points for 1+ Tdap in 2011 and 2014, respectively. The difference for 1+ MenACWY in 2012, -1.3 percentage points, is also small, but the difference in 2015, 11.5 percentage points, is larger and statistically significant (p=0.00). NIS-Teen estimates of HPV vaccination coverage are much larger than the corresponding KIS estimates. In 2016, the difference in estimates for 1+ HPV is -22.3 percentage points for males and females combined, -28.7 percentage points for females, and -15.9 percentage points for males, all of which are highly statistically significant. These differences may be due to (1) KIS estimates being based on parental reports while NIS-Teen estimates are based on provider vaccination histories, (2) differential nonresponse error for the KIS and NIS-Teen, and (3) the KIS including children younger than 13 whereas NIS-Teen estimates are for 13- to 17-year-olds.

Figure 2.6a: Comparison of Vaccination Coverage Estimates (in %): KIS v. NIS-Teen in KS, Various Years

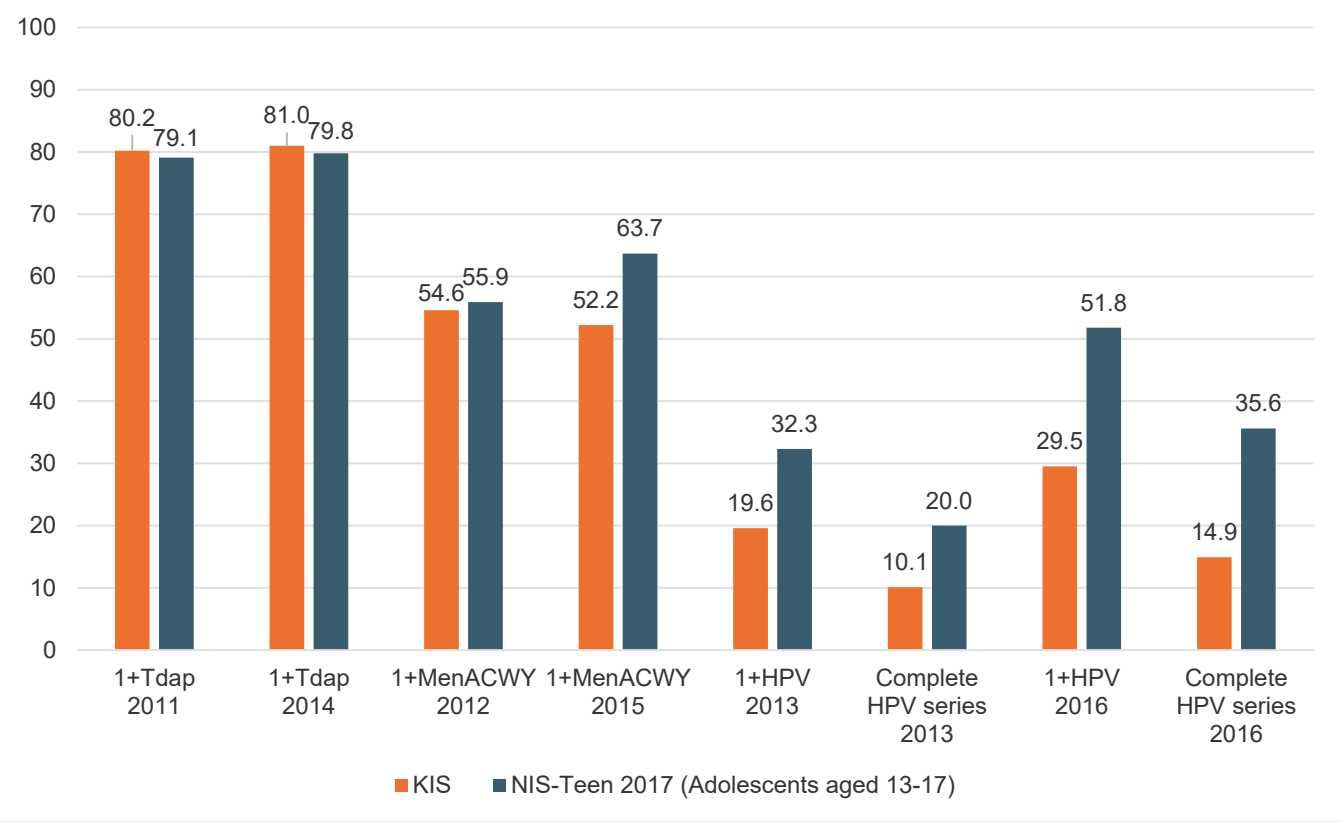
