Total Survey Error and Component Errors For COVID-19 Vaccination Among Children in the National Immunization Survey-Child COVID Module

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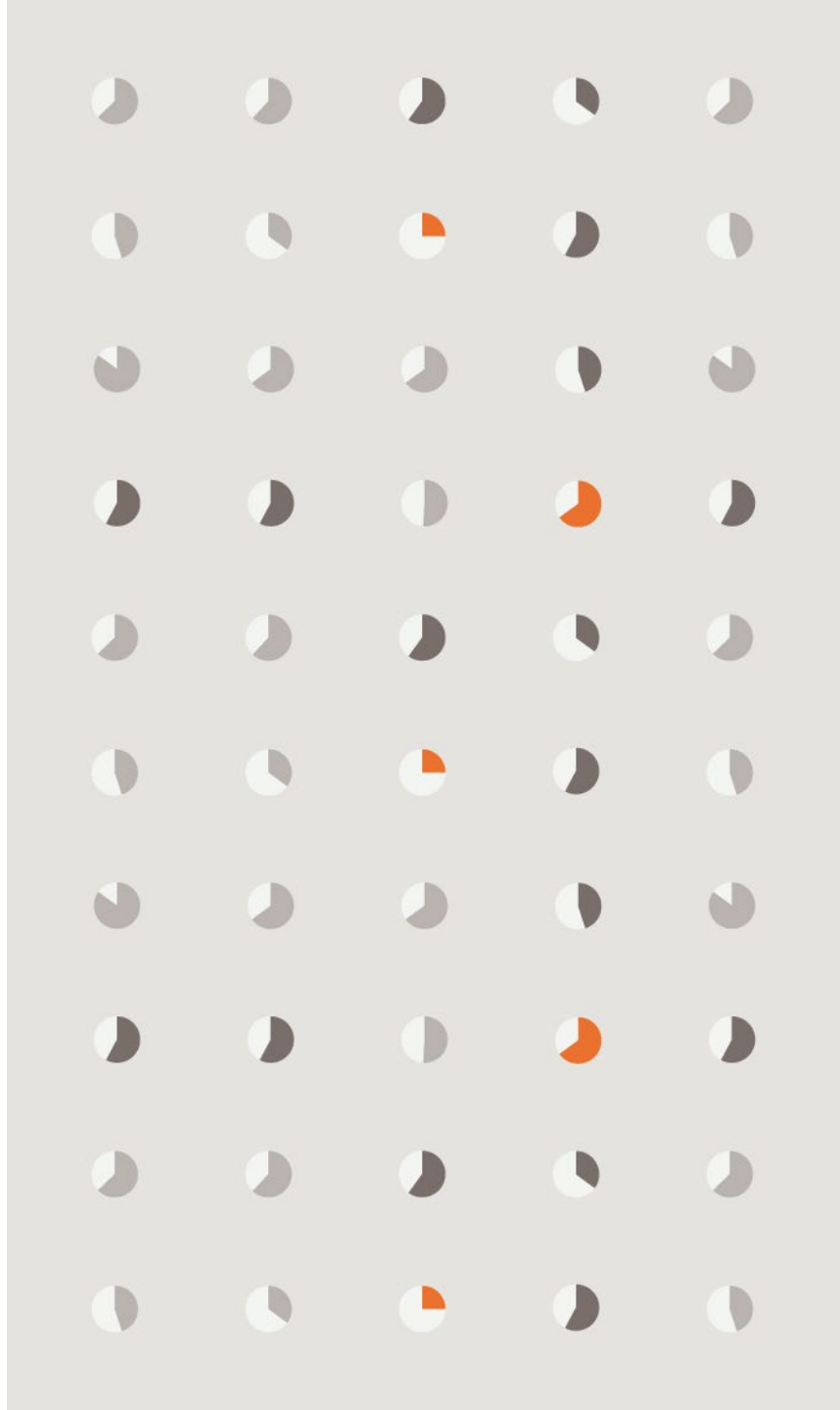
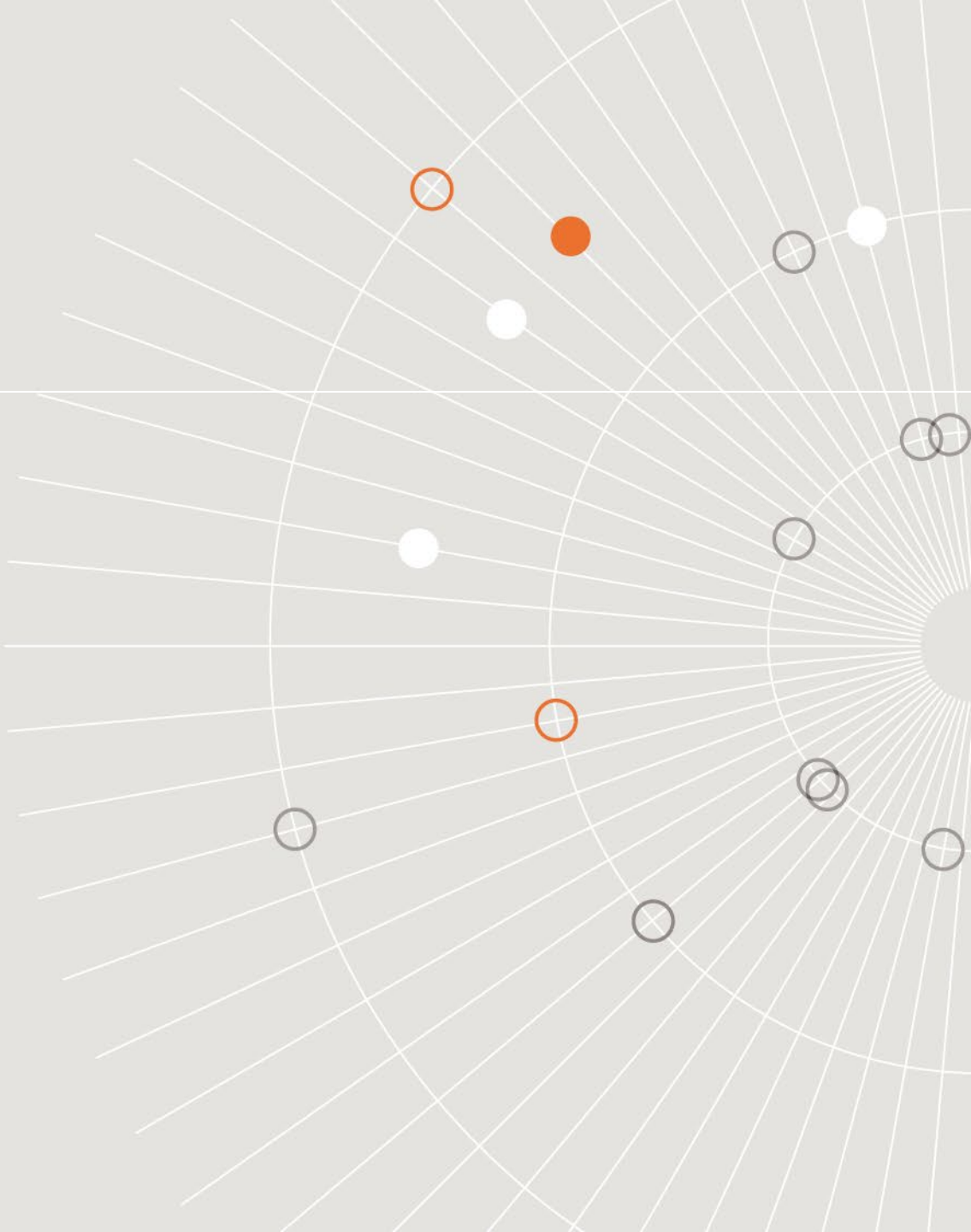


