Noncoverage Adjustments in a Single-Frame Cell-Phone Survey: Weighting Approach to Adjust for Phoneless and Landline-Only Households

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Abstract[1]

In 2011, the National Immunization Survey (NIS) began using a dual-frame landline and cell-phone sample design to monitor vaccination coverage rates among children 19-35 months. As of 2012, coverage of the cell-phone sampling frame has increased to 92.9% of all age-eligible children in the NIS. Thus, a single-frame cell-phone sample design could be a viable option for the NIS, but such a sample design would not cover children living in landline-only and phoneless households. In order to adjust for the noncoverage of children living in landline-only and phoneless households, we propose two distinct adjustment methods. The first option is to identify a subset of cell-phone households with sampled children who have similar socio-demographic characteristics as those from landline-only and phoneless households and use a weighting class based approach to adjust for the noncoverage. The second option is to adjust for the noncoverage by using socio-demographic characteristics in a raking adjustment step. We implemented the proposed methods with 2012 NIS data and compared survey estimates generated under a single-frame cell-phone sample design with similar estimates from the current dual-frame sample design.

Key Words: Cell-phone sample; dual-frame sample design; National Immunization Survey; noncoverage; RDD telephone surveys; single-frame sample design; weighting

1. Introduction

The National Immunization Survey (NIS), sponsored by the Centers for Disease Control and Prevention, monitors vaccination coverage among children between 19 and 35 months of age. Data from the NIS are used to produce estimates of vaccination coverage rates for all childhood vaccinations recommended by the Advisory Committee on Immunization Practices (ACIP). Estimates are produced for the nation and non-overlapping geographic areas consisting of the 50 states, the District of Columbia, and selected large urban areas. The 56 core NIS areas (referred to as "estimation areas") are New York City; NY-Rest of State (i.e., state of NY excluding New York City); Philadelphia County, PA; PA-Rest of State; the District of Columbia; the city of Chicago, IL; IL-Rest of State; Bexar County, TX; the city of Houston, TX; TX-Rest of State; and each of the remaining 46 states. In 2012, Dallas County, TX and El Paso County, TX were additional NIS estimation areas.

[1] The findings and conclusions in this article are solely the responsibility of the authors and do not necessarily represent the official view of Centers for Disease Control and Prevention and NORC.

The NIS data collection involves two phases. The first phase is a household telephone interview where the most knowledgeable parent or guardian of the child is interviewed. The second phase is a provider record check where, with the consent of the child's parent or guardian, the child's health care provider(s) are contacted to request information on vaccinations from the child's medical records. NIS vaccination coverage rates are based on provider reported data (for additional details on the 2012 NIS, see CDC, 2013).

From 1994 to 2010, the NIS used a Random-Digit-Dial (RDD) list-assisted landline telephone sampling frame. However, over the last several years, landline telephone use has decreased while cell-phone use has substantially increased (see Figure 1). By 2012, 52.6% of all 1-2 year old children in the United States lived in households with only cell-phone service[2] (National Health Interview Survey [NHIS], 2007-2012). Beginning in 2011, to reduce potential noncoverage bias in the NIS vaccination coverage rates, official vaccination coverage rates are based on a dual-frame sampling design including both landline and cell-phone samples.

As of 2012, the cell-phone sampling frame covers 92.9% of the target NIS population (see Figure 1). Given that the cell-phone sampling frame has high coverage of the target NIS population, in this paper, we evaluate the feasibility of using a single-frame cell-phone sample design for the NIS using the 2012 NIS data. In Section 2, we introduce the single-frame cell-phone sample design. In Section 3, we briefly discuss weighting for the 2012 NIS dual-frame and single-frame sample designs. Since a single-frame cell-phone sample design does not cover children living in landline-only and phoneless households, in Section 4, we discuss two approaches to adjust for this noncoverage. Section 5 presents some results comparing the current dual-frame sample design with a single-frame cell-phone sample design. A discussion of the results is presented in Section 6 and some limitations of our study are given in Section 7. Finally, some concluding remarks are given in Section 8