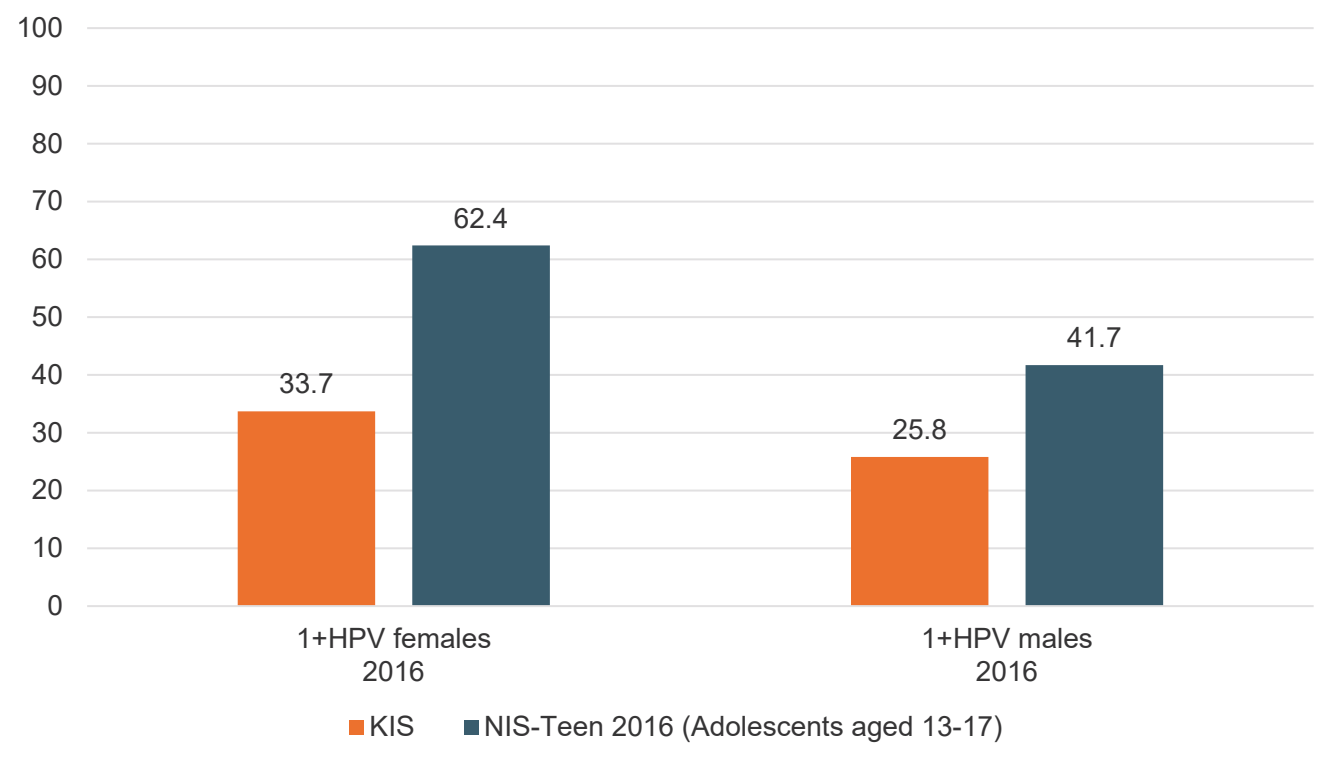


Figure 2.6b: Comparison of 1+HPV Coverage Estimates (in %) by Sex: KIS v. NIS-Teen in KS, 2016



Comparison to Other IIS-Based Vaccination Coverage Estimates

Additional comparisons of estimates of vaccination coverage from state IIS to estimates from NIS-Teen have been studied. First, Staras et al. (2021) examined estimates of vaccination coverage for 13- to 17-year-olds with 1+ doses of HPV vaccine as well as for UTD for HPV vaccination as determined from Florida's IIS, known as the State Health Online Tracking System (SHOTS). They compared these estimates to those from NIS-Teen from 2009 to 2018. The authors find that the estimates from Florida SHOTS and NIS-Teen are similar for males, while estimates from Florida SHOTS are higher than NIS-Teen for females for 1+ doses of HPV vaccination. The findings are consistent with the range of levels of agreement found between IISAR and NIS-Teen estimates of vaccination coverage across different estimation areas described in Section 2.2.