Background



National Immunization Surveys

- The National Immunization Surveys (NIS) are a family of random-digit dial cell-phone surveys used to monitor and provide estimates of vaccination coverage at the national, state, and selected local area and U.S. territory level using a standard methodology.
- Monitors vaccination coverage for recommended vaccines for
  - children aged 19-35 months (NIS-Child), utilizing household survey & Provider Record Check (PRC),
  - adolescents aged 13-17 years (NIS-Teen), utilizing household survey & Provider Record Check (PRC), and
  - children aged 6 months to 17 years (NIS-Flu), using only household survey data.
- In response to the COVID-19 pandemic, the NIS-Child COVID Module (NIS-CCM) was added to the NIS family of surveys in July 2021 to assess COVID-19 vaccination coverage and parental intent to vaccinate children.
  - Due to the availability of the vaccine for different age groups, NIS-CCM was initially fielded only to parents of adolescents aged 13-17 years who responded to the NIS-Teen household survey and later extended to include children 5-12 years beginning October 1, 2021, and children 6 months to 4 years beginning December 19, 2021.

Total Survey Error (TSE)

TSE is the difference between the estimate of a population parameter of interest measured in a survey and the true value of that population parameter in a population, including both sampling and nonsampling error.

- Sampling error is determined by the sample size, survey design, and estimation method.
- Nonsampling error arises primarily from noncoverage of the target population by the survey sampling frame, nonresponse to the survey, and recall or other reporting error in measured outcomes.

Noncoverage error source	Nonresponse error source	Reporting error source
• Phoneless households • Landline-only households	• Non-resolution of telephone numbers • Screener nonresponse among identified households • Failure to report eligible children in the completed screening interview • Interview nonresponse among eligible households • Failure to answer the questionnaire item on children's COVID-19 vaccination	• Overreporting • Underreporting

Objective and Methods

Research Objective: Assess Total Survey Error (TSE) and component errors for estimates of vaccination coverage with one or more doses of COVID-19 vaccine (1+ COVID-19) as of June 2023, estimated using June through July 2023 NIS-CCM data.

Methodology

The analysis is based on Monte Carlo simulation of TSE model which is parameterized by nine free parameters based on the three-stage of non-sampling error, similar methodology to NIS-Flu TSE analyses (NORC, 2023). The full methodology is described in Wolter et al (2017).

Key methodological differences from other NIS TSE analyses

- Unlike NIS-Child, NIS-Teen, and NIS-Flu TSE analyses, model inputs for the reporting stage for NIS-CCM were derived using NIS-Child and NIS-Teen provider reports only, without incorporating data from state and local Immunization Information System (IIS).
- Similar to NIS-Flu TSE analyses, indirect approach for reporting error model inputs was used due to the unavailability of provider records for children in age groups that are not covered in the NIS-Child and NIS-Teen.

Methodology: Monte Carlo Simulation of TSE Distribution

The simulation was conducted by specifying the means and standard errors of the distributions of nine free parameters $(p_{1A}, p_{1B}, p_{2A}, p_{3A}, p_{3B}, \mu_3, \mu_{2A}, \mu_{1A}, \mu_{1B})$ and assuming that they are independently and normally distributed.

Our central interest in this analysis is the total error q_o , defined by:

$$q_o = \hat{\mu} - \mu_0,$$

where $\hat{\mu}$ denotes vaccination coverage with one or more doses of COVID-19 vaccine (1+ COVID-19) as of June 2023, and μ_0 denotes the true but unknown vaccination coverage, quantified by the nine free parameters based on the three-stage parameterization of the TSE model as follow:

$$\mu_0 = 1 - p_{1A} - p_{1B}[1 - p_{2A}\{1 - p_{3A} - p_{3B}\mu_3 + p_{3B}\} + p_{2A}\mu_{2A}] + p_{1A}\mu_{1A} + p_{1B}\mu_{1B}.$$

Model Parameters for 2023 COVID Vaccination Coverage Rates Total Survey Error Analysis and Sources