2. Single-Frame Cell-Phone Sample Design

A single-frame cell-phone sample design is motivated by the increasing coverage of the cell-phone sampling frame. Furthermore, a single-frame cell-phone sample design may generate estimates for outcome variables that have smaller variance and larger effective sample size compared to a dual-frame sample design (Peytchev and Neely, 2013). In order to investigate a single-frame cell-phone sample design for our study, we used data collected from the existing dual-frame sample design and subsetted the data to all children sampled from the cell-phone sampling frame. One obvious drawback of this approach is that the sample size for the single-frame cell-phone sample design is much smaller than the dual-frame sample design. In Table 1, for the single-frame and dual-frame sample designs, we give the distribution (minimum, median, maximum) across all 58 estimation areas for the number of children with adequate provider data[3] for 2012 NIS. The median value for the sample size across all estimation areas under the current dual-frame sample design is 283, while after subsetting the data to simulate a single-frame cell-phone sample design, the median sample size across all estimation areas is 138. Thus, the single-frame cell-phone

[2] Source: 2007-2012 NHIS, annual national estimate.

[3] NIS uses child's adequate provider reported data to generate vaccination coverage rates. Children with adequate provider data refers to children with a completed household interview, and with reliable provider reported data to determine their up-to-date status for vaccines.

sample design had approximately 50% less data than the dual-frame sample design, and this has implications when making comparisons between the two sample designs.

3. Dual-Frame and Single-Frame Weighting

In this section, we briefly discuss NIS weighting methodology for the current dual-frame sample design and the alternative single-frame cell-phone sample design. Weighting for the NIS is conducted within each of the estimation areas. The NIS dual-frame weighting scheme for each estimation area involves the following three broad stages and multiple steps within each stage:

1) Calculating base sampling weights and household nonresponse adjusted weights
    i. The initial step in weighting is calculating base sampling weights for each sampled telephone number based on the probability of selecting the telephone number.
    ii. Similar to other telephone surveys, some sampled telephone numbers are not resolved, some working residential telephone numbers do not complete the NIS household screener interview, and some eligible households do not complete the NIS household interview. Thus, for each stage of household nonresponse, a corresponding nonresponse adjusted weight is derived.
    iii. Some households have multiple telephone lines and an adjustment is performed to account for the multiple chances of selection for these households. All weighting adjustment steps up to this stage were performed separately for the landline sample and the cell-phone sample.

2) Adjustment to independent population control totals and final household-phase weights
    i. At this stage, weights were adjusted to independent population control totals for the number of children 19-35 months living in cell-phone-only, landline and cell-phone dual user, and landline-only households. There was an adjustment to account for noncoverage of children living in phoneless households.
    ii. The final step of weighting for children with a completed household interview involves adjusting survey weights via a raking ratio method to agree with independent population control totals for various socio-demographic characteristics such as age, gender, race/ethnicity, mother’s education, and telephone status. This weight after the raking ratio adjustment is referred to as the final household-phase weight.

3) Adjustment for provider nonresponse and final provider-phase weights
    i. Some children’s health care providers do not respond to the request to provide information on a child’s vaccination status and an adjustment is performed to account for provider nonresponse. The final household-phase weights for children with adequate provider data were adjusted to represent the children who do not have complete and accurate provider reported data.
    ii. The final step of weighting for children with adequate provider data involves adjusting the weights from the previous step via a raking ratio

method to agree with independent population control totals for various socio-demographic characteristics. This raking ratio adjustment is similar to the raking ratio adjustment for children with a completed household interview. This weight after the raking ratio adjustment is referred to as the final provider-phase weight and is used to derive official vaccination coverage rates.

The single-frame cell-phone sample weighting scheme followed the same methodology as the dual-frame weighting scheme except for step (2)(i) which is modified to adjust for noncoverage of children living in phoneless and landline-only households.

4. Noncoverage Adjustments for Landline-Only and Phoneless Children

We considered two distinct methods to adjust for noncoverage of children living in landline-only and phoneless households in the single-frame cell-phone sample design. In the first method (Method 1), two separate subgroups were identified to represent landline-only children and phoneless children. In the second method (Method 2), we did not explicitly adjust for noncoverage of landline-only and phoneless children, but instead noncovered children were adjusted for in the socio-demographic raking ratio adjustment steps corresponding to steps (2)(ii) and (3)(ii) in Section 3.