Second, we compared state-level estimates for UTD for HPV from the Wisconsin Immunization Registration (WIR) as reported by Weatherer et al. (2021) to corresponding estimates from NIS-Teen. The estimates from NIS-Teen were higher than those derived from WIR. The 2019 Wisconsin NIS-Teen UTD for HPV estimate among 13- to 17-year-old adolescents was 56.0% with a 95% margin of error of 9.0 percentage points, compared with 45.6% reported from WIR. The 2016 NIS-Teen estimate was 45.5% with a 6.5 percentage point margin of error, compared with 34.0% from WIR. It is possible that these differences reflect under-reporting of HPV vaccination coverage for WIR for these years.

In summary, research on estimates from Florida and Wisconsin IIS vaccination coverage estimates is consistent with other evidence on rates of agreement between IIS and NIS-Teen estimates, and some differences may be due to under-reporting of vaccination coverage in IIS data. Additionally, state survey estimates of vaccination coverage from Georgia (via the GIS) and Kansas (via the KIS) exhibit reasonable agreement with NIS-Teen vaccination coverage estimates for 1+ Tdap and 1+ MenACWY. However, NIS-Teen HPV vaccination coverage estimates are much higher than the corresponding estimates from GIS and KIS, likely because GIS assesses younger adolescents (seventh grade students tend to be 12 years old, before the main uptake of HPV vaccine, and below the NIS-Teen eligible age range that better represents the main uptake). Additionally, the KIS assessment is based on parental recall, known to be less accurate than provider reporting, and includes younger children. KIS and GIS may have differential nonresponse error relative to NIS-Teen. After making allowance for the known differences in survey methods, it is not unreasonable to conclude that both GIS and NIS-Teen for Georgia and KIS and NIS-Teen for Kansas tend towards consistent measurements.

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 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

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

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

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

where $\mu_1$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

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

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

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

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

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

We can also write the TSE as

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

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

The seven parameters on the right side of (5) are $\boldsymbol{\phi} = (\mu_{1A}, \mu_{2A}, \mu_{3A}, \mu_3, p_{1A}, p_{2A}, p_{3A})'$. Estimates of the values of these seven parameters, based on the analyses to be presented in Sections 3.2 through 3.4 below, are denoted by $\widehat{\boldsymbol{\phi}} = (\hat{\mu}_{1A}, \hat{\mu}_{2A}, \hat{\mu}_{3A}, \hat{\mu}_3, \hat{p}_{1A}, \hat{p}_{2A}, \hat{p}_{3A})'$. Let $\widehat{\boldsymbol{\Sigma}}$ denote the estimated variance-covariance matrix of $\boldsymbol{\phi}$. We assume the seven parameters are independently distributed and that $\widehat{\boldsymbol{\Sigma}} = \text{diag}\left(\hat{\sigma}^2_{\mu 1A}, \hat{\sigma}^2_{\mu 2A}, \hat{\sigma}^2_{\mu 3A}, \hat{\sigma}^2_{\mu 3}, \hat{\sigma}^2_{p1A}, \hat{\sigma}^2_{p2A}, \hat{\sigma}^2_{p3A}\right)'$, 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 $\widehat{\boldsymbol{\phi}}$ and $\widehat{\boldsymbol{\Sigma}}$. We assess TSE by making random draws of $\boldsymbol{\phi}$ and $\boldsymbol{\Sigma}$ from their distributions. 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 the 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 1,300 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 2022 NIS-Teen. Finally, we close this section by examining the change in the TSE, from the 2021 NIS-Teen to the 2022 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 adjustment to the weights by raking the weights to select demographic characteristics of the population of adolescents 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 differ from the rates of adolescents in the included domains, which may introduce bias into the estimator of the vaccination coverage.

In this section, 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 13-17 years in the population by telephone status by year for 2012-2021 based on estimates from the NHIS, as 2021 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, 98.1% in 2019, 98.6% in 2020, and 99.2% in 2021. As a result, the estimated proportion of uncovered households decreased from 4.5% in 2018 to 0.8% in 2021.