Stage	Input	Definition	Source
Coverage	$\hat{p}_{1A}, \hat{\sigma}_{1A}$	Proportion of children in phoneless households, and standard error	**2023 NHIS**
	$\hat{p}_{1B}, \hat{\sigma}_{1B}$	Proportion of children in landline-only households, and standard error	**2023 NHIS**
	$\hat{\mu}_{1A}, \hat{v}_{1A}$	1+ COVID-19 vaccination coverage rate among children in phoneless households, and standard error	**2023 NHIS**
	$\hat{\mu}_{1B}, \hat{v}_{1B}$	1+ COVID-19 vaccination coverage rate among children in landline-only households, and standard error	**2023 NHIS**
Response	$\hat{p}_{2A}, \hat{\sigma}_{2A}$	Nonresponse rate, and standard error	**NIS-CCM**
	$\hat{\mu}_{2A}, \hat{v}_{2A}$	1+ COVID-19 vaccination coverage rate among children in frame-covered, nonresponding households, and standard error	**2023 NHIS**
Reporting	$\hat{p}_{3A}, \hat{\sigma}_{3A}$	Proportion of children with parents overreporting, and standard error	**NIS-Child and NIS-Teen**[1]
	$\hat{p}_{3B}, \hat{\sigma}_{3B}$	Proportion of children with parents underreporting, and standard error	**NIS-Child and NIS-Teen**[1]
	$\hat{\mu}_3, \hat{v}_3$	1+ COVID-19 vaccination coverage rate among children with consistent parent report and provider report of COVID-19 vaccine, and standard error	$\hat{\mu}_3 = \frac{\hat{\mu}_2 - \hat{p}_{3B}}{1 - \hat{p}_{3A} - \hat{p}_{3B}}$
	$\hat{\mu}$	1+ COVID-19 vaccination coverage rate as of June, 2023[2]	**NIS-CCM**

[1] Unlike TSE analysis for 1+ Flu coverage estimates in the NIS-Flu , model inputs for the reporting stage for 1+COVID-19 coverage estimates were derived based on NIS-Child and NIS-Teen provider histories, without the National Immunization Survey-Immunization Information System (NIS-IIS) matched data which were collected prior to COVID-19 pandemic.

[2] Vaccination coverage based on data collected in June and July 2023, estimated using demographically raked survey weights.

Data Source and TSE Model Inputs Derivation

The population coverage stage involves four model inputs that are derived from 2023 NHIS public-use data.

- Percentage of children in no-phone households,
- Percentage of children in landline-only households,
- Influenza vaccination rate among children in no-phone households, and
- Influenza vaccination rate among children in landline-only households.

The response stage involves two model inputs:

- Percentage of children covered by the sampling frame whose parents or guardians either did not respond to the survey at all or answered “don’t know” or “refused” to the COVID-19 vaccination question in the NIS-CCM.
- 1+ COVID-19 vaccination rate among covered children with nonresponse estimated using 2023 NHIS public-use data.

Data Source and TSE Model Inputs Derivation (continued)

The reporting stage inputs include an overreporting rate and an underreporting rate which were calculated based on a comparison of household-reported vaccination status in NIS-CCM to provider-reported vaccination status which were collected as part of Provider Record Check (PRC) for NIS-Child and NIS-Teen.[1]

- Overreporting rate and underreporting rate for children in age groups that were not covered by the NIS-Child and NIS-Teen were approximated.[2]
  - Estimates computed using NIS-Child data for 19-35 month old children are assumed to hold for all children age 6 months to 4 years.
  - Estimates computed using NIS-Teen data for 13-17 years are assumed to hold for all children 12-17 years.
  - Estimates for children 5-11 years old were approximated by taking the midpoint of the estimates for young children and teens.
  - Estimates for all children 6 months – 17 years old were approximated by taking the average of the estimates for the three age groups, weighted using the distribution of NIS-CCM completes across age groups.

[1] This analysis is restricted to NIS-CCM children who completed NIS-Child and NIS-Teen and have adequate provider data.
[2] Following similar method to the one used for NIS-Flu TSE analyses (NORC, 2023).