For Method 1, in order to identify a subgroup to represent phoneless children, the National Health Interview Survey-Provider Records Check (NHIS-PRC) data were used to predict phoneless children using a logistic regression model. The significant variables in the logistic regression model were: child's race/ethnicity, child's mother's age, family income-to-poverty ratio, and child's housing tenure. The NHIS-PRC data was comprised of NIS age-eligible children identified through the National Health Interview Survey (NHIS) which is based on an area-probability design. The NHIS-PRC covered all NIS age-eligible children, not just those living in households with a landline telephone or cell-phone, and thus could be used to identify the phoneless population. The fitted model and estimated parameters obtained from the logistic regression model with NHIS-PRC data were used to estimate the propensity of each child with a completed household interview from the NIS cell-phone sample being "similar" to a phoneless child. NIS cell-phone sample children predicted as having a relatively high likelihood of being "similar" to children living in phoneless households served as "proxy phoneless" children; these proxy phoneless children were weighted to represent children living in phoneless households. Among children with adequate provider data, the distribution of the sample size for proxy phoneless children across all estimation areas varied from a minimum of 7 to a maximum of 45 with a median value of 17. We noted that the predictive power of the logistic regression model was poor with the area under the ROC curve equal to 0.63. The adjustment for noncoverage of phoneless children was implemented as follows:

$$W_{2j}^{PH} = \begin{cases} \dfrac{N_{PH}}{\sum_{j \in A} W_{1j}} W_{1j} & \text{if } j \in A \\ 0 & \text{if } j \notin A \end{cases}$$

where A is the proxy phoneless subgroup identified to represent phoneless children, N_{PH} is the independent population control total for the number of phoneless children, and W_{1j} is the weight after step (1)(iii) in Section 3.

A similar method was used to adjust for the noncoverage of children living in landline-only households. Children sampled from the cell-phone sampling frame and predicted as having a relatively high likelihood of being "similar" to children living in landline-only households served as "proxy landline-only" children; these proxy landline-only children were weighted to represent children living in landline-only households. The predicted probability of a child being "similar" to a child living in a landline-only household was determined using a logistic regression model for predicting landline-only status based on the NIS dual-frame sample cases (i.e., both landline and cell-phone sample cases), including socio-demographic characteristics as explanatory variables. The significant variables in the logistic regression model were: family poverty status, child's mother's education, MSA status, child's mother's age, first born status of child, relationship of respondent to child, housing tenure, child's race/ethnicity, marital status of child's mother, and interactions between mother's education and mother's age, mother's education and mother's marital status, mother's age and mother's marital status, mother's marital status and child's race/ethnicity.

Cell-phone sample children with a predicted probability above a determined cutoff level were classified as proxy landline-only children. Among children with adequate provider data, the distribution of the sample size for proxy landline-only children across all estimation areas varied from a minimum of 3 to a maximum of 44 with a median value of 14. The predictive power of the logistic regression model for landline-only children was moderately better than the logistic regression model for phoneless children with the area under the ROC curve equal to 0.76. The adjustment for noncoverage of landline-only children was implemented as follows:

$$W_{2j}^{LO} = \begin{cases} \dfrac{N_{LO}}{\sum_{j\in B} W_{1j}} W_{1j} & \text{if } j \in B \\ 0 & \text{if } j \notin B \end{cases}$$

where B is the proxy landline-only subgroup identified to represent landline-only children and N_{LO} is the independent population control total for the number of landline-only children.

For Method 1, the single-frame cell-phone sample weights adjusted to agree with independent population control totals for each telephone domain are given by

$$W_{2j} = W_{2j}^{CPO} + W_{2j}^{DU} + W_{2j}^{LO} + W_{2j}^{PH}$$

where W_{2j}^{CPO}, W_{2j}^{DU} are respectively the weights adjusted to agree with independent population control totals for the number of children living in cell-phone-only, cell and landline dual user households, and are defined as

$$W_{2j}^{CPO} = \begin{cases} \dfrac{N_{CPO}}{\sum_{j\in C} W_{1j}} W_{1j} & \text{if } j \in C \\ 0 & \text{if } j \notin C \end{cases}$$

$$W_{2j}^{DU} = \begin{cases} \dfrac{N_{DU}}{\sum_{j\in D} W_{1j}} W_{1j} & \text{if } j \in D \\ 0 & \text{if } j \notin D \end{cases}$$

where C, D respectively represent the cell-phone sample children with a completed household interview who live in cell-phone-only, cell and landline dual user households, and N_{CPO}, N_{DU} respectively represent the independent population control totals for the number of children living in cell-phone-only, cell and landline dual user households. The weight W_{2j} for the single-frame sample design was similar to the weight after step (2)(i) in Section 3 for the dual-frame sample design. Following the adjustment to independent population control totals by telephone status, the remaining steps in the weighting process for the single-frame sample design were carried out in a similar manner as the current dual-frame sample design.