Table 3.1: Percentage of Age-Eligible Adolescents in the Population by Telephone Status by Year: NIS-Teen, United States, 2012-2021

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

Source: Produced using the methods of Blumberg, Ganesh, Luke, and Gonzales (2013) applied to data from the 2012-2021 National Health Interview Survey sponsored by CDC's National Center for Health Statistics (https://www.cdc.gov/nchs/nhis/index.htm).

The 2022 NIS-Teen did not directly measure LLO or phoneless adolescents, and to assess vaccination coverage estimates 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 2022. 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 LLO Domains: NIS-Teen, United States, 2017

Variance/Series	Cell-Phone Domain		Landline-Only Domain		Difference	
	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
UTD for HPV	48.7	0.66	40.3	7.29	8.5	7.3
UTD for HPV among females	53.1	0.97	55.0	9.70	-1.9	9.8
UTD for HPV among males	44.5	0.88	31.6	10.13	12.8	10.2

$* \ p \leq 0.05.$

Since NIS-Teen has never included direct sampling of phoneless adolescents, we study vaccination estimates in the phoneless domain using estimates from the 2012 National Health Interview Survey-Provider Record Check (NHIS-PRC).[8] 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.

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: NHIS-PRC, United States, 2012

Vaccine	Cell-Phone Domain		Phoneless Domain		Difference	
	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 NHIS-PRC, 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.

[8] 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.

The foregoing tables can be translated into an assessment of sampling-frame coverage error in 2022 NIS-Teen estimated vaccination coverage. We can also write the true vaccination coverage estimate as

$$\boldsymbol{\mu_0 = \mu_1 - q_1}\ , \tag{7}$$

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 2021 (the most recent year available), and $\hat{\mu}_{1A}$ will be obtained from the results of the 2022 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 2022 NIS-Teen and from work we will do in 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 essentially μ_1. Then, 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 %): NIS-Teen, United States, 2022

Vaccine	$\hat{\mu}_1$ (2022 NIS-Teen Vaccination Coverage Estimate)	$\hat{q}_1$[a]	$\hat{\mu}_0$(Mean of μ_0, the True 2022 Vaccination Coverage)	Standard Error of μ_0
1+ Tdap	89.9	0.0	89.9	0.5
1+ MenACWY	88.6	0.0	88.6	0.5
UTD for HPV	62.6	0.1	62.5	0.7
UTD for HPV among females	64.6	0.1	64.6	1.0
UTD for HPV among males	60.6	0.1	60.5	1.0

[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. This section focuses on assessing survey error due to unit nonresponse. We conclude with a review of 2022 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 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 section assesses the extent of nonresponse error in the 2022 NIS-Teen estimates of vaccination coverage for three different vaccines, including 1+ Tdap, 1+ MenACWY, and UTD for HPV, 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 2022 NIS-Teen realization rate[9] of adolescents with adequate provider data was 2.8 percent with a standard error of 0.03 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 2.8 percent, or 97.2 percent without adequate provider data, with a standard error of 0.2 percentage points. These two numbers (97.2% 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 2022 NIS-Teen is data available from the 2021 NHIS, because it provides representation 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 2021 being 49.9%.[10]

Comparing NIS-Teen estimates to those based on the 2021 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 does not produce direct estimates of vaccination coverage, we can compare indirect vaccination coverage estimates derived from the NHIS to the direct vaccination coverage estimates derived from the NIS-Teen. We take advantage of the range of variables that are common to both the 2022 NIS-Teen and the 2021 NHIS and produce estimates of nonresponse error for the following vaccination series: 1+ Tdap, 1+ MenACWY, and UTD for HPV. 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 2021 NHIS Public Use File (CDC, 2022). 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

[9] 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.

[10] See p. 26 of https://ftp.cdc.gov/pub/Health_Statistics/NCHS/Dataset_Documentation/NHIS/2021/srvydesc-508.pdf

vaccination coverage among the population covered by the NIS-Teen 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.[11]

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 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 0.4 percentage points higher than the estimates based on NHIS imputations for 1+ Tdap, 0.3 percentage points higher for 1+ MenACWY, and 0.9 percentage points lower for UTD for HPV. None of these differences are statistically significant (*p*-values of 0.73, 0.81, and 0.60 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 1.0 percentage points lower for females (*p*-value 0.67) and 0.7 percentage points higher for males (*p*-value 0.78). For our TSE model, we estimate $\hat{\mu}_{2A}$ and $\hat{\sigma}_{\mu 2A}$ 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.