Key analyses reported in this presentation:

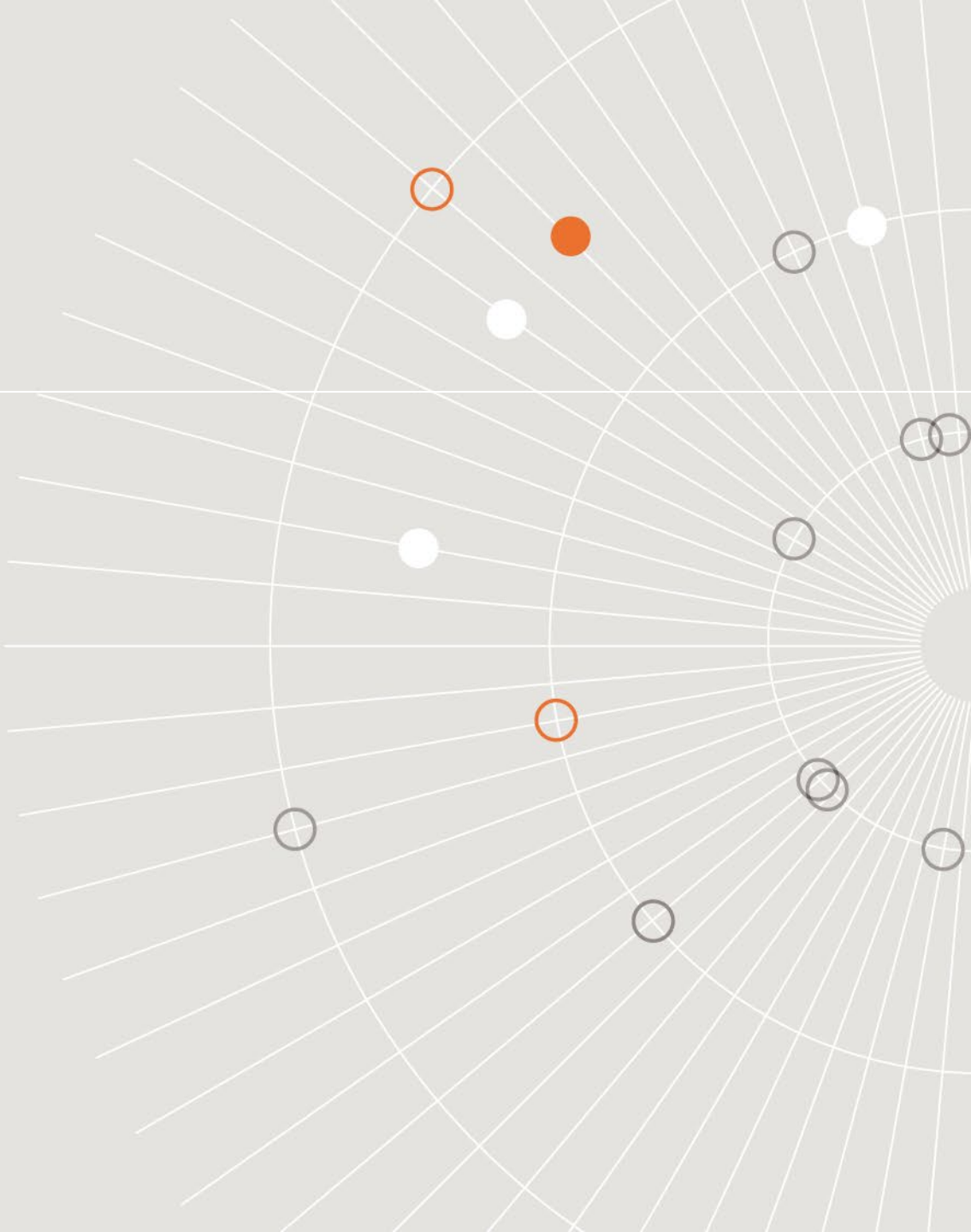
I. TSE Model Inputs

II. Overall TSE component estimates for 1+ COVID-19 vaccination coverage among children 6 months-17 years and by age group and race/ethnicity.