For Method 2, there was no explicit adjustment for noncoverage of children living in landline-only and phoneless households. For this method, the single-frame cell-phone sample weights adjusted to agree with independent population control totals for each telephone domain are given by

$$W_{2j} = W_{2j}^{CPO} + W_{2j}^{DU}.$$

where W_{2j}^{CPO} and W_{2j}^{DU} are defined above. Once again, the weight W_{2j} was similar to the weight after step (2)(i) in Section 3 for the dual-frame sample design. The remaining steps in the weighting process were carried out in a similar manner as the current dual-frame weighting procedure, and landline-only and phoneless children were adjusted for in the socio-demographic raking steps corresponding to steps (2)(ii) and (3)(ii) in Section 3.

5. Results

We compared the dual-frame and single-frame sample designs using 13 vaccines and vaccination series given in Table 2. At the national-level, we also compared these vaccination coverage rates against similar vaccination coverage rates for the same NIS age-eligible population obtained from the National Health Interview Survey-Provider Records Check (NHIS-PRC).

Table 3 gives the national-level vaccination coverage rates for the dual-frame and single-frame sample designs and NHIS-PRC. In general, the single-frame sample design gives similar vaccination coverage rates as the dual-frame sample design. Methods 1 and 2 for the single-frame sample design yielded almost identical vaccination coverage rates and when compared to the NHIS-PRC vaccination coverage rates, all differences were within +/- 1.2 percentage points. We also compared vaccination coverage rates at the national-level by subgroup (child's race/ethnicity, child's mother's education, child's age, child's sex). By subgroup, there were some large differences, though when the single-frame and dual-frame estimates were compared, all differences were within +/- 2.7 percentage points; when the single-frame and NHIS-PRC estimates were compared, most differences were within +/- 2.7 percentage points but there were some large differences. In Table 4, we give the vaccination coverage rates by subgroup for one of the vaccination series (4:3:1:3:3:1:4).

At the estimation area level, across all vaccines and vaccination series, nearly all differences between Methods 1 and 2 across all estimation areas were within +/- 1 percentage point. There were up to 8 estimation areas with differences as large as 1-2 percentage points for some vaccines and vaccinations series. There were large differences between the dual-frame and single-frame estimates. Across all vaccines and estimation areas, the 25th and 75th percentile of the differences between vaccination coverage rates obtained from the dual-frame and single-frame sample designs were within +/- 2.5 percentage points, but for some vaccines and vaccination series, there were 3-5 estimation areas with large differences (> 5 percentage points).

Finally, we compared the estimation area level design effects under the dual-frame and single-frame sample designs (Table 6). Both single-frame weighting methods (Methods 1 and 2) had similar median design effects across all estimation areas. For the dual-frame sample design, the median value for the design effect across all estimation areas was 1.68 compared to the median value for the design effect across all estimation areas under the single-frame sample design which was 1.44. The single-frame sample design resulted in some estimation areas having a design effect greater than 3. For example, Virginia had a design effect of 3.69 under the single-frame sample design (with Method 1 weighting) and a design effect of 2.15 under the current dual-frame sample design.

6. Discussion

The dual-frame and single-frame sample designs for NIS yielded similar vaccination coverage rates for 2012 for the 13 vaccines and vaccination series that were considered. At the estimation area level, there were some large differences in vaccination coverage rates between the dual-frame and single-frame sample designs, but these differences were not directional and were likely due to sampling error and the small sample sizes associated with the single-frame sample design. There was little or no difference in vaccination coverage rates between the two methods we considered to adjust for noncoverage of landline-only and phoneless children. At the national-level, the vaccination coverage rates from the single-frame sample design were similar to the NHIS-PRC vaccination coverage rates, though there were some differences at the national-level by subgroup. This was possibly due to the smaller sample size for the NHIS-PRC survey compared to the NIS, difference in time periods between NIS (January-December 2012) and NHIS-PRC (July 2011-June 2012) and possibly a result of the lower adequate provider data rate associated with NHIS-PRC. The adequate provider data rate referred to the percent of children with a completed household interview who had complete and accurate health care provider reported data. The lower adequate provider data rate for NHIS-PRC may result in larger nonresponse bias in the NHIS-PRC vaccination coverage rates compared to the NIS vaccination coverage rates.