The NIS-Teen estimates based on final weights are 0.5 percentage points lower than the estimates based on NHIS imputations for 1+ Tdap, 0.4 percentage points lower for 1+ MenACWY, and 1.5 percentage points lower for UTD for HPV. Examining HPV estimates by sex, NIS-Teen estimates are 2.1 percentage points lower for females and 1.1 percentage points lower for males. Overall, when viewing the estimates based on NHIS imputations (a) as the full-response estimate of vaccination coverage, these results suggest that nonresponse error in these NIS-Teen estimates is small, although the standard errors reflect uncertainty in our knowledge about the extent of nonresponse error.

[11] Details of our methods for estimating nonresponse error are available from the authors.

Table 3.5: Estimated Parameters of Nonresponse Error in Vaccination Coverage Estimates (in %) Derived from the 2022 NIS-Teen and the 2021 NHIS

Statistics	1+ Tdap	1+ MenACWY	UTD for HPV	UTD for HPV among Females	UTD for HPV among Males
(a) Estimate Based on NHIS Imputations	90.4	89.0	64.1	66.7	61.7
Standard Error	1.0	1.0	1.5	2.3	2.1
(b) NIS-Teen Estimate (Design Weighted)	90.8	89.3	63.2	65.7	61.1
Standard Error	0.4	0.5	0.7	1.0	1.0
(c) NIS-Teen Estimate (Final Weighted)	89.9	88.6	62.6	64.6	60.6
Standard Error	0.5	0.5	0.7	1.0	1.0
(d) Difference, (b) – (a)	0.4	0.3	-0.9	-1.0	-0.7
Standard Error of Difference	1.0	1.1	1.7	2.5	2.3
t-statistic	0.35	0.25	-0.53	-0.42	-0.28
p-value (2-sided)	0.73	0.81	0.60	0.67	0.78
(d) Difference, (c) – (a)	-0.5	-0.4	-1.5	-2.1	-1.1
Standard Error of Difference	1.1	1.1	1.7	2.5	2.3
t-statistic	-0.43	-0.38	-0.92	-0.83	-0.48
p-value (2-sided)	0.67	0.70	0.36	0.41	0.63

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 section has focused on assessing error in vaccination coverage rates 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 which a higher item nonresponse rate of 26.5%, 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, 2022

Variable	2022 Item Nonresponse Rate (Percent)*
Sex of adolescent	0.6
Hispanicity 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	1.0
Family income	26.5
Exact income not reported but income cascade completed	18.1
Exact income not reported and income cascade not completed	8.4

* 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.

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 are either 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 complete vaccination records (such as when an adolescent moved out-of-area and vaccination records were not forwarded).

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 twenty 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 at or after age 10 years	4.7	0.33
≥1 Meningococcal ACWY	4.1	0.33
UTD for HPV*	2.5	0.25
UTD for HPV among females	2.3	0.33
UTD for HPV 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.
* ≥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 2022 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 0.4 to 1.0 percentage points.

Table 3.8: Vaccination Coverage Estimates and Standard Errors Using Design Weight and Final Weight: NIS-Teen, United States, 2022

Vaccine	Design Weight		Final Weight	
	Estimate (%)	Standard Error (percentage points)	Estimate (%)	Standard Error (percentage points)
1+ Tdap at or after age 10 years	90.8	0.4	89.9	0.5
1+ MenACWY	89.3	0.5	88.6	0.5
UTD for HPV*	63.2	0.7	62.6	0.7
UTD for HPV among females	65.7	1.0	64.6	1.0
UTD for HPV among males	61.1	1.0	60.6	1.0

Note: Excludes U.S. territory samples.

* ≥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 section 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 total survey error for estimated vaccination coverage corresponding to 1+ Tdap, 1+ MenACWY, and UTD for HPV both overall and separately for males and females. The section 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 2022 NIS-Teen. These values arise from the analyses described in Sections 3.2 through 3.4 above.[12] We assume the logit transformations of the inputs are normally distributed and independent (i.e., no covariance between inputs).