III. Comparison to TSE component estimates for 1+ Flu vaccination coverage in the NIS-Flu

IV. Conclusions and Limitations

Results



Results I: TSE Model Inputs for 1+ COVID-19 Vaccination Coverage

Stage	Input	Definition	Estimated Mean	Estimated Standard Error
Coverage	$\hat{p}_{1A}$	Proportion of children (in percent) in phoneless households	1.21	0.17
	$\hat{p}_{1B}$	Proportion of children (in percent) in landline-only households	0.24	0.08
	$\hat{\mu}_{1A}$	1+ COVID-19 vaccination coverage rate (in percent) among children in phoneless households	45.24	11.53
	$\hat{\mu}_{1B}$	1+ COVID-19 vaccination coverage rate (in percent) among children in landline-only households	17.99	17.47
Response	$\hat{p}_{2A}$	Nonresponse rate (in percent), and standard error	95.47	0.01
	$\hat{\mu}_{2A}$	1+ COVID-19 vaccination coverage rate (in percent) among children in frame-covered, nonresponding households	39.09	1.62
Reporting	$\hat{p}_{3A}$	Proportion of children (in percent) with parents overreporting, and standard error	14.11	1.00
	$\hat{p}_{3B}$	Proportion of children (in percent) with parents underreporting, and standard error	0.35	0.19
	$\hat{\mu}_3$	1+ COVID-19 vaccination coverage rate (in percent) among children with consistent parent report and provider report of COVID-19 vaccine, and standard error	42.94	1.06
	$\hat{\mu}$	1+ COVID-19 vaccination coverage rate (in percent) as of June, 2023	50.84	

Results II: TSE Component for Total Population of Children 6 Months to 17 Years

The mean estimate of TSE among all children 6 months to 17 years is 11.83 percentage points which suggests overestimation of 1+ COVID-19 vaccination coverage. Noncoverage error and nonresponse error are small while reporting error is the largest contributor to TSE.

Error Component	Mean Error	95-Percent Credible Interval
TSE	11.83	(8.79 , 14.89)
Noncoverage Error	-0.02	(-0.33 , 0.27)
Nonresponse Error	-1.90	(-5.48 , 1.67)
Reporting Error	13.75	(11.75 , 15.76)
Sampling Error	0.00	(-2.07 , 2.14)

Results III: TSE Component estimates by age group

- TSE does not vary substantially by age group, while nonresponse error and reporting error components tend to vary by age group.
- Reporting error was larger among teens and smaller among the younger age groups.
  - These results are consistent with previous analyses on household vs provider reports comparison of COVID-19 vaccination status (NORC, 2023).
  - Younger children were more likely to be vaccinated at a medically-related site than teenagers. Hence, they are also more likely to have more accurate provider reports used to estimate the reporting stage model inputs.
- Large non-response and reporting error components are observed among 12-17 years.

Error Component	6 months - 4 Years		5 - 11 Years		12 – 17 years	
	Mean Error	95-Percent Credible Interval	Mean Error	95-Percent Credible Interval	Mean Error	95-Percent Credible Interval
TSE	10.84	(6.92 , 14.8)	12.60	(8.36 , 16.81)	12.54	(7.84 , 17.09)
Noncoverage	0.24	(0.13 , 0.38)	-0.20	(-0.85 , 0.4)	-0.12	(-0.46 , 0.19)
Nonresponse	5.84	(1.44 , 10.27)	-0.57	(-5.43 , 4.37)	-9.27	(-15.12 , -3.49)
Reporting	4.77	(2.77 , 6.76)	13.36	(10.99 , 15.74)	21.93	(19.34 , 24.6)
Sampling	-0.02	(-2.41 , 2.36)	0.00	(-2.62 , 2.65)	0.00	(-3.35 , 3.45)

Results IV: TSE Component estimates by race and ethnicity

- TSE does not vary substantially by race and ethnicity.
- Nonresponse error and reporting error are two largest contributors to TSE among Hispanic children.
- Reporting error is significantly higher for Hispanic compared to non-Hispanic White.
- Overall, reporting error is the largest contributor to TSE.