When comparing the median value of the design effect across all estimation areas, the single-frame sample design had a smaller median design effect compared to the current dual-frame sample design. We noted that geographic inaccuracy, nonresponse, and other factors may increase the design effect for some estimation areas under a single-frame sample design. This increase in design effect was potentially a result of geographic inaccuracy, nonresponse, and other factors (see Tao et. al., 2014). Finally, the estimation area design effects for Method 1 for the single-frame sample design depend on the sample size of the proxy phoneless and proxy landline-only groups. By varying the threshold that defines these proxy groups, the sample size for the proxy groups could be made to be larger or smaller.

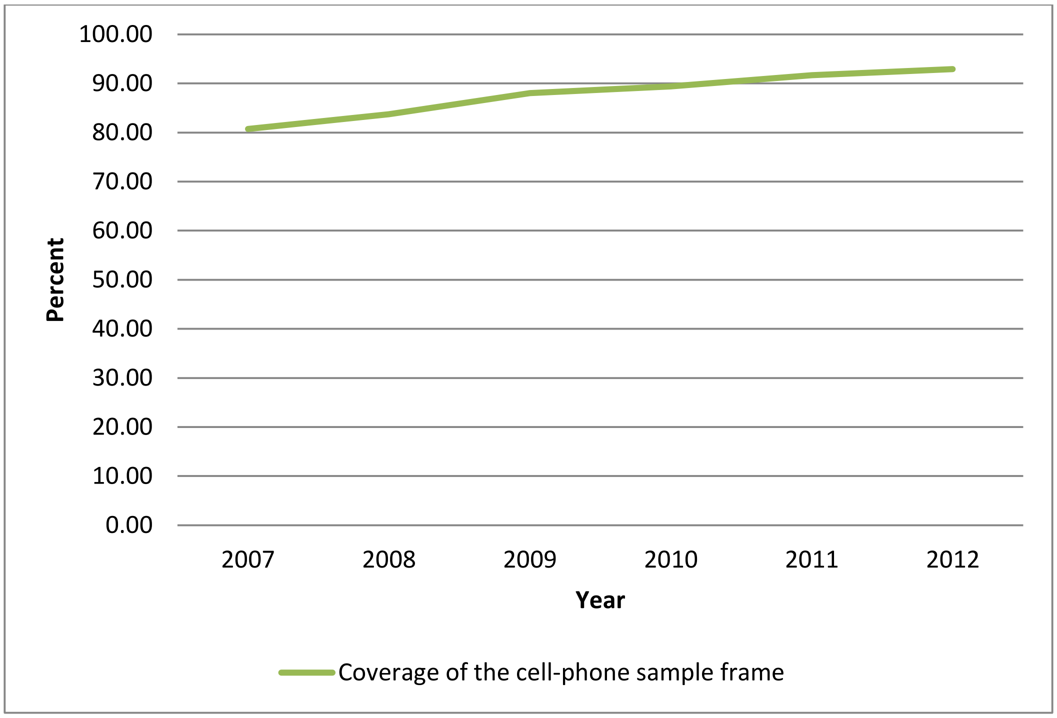
7. Limitations

There were a few limitations with respect to our study. The logistic regression models for identifying the proxy landline-only and proxy phoneless groups had poor to moderate predictive power. Furthermore, the small sample sizes associated with the single-frame cell-phone sample design limited the ability to detect statistically significant differences in vaccination coverage rates between the dual-frame and single-frame sample designs even if differences exist.