[12] $\hat{\mu}_{1A}$ 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, 2022

Parameter	1+ Tdap	1+ MenACWY	UTD for HPV	UTD for HPV among Females	UTD for HPV among Males
		Stage 1: Sampling-Frame Coverage Error			
$\hat{p}_{1A}$	0.8%	0.8%	0.8%	0.8%	0.8%
$\hat{\sigma}_{p1A}$	0.2%	0.2%	0.2%	0.2%	0.2%
$\hat{\mu}_{1A}$	94.7%	95.7%	54.9%	58.5%	52.4%
$\hat{\sigma}_{\mu 1A}$	9.3%	8.6%	11.1%	11.2%	9.7%
		Stage 2: Nonresponse Error			
$\hat{p}_{2A}$	97.2%	97.2%	97.2%	97.2%	97.2%
$\hat{\sigma}_{p2A}$	0.2%	0.2%	0.2%	0.2%	0.2%
$\hat{\mu}_{2A}$	95.1%	93.1%	66.6%	69.0%	64.3%
$\hat{\sigma}_{\mu 2A}$	1.0%	1.1%	1.6%	2.4%	2.2%
		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%
$\hat{\mu}_{3}$	95.3%	93.1%	64.8%	67.2%	62.7%
$\hat{\sigma}_{\mu 3}$	0.6%	0.6%	0.7%	1.0%	1.0%

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 -5.0 percentage points for 1+ Tdap, -4.4 percentage points for 1+ MenACWY, -3.9 percentage points for HPV, -4.2 percentage points for HPV among females, and -3.5 percentage points for HPV among males. The 95% credible intervals for the two UTD for HPV total error estimates by sex include 0. These results suggest that the 2022 NIS-Teen may have somewhat underestimated the true vaccination coverage for 1+ Tdap, 1+ MenACWY, and UTD for HPV. The largest estimated component of error in absolute value for all three series is measurement error, i.e., provider under-reporting error.

Table 3.10: Mean and 95% Credible Interval for the Estimated TSE Distribution and Component Error Distributions: NIS-Teen, United States, 2022

Vaccine or Series	Component	Mean TSE (percentage points)	95% Credible Interval (percentage points)
1+ Tdap	TSE (final weighted)	-5.0	(-6.8, -2.6)*
	TSE (design weighted)	-4.2	(-5.9, -1.8)*
	Noncoverage error	0.1	(-0.1, 0.6)
	Nonresponse error	0.4	(-1.6, 3.0)
	Measurement error	-4.7	(-5.6, -3.6)*
	Sampling error	0.0	(-1.1, 1.4)
1+ MenACWY	TSE (final weighted)	-4.4	(-6.3, -2.1)*
	TSE (design weighted)	-3.7	(-5.6, -1.4)*
	Noncoverage error	0.1	(-0.1, 0.6)
	Nonresponse error	0.3	(-1.8, 2.8)
	Measurement error	-4.1	(-5.1, -3.0)*
	Sampling error	0.0	(-1.2, 1.3)
UTD for HPV	TSE (final weighted)	-3.9	(-6.7, -0.8)*
	TSE (design weighted)	-3.2	(-6.1, -0.2)*
	Noncoverage error	0.2	(-0.1, 0.4)
	Nonresponse error	-0.9	(-4.1, 2.4)
	Measurement error	-2.5	(-3.8, -1.0)*
	Sampling error	0.0	(-1.4, 1.5)
UTD for HPV among females	TSE (final weighted)	-4.2	(-8.5, 0.4)
	TSE (design weighted)	-3.2	(-7.4, 1.4)
	Noncoverage error	0.1	(-0.1, 0.4)
	Nonresponse error	-1.0	(-5.7, 3.9)
	Measurement error	-2.3	(-4.2, -0.3)*
	Sampling error	0.0	(-2.0, 2.0)
UTD for HPV among males	TSE (final weighted)	-3.5	(-7.5, 0.7)
	TSE (design weighted)	-3.0	(-7.0, 1.2)
	Noncoverage error	0.2	(-0.1, 0.4)
	Nonresponse error	-0.6	(-5.2, 4.1)
	Measurement error	-2.6	(-4.6, -0.6)*
	Sampling error	0.0	(-2.0, 2.1)

* 95% credible interval does not include 0.

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

In the previous section, we assessed TSE in the 2022 NIS-Teen estimated vaccination coverage, while in the current section, we assess the change in TSE between vaccination coverage estimates produced from the 2021 and 2022 NIS-Teen samples. Change is now 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 2021 and 2022, the bridging cohort extends from adolescents born in Q1 2004 through adolescents born in Q4 2008.