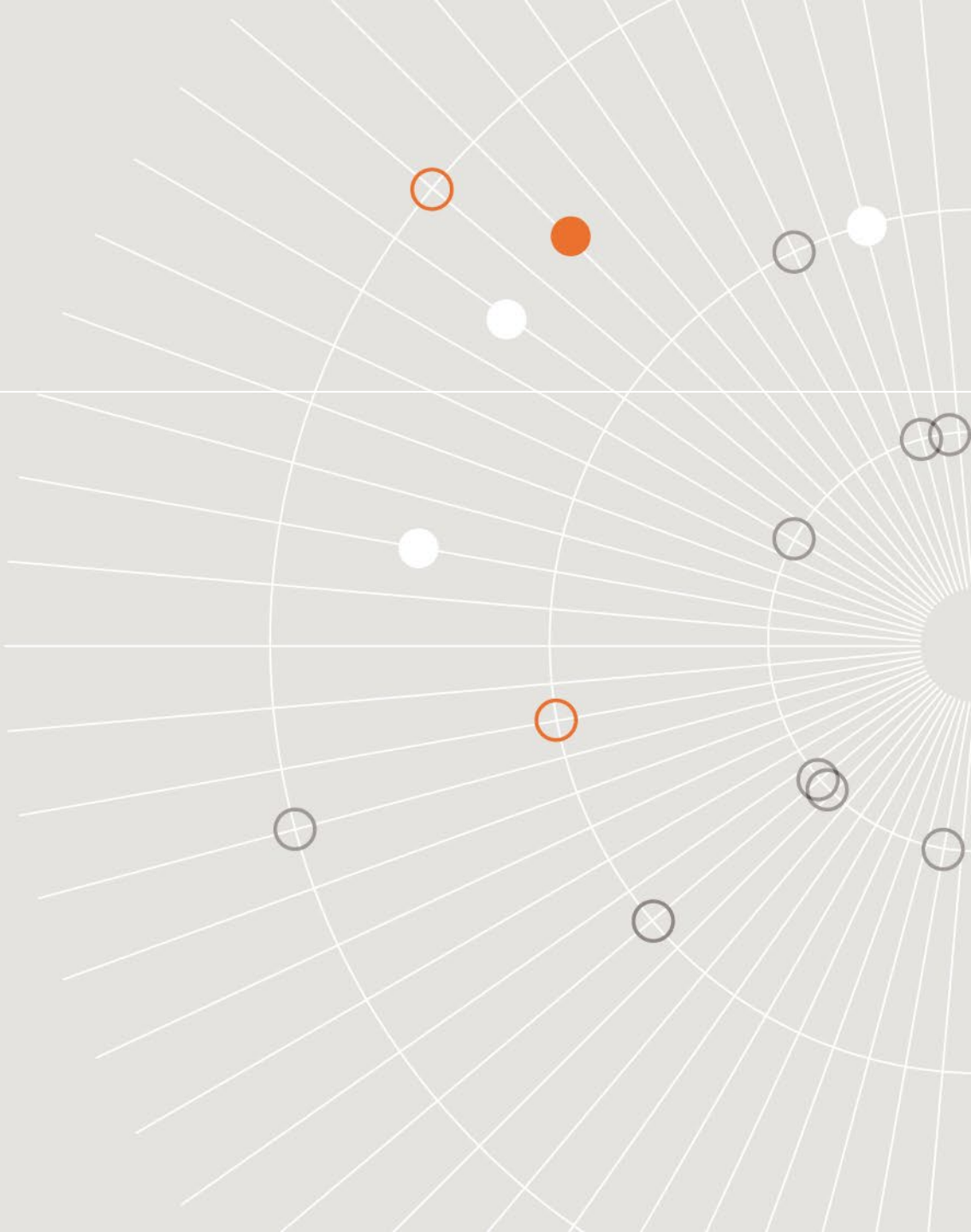
Error Component	Hispanic		Non-Hispanic White Only		Non-Hispanic Black Only		Non-Hispanic Other/Multiple Race	
	Mean Error	95-Percent Credible Interval	Mean Error	95-Percent Credible Interval	Mean Error	95-Percent Credible Interval	Mean Error	95-Percent Credible Interval
TSE	9.01	(2.57 , 15.4)	13.76	(9.72 , 17.84)	11.30	(2.6 , 19.94)	11.03	(2.43 , 19.49)
Noncoverage	-0.04	(-0.61 , 0.5)	0.10	(-0.26 , 0.49)	-0.54	(-1.57 , 0.24)	0.13	(-0.49 , 0.78)
Nonresponse	-10.40	(-18.21 , -2.46)	3.35	(-1.37 , 8.02)	-5.60	(-15.65 , 4.84)	-1.65	(-11.83 , 8.46)
Reporting	19.46	(14.84 , 24.19)	10.31	(7.83 , 12.75)	17.53	(11.8 , 23.33)	12.54	(7.19 , 17.86)
Sampling	0.00	(-5.26 , 5.35)	0.00	(-2.55 , 2.64)	-0.09	(-6.15 , 6.22)	0.02	(-5.35 , 5.49)