8. Conclusion

This study suggests that a single-frame cell-phone sample design might be an option for the NIS in the future. However, the cost implications and advantages of a single-frame cell-phone sample design must be thoroughly understood before modifying the NIS. Given that there was minimal difference between the two noncoverage adjustment methods that we considered for the single-frame cell-phone sample design, it may be preferable to use Method 2 given the potential for increasing variance associated with outcome estimates when performing an additional (and possibly unnecessary) adjustment.

Figure 1: Percent of 1-2 year old children* in the United States that are covered by the cell-phone sample frame, National Health Interview Survey (NHIS), 2007-2012.



*Based on the authors' analysis using 2007-2012 NHIS data.

Table 1: Distribution across estimation areas for the number of children with adequate provider data, NIS, 2012.

Sample Design	Sample size distribution across estimation areas		
	Minimum	Median	Maximum
Dual-frame	228	283	547
Single-frame cell-phone	82	138	389

Table 2: Description of vaccines and vaccination series, NIS, 2012.

Vaccines and Vaccine Series	Description
3+ DTaP	3 or more doses of diphtheria and tetanus toxoids and acellular pertussis vaccine, diphtheria and tetanus toxoids and pertussis vaccine, or diphtheria and tetanus toxoids vaccine (DTaP/DTP/DT)
4+ DTaP	4 or more doses of DTaP/DTP/DT
3+ Polio	3 or more doses of poliovirus vaccine
1+ MMR	1 or more doses of measles/mumps/rubella vaccine (MMR)
3+ Hib	3 or more doses of Haemophilus influenzae type b (Hib)-containing or 2+ Hib-Merck vaccine
3+ Hep B	3 or more doses of hepatitis B vaccine
1+ Var	1 or more doses of varicella zoster (chicken pox) vaccine at or after 12 months of age
3+ PCV	3 or more doses of pneumococcal conjugate vaccine
4:3:1	4 or more doses of DTaP/DTP/DT, 3 or more doses of polio, and 1 or more doses of MCV
4:3:1:3	4 or more doses of DTaP/DTP/DT, 3 or more doses of polio, 1 or more doses of MCV, and 3 or more doses of Hib-containing or 2 or more doses of Hib-Merck vaccine
4:3:1:3:3	4 or more doses of DTaP/DTP/DT, 3 or more doses of polio, 1 or more doses of MCV, 3 or more doses of Hib-containing or 2 or more doses of Hib-Merck vaccine, and 3 or more doses of Hep B vaccine
4:3:1:3:3:1	4 or more doses of DTaP/DTP/DT, 3 or more doses of polio, 1 or more doses of MCV, 3 or more doses of Hib-containing or 2 or more doses of Hib-Merck vaccine, 3 or more doses of Hep B, and 1 or more doses of varicella vaccine (the last at or after 12 months of age)
4:3:1:3:3:1:4	4 or more doses of DTaP/DTP/DT, 3 or more doses of polio, 1 or more doses of MCV, 3 or more doses of Hib-containing or 2 or more doses of Hib-Merck vaccine, 3 or more doses of Hep B, 1 or more doses of varicella vaccine (the last at or after 12 months of age), and 4 or more doses of pneumococcal conjugate vaccine

Table 3: Comparison of vaccination coverage rates at the national-level, 2012 NIS and Q3/2011-Q2/2012 NHIS-PRC.

Vaccine / Vaccination Series	Dual-Frame Sample Design	Single-Frame Cell-Phone Sample Design		NHIS-PRC	Diff = Method 1 - Dual-Frame	Diff = Method 1 - Method 2	Diff = Method 1 - NHIS-PRC
		Method 1	Method 2				
3+ DTaP	94.3%	94.7%	94.8%	94.8%	0.4%	-0.1%	-0.1%
4+ DTaP	82.5%	83.0%	83.2%	83.2%	0.4%	-0.2%	-0.2%
3+ Polio	92.8%	93.1%	93.2%	92.4%	0.3%	-0.1%	0.6%
1+ MMR	90.8%	91.7%	91.8%	91.3%	1.0%	0.0%	0.4%
3+ Hib	93.0%	93.5%	93.6%	94.1%	0.5%	-0.1%	-0.6%
3+ Hep B	89.7%	90.7%	90.7%	91.4%	0.9%	0.0%	-0.7%
1+ Var	90.2%	90.6%	90.6%	91.2%	0.3%	-0.1%	-0.6%
3+ PCV	92.3%	92.9%	93.1%	91.9%	0.6%	-0.1%	1.1%
4:3:1	80.5%	81.1%	81.3%	80.7%	0.6%	-0.2%	0.4%
4:3:1:3	80.0%	80.5%	80.7%	80.4%	0.6%	-0.2%	0.1%
4:3:1:3:3	77.1%	77.8%	78.0%	78.4%	0.7%	-0.2%	-0.6%
4:3:1:3:3:1	75.7%	76.2%	76.3%	77.4%	0.5%	-0.1%	-1.2%
4:3:1:3:3:1:4	71.0%	71.6%	71.8%	72.2%	0.7%	-0.1%	-0.6%