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 2021 NIS-Teen sample and the second using the corresponding sample of adolescents within the 2022 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 2021-2022 bridging cohort. The columns on the right side of the table reveal the differences between the 2022 and 2021 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 do not observe any statistically significant differences between the 2022 and 2021 vaccination coverage estimates for the 2021-2022 bridging cohort. That is, there is no statistical evidence of a change in mean TSE between 2021 and 2022.

Table 3.11: Difference between the Estimates* for the Bridging Birth Cohort: NIS-Teen, United States, 2021 vs. 2022

	2021		2022		Difference		
Description	Estimate	Standard Error	Estimate	Standard Error	Estimate	Standard Error	p-value for Test of No Difference
1+ Tdap by 13 years	88.8	0.62	88.0	0.55	-0.8	0.83	0.361
1+ MenACWY by 13 years	83.3	0.76	83.0	0.63	-0.4	0.99	0.716
UTD for HPV[&] by 13 years	36.9	0.94	36.8	0.75	-0.1	1.20	0.961
UTD for HPV by 13 years among females	38.8	1.38	38.8	1.10	-0.4	1.76	0.805
UTD for HPV by 13 years among males	35.5	1.27	35.0	1.03	-0.5	1.64	0.770

* 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 2004 and December 2008. Final provider-phase weights for 2021 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 2022 within the corresponding monthly birth cohort.
[&] ≥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 2022 NIS-Teen statistics at the national level (excluding U.S. territories) 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 2022 sources and studies to assess error in the 2022 NIS-Teen. Where 2022 sources were not available, we reported information from prior year sources as the best information available for understanding error in the 2022 NIS-Teen.

In Part I, we compared NIS-Teen demographic distributions (age, sex, race/ethnicity, mother's education, mother's age) to benchmark values 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 2022 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 NIS-Teen vaccination coverage estimates are higher in many jurisdictions. For five of the six 2013-2017 sentinel sites, we found good agreement between NIS-Teen and IISAR estimates. (For the sixth sentinel site, the IISAR estimate was over 100 percent and therefore a clear over-estimate.) 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.

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 produced by immunization surveys sponsored by states. Results of the Georgia Adolescent Immunization Study (GIS) and an analysis of Kansas BRFSS data (KIS) were the only such statistics available at this time. GIS and NIS-Teen, and KIS and NIS-Teen displayed reasonably similar vaccination coverage estimates for 1+ Tdap and 1+ MenACWY. For males and females both separately and combined, NIS-Teen vaccination coverage estimates for UTD for HPV were substantially and statistically significantly higher than the corresponding estimates from GIS and KIS. In the case of GIS, this finding is likely due to differences in the age groups included in the study populations, and in the case of KIS, to incomplete reporting by the parental respondents and the likely inclusion of 12-year-olds for estimates.

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 2021 to 2022.

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 Provider Record Check. 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 2021 NHIS and 2022 NIS-Teen to assess nonresponse error in the 2022 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 over 90% of the age-eligible sample of households failed to respond to the NIS-Teen. Despite this large percentage, we found mean nonresponse error in vaccination coverage estimates to be modest and not statistically significant for all of the vaccine series examined.

We used twenty 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 of the component errors and assessed the distribution of total survey error in the NIS-Teen vaccination coverage rates, using a Monte Carlo technique. For the 1+ Tdap vaccination coverage rate, we found the mean of the TSE distribution to be -5.0 percentage points with a 95% credible interval of (-6.8, -2.6) percentage points. That is, the NIS-Teen vaccination coverage rate was on average about 5.0 percentage points too low. For the 1+ MenACWY vaccination coverage rate, we found the mean of the TSE distribution to be -4.4 percentage points with a 95% credible interval of (-6.3, -2.1) percentage points, and for the UTD for HPV vaccination coverage rate, we found the mean of the TSE distribution to be -3.9 percentage points with a credible interval of (-6.7, -0.8) 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 2021 and 2022 NIS-Teen by comparing vaccination coverage estimates for adolescents born between the first quarter of

2004 and the fourth quarter of 2008 available from both survey years. In conducting comparisons for five key vaccination coverage estimates, we found no statistically significant differences and no evidence of a change in mean TSE between 2021 and 2022.

Our results for the 2022 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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