Results V: Comparison to TSE component estimates for 1+ Flu vaccination coverage in the NIS-Flu

TSE is slightly higher for 1+ COVID-19 compared to 1+ Flu for all children (6 months to 17 years), but the difference is not significant. Overall, reporting error is the largest contributor to TSE for both vaccines.

Error Component	1+ COVID-19 (NIS-CCM, 2022-2023 Influenza Season)		1+ Flu (NIS-Flu, 2022-2023 Influenza Season)	
	Mean Error	95-Percent Credible Interval	Mean Error	95-Percent Credible Interval
TSE	11.83	(8.79 , 14.89)	9.17	(5.73 , 12.68)
Noncoverage	-0.02	(-0.33 , 0.27)	0.02	(-0.21 , 0.26)
Nonresponse	-1.90	(-5.48 , 1.67)	0.23	(-4.06 , 4.51)
Reporting	13.75	(11.75 , 15.76)	8.92	(6.5 , 11.36)
Sampling	0.00	(-2.07 , 2.14)	0.00	(-2.62 , 2.63)

Conclusions and Discussion



Conclusions

- For overall children 6 months – 17 years, noncoverage error and nonresponse error are small while reporting error is the largest contributor to TSE.
- Reporting error was larger among teens and smaller among the younger age groups.
- Overall TSE does not vary substantially by race and ethnicity. Nonresponse error and reporting error components, however, tend to vary by race and ethnicity.
- TSE is not significantly different for 1+ COVID-19 compared to 1+ Flu for children 6 months to 17 years. Reporting error is the largest contributor to TSE for both vaccines.

Discussion

- Indirect approach was implemented for reporting error model inputs due to provider records availability which were limited to children 19 to 35 months and 13 to 17 years.
- The rollout of COVID-19 vaccines was unique and different from other routine adolescent vaccines, relying much more on pharmacies, schools, etc. than traditional providers.
  - Older children were more likely to be vaccinated at a non-medically-related site such as pharmacy or mass vaccination site compared to younger children. Provider report of vaccination received at a non-medically-related place is potentially more likely to be missing than provider report of vaccination received at a medically-related place.
- Assumption of normal, independently distributed parameters for TSE model inputs.

Discussion (continued)

- Results depend on accuracy of external data sources.
- The NIS has a standard framework for TSE which allowed us to implement the approach for NIS-CCM and estimate TSE for overall and for key demographic subgroups in a reasonable time frame.
- Provider data for COVID-19 vaccinations are potentially subject to greater under-ascertainment and incompleteness compared to other vaccines routinely assessed by the NIS-Child and NIS-Teen which may have impacted the reporting stage model inputs.
- Additional evaluation is needed to assess completeness of provider records relative to Immunization Information System (IIS).

Thank you

The findings and conclusions in this presentation are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention or NORC at the University of Chicago.

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