Table 4: Comparison of vaccination coverage rates by subgroup for 4:3:1:3:3:1:4 vaccination series, 2012 NIS and Q3/2011-Q2/2012 NHIS-PRC.

Subgroup	Dual-Frame Sample Design	Single-Frame Cell-Phone Sample Design		NHIS-PRC	Diff = Method 1 - Dual-Frame	Diff = Method 1 - Method 2	Diff = Method 1 - NHIS-PRC
		Method 1	Method 2				
Child’s Race/Ethnicity: Hispanic	70.4%	71.2%	71.4%	73.7%	0.8%	-0.2%	-2.4%
Child’s Race/Ethnicity: Non-Hispanic Black	67.4%	64.7%	65.0%	65.6%	-2.7%	-0.3%	-0.9%
Child’s Race/Ethnicity: Non-Hispanic White/Other	72.1%	73.4%	73.4%	73.1%	1.3%	0.0%	0.3%
Mother's Education: <=12 years	66.9%	68.1%	68.2%	70.4%	1.1%	-0.1%	-2.3%
Mother's Education: >12 years	74.5%	74.7%	74.8%	73.9%	0.2%	-0.1%	0.8%
Child’s Age: 19-23 months	64.6%	65.8%	65.8%	63.0%	1.2%	0.0%	2.8%
Child’s Age: 24-29 months	73.5%	73.6%	73.8%	72.1%	0.1%	-0.2%	1.6%
Child’s Age: 30-35 months	73.8%	74.6%	74.7%	79.9%	0.7%	-0.2%	-5.3%
Child’s Sex: Female	70.2%	70.9%	71.1%	71.3%	0.7%	-0.2%	-0.4%
Child’s Sex: Male	71.7%	72.4%	72.4%	73.1%	0.6%	-0.1%	-0.7%

Table 5: Comparison of vaccination coverage rates by estimation area for 4:3:1:3:3:1:4 vaccination series, NIS, 2012.

Estimation Area Name	Dual-Frame Sample Design	Single-Frame Cell-Phone Sample Design		Diff = Method 1 - Dual-Frame	Diff = Method 1 - Method 2
		Method 1	Method 2		
Connecticut	79.9%	75.6%	76.4%	-4.3%	-0.8%
Massachusetts	74.8%	73.3%	75.2%	-1.5%	-1.9%
Maine	76.4%	79.0%	79.0%	2.6%	0.0%
New Hampshire	80.7%	84.3%	85.1%	3.6%	-0.8%
Rhode Island	80.0%	75.4%	75.8%	-4.5%	-0.4%
Vermont	65.4%	69.0%	69.7%	3.6%	-0.7%
New Jersey	74.0%	70.4%	70.4%	-3.6%	0.0%
NY-Rest of State	68.6%	73.9%	73.6%	5.4%	0.3%
NY-City of New York	64.6%	64.7%	66.6%	0.1%	-1.9%
District of Columbia	75.4%	71.9%	72.3%	-3.6%	-0.4%
Delaware	74.7%	76.1%	76.4%	1.5%	-0.3%
Maryland	70.3%	72.6%	72.3%	2.3%	0.2%
PA-Rest of State	69.5%	72.2%	71.7%	2.7%	0.4%
PA-Philadelphia County	75.1%	73.6%	74.7%	-1.5%	-1.2%
Virginia	74.6%	71.0%	70.8%	-3.6%	0.2%
West Virginia	61.7%	61.7%	62.4%	0.0%	-0.7%
Alabama	75.3%	76.5%	76.8%	1.2%	-0.4%
Florida	70.4%	70.7%	70.4%	0.3%	0.3%
Georgia	77.5%	68.2%	67.3%	-9.3%	0.8%
Kentucky	71.8%	71.8%	71.7%	0.1%	0.1%
Mississippi	80.3%	80.2%	81.3%	-0.1%	-1.1%
North Carolina	76.1%	79.4%	79.3%	3.3%	0.1%
South Carolina	74.2%	77.3%	77.2%	3.2%	0.2%
Tennessee	75.1%	77.8%	77.8%	2.7%	0.0%
IL-Rest of State	74.9%	73.9%	74.7%	-0.9%	-0.7%
IL-City of Chicago*	63.5%	74.5%	74.9%	11.0%	-0.4%
Indiana	62.6%	63.6%	62.2%	1.0%	1.4%
Michigan	71.1%	77.1%	78.1%	6.0%	-1.0%
Minnesota	71.3%	72.6%	72.5%	1.2%	0.0%
Ohio	69.4%	67.6%	68.0%	-1.7%	-0.3%
Wisconsin	76.6%	80.4%	80.0%	3.8%	0.4%
Arkansas	68.0%	65.3%	64.8%	-2.7%	0.5%
Louisiana	70.4%	73.6%	73.1%	3.2%	0.5%
New Mexico	73.4%	73.6%	73.0%	0.2%	0.6%
Oklahoma	67.0%	69.9%	69.0%	3.0%	1.0%
TX-Rest of State	65.7%	66.6%	66.8%	0.9%	-0.2%
TX-Dallas County	70.6%	67.7%	68.0%	-3.0%	-0.4%
TX-El Paso County	65.3%	64.8%	64.9%	-0.5%	-0.1%
TX-City of Houston	74.3%	74.6%	74.9%	0.3%	-0.3%
TX-Bexar County	68.2%	64.7%	64.4%	-3.5%	0.4%
Iowa	77.7%	80.9%	81.1%	3.2%	-0.1%
Kansas	68.1%	68.7%	69.2%	0.7%	-0.4%
Missouri	68.1%	67.0%	66.4%	-1.2%	0.6%

Estimation Area Name	Dual-Frame Sample Design	Single-Frame Cell-Phone Sample Design		Diff = Method 1 - Dual-Frame	Diff = Method 1 - Method 2
		Method 1	Method 2		
Nebraska	74.2%	72.7%	72.4%	-1.5%	0.3%
Colorado	72.8%	71.4%	71.9%	-1.4%	-0.5%
Montana	68.8%	66.6%	65.6%	-2.1%	1.0%
North Dakota	74.1%	72.2%	71.8%	-1.8%	0.4%
South Dakota	67.9%	65.2%	65.9%	-2.7%	-0.7%
Utah	74.4%	67.3%	67.9%	-7.1%	-0.6%
Wyoming	68.1%	70.8%	72.1%	2.7%	-1.4%
Arizona	69.9%	67.9%	68.5%	-1.9%	-0.6%
California	69.5%	73.5%	74.0%	4.0%	-0.5%
Hawaii	83.1%	86.4%	85.6%	3.3%	0.8%
Nevada	70.9%	69.9%	69.7%	-1.1%	0.2%
Alaska	67.8%	68.6%	68.7%	0.8%	-0.1%
Idaho	68.1%	70.6%	71.3%	2.5%	-0.6%
Oregon	69.2%	68.3%	67.8%	-0.9%	0.5%
Washington	68.4%	67.1%	66.3%	-1.2%	0.8%

*For the single-frame cell-phone sample design, IL-City of Chicago had the smallest number of children with adequate provider data; thus, the large difference in vaccination coverage rates between the single-frame and dual-frame sample designs was possibly a result of sampling error.

Table 6: Distribution of design effect across estimation areas, NIS, 2012.

	Dual-Frame Sample Design	Single-Frame Cell-Phone Sample Design	
		Method 1	Method 2
Minimum	1.04	0.97	0.97
25th percentile	1.47	1.30	1.31
Median	1.68	1.44	1.43
75th percentile	1.93	1.59	1.59
Maximum*	2.45	3.69	3.72

*For the single-frame cell-phone sample design, one estimation area had a design effect larger than 3 possibly due to geographic inaccuracy, nonresponse, and other factors associated with the cell-phone sample design.

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