Assessment of Potential Bias in the National Immunization Survey (NIS) Estimates using Data on Telephone Status from the 2007 NHIS

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Abstract[1]

The Quality and validity of survey estimates depend on coverage of the target population and the magnitude of bias in estimates. According to estimates from the National Health Interview Survey (NHIS), wireless substitution is rapidly increasing among adults. The prevalence of wireless-only households with children less than 18 years of age has increased from 3.7% in 2003 (January-June) to 19% in 2008 (July-December). Households with wireless-only telephone service accounted for more than 83% of households without landline telephone service. In addition, households with mixed telephone service where members primarily use wireless telephones for most calls (wireless-mostly) may not respond to a survey if called on their landline telephone. In 2007, wireless-mostly and wireless-only households accounted for 13.5% and 20.1% of children aged 1-4 years, and 16.2% and 8.7% of teens aged 13-17 years, respectively. The increasing prevalence of wireless-only and wireless-mostly households may affect the validity of estimates from telephone surveys such as the National Immunization Survey (NIS). The NIS is a large telephone survey of households with children aged 19-35 months followed by a mail survey of providers to obtain vaccination records; the NIS-Teen uses the same methodology for adolescents aged 13-17 years. Data from households with children aged 1-4 years from the 2007 NHIS are used to evaluate potential noncoverage bias and methods to adjust sampling weights for noncoverage using information from wireless-mostly and wireless-only households. Noncoverage bias is evaluated by comparing characteristics of household members and estimates of selected outcome measures associated with vaccination coverage by type of household telephone service. The purpose of this paper is to continue the evaluation of potential noncoverage bias in the NIS survey estimates due to noncoverage of wireless-only and wireless-mostly households, with emphasis on evaluating weighting methods to reduce non-coverage bias.

Keywords: Weighting, propensity score models, RDD telephone survey

Introduction

The quality and validity of survey estimates depend on coverage of the target population, response rates, and the extent of measurement errors. Response rates for household-based telephone surveys have been continuously declining for the last decade (Battaglia *et al.*, 2007, Curtin et al., 2005). With rapidly changing technology and telephony, households (i.e., persons) are substituting residential landline telephones with wireless (aka cell-

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phone or mobile) telephones, and as a result, coverage of residential households in landline telephone (LT) surveys has been decreasing. Despite all challenges, random-digit-dialing (RDD) landline telephone surveys remain a quick and cost-effective method for data collection to investigate emerging public health issues. The goal of household-based RDD surveys is to produce unbiased estimates, but high noncoverage and nonresponse increase the potential for bias in survey estimates. Landline RDD surveys specifically exclude households that do not have landline telephones (NLT), consisting of wireless-only (WPO) and phoneless (NP) households.

Blumberg and Luke (2009a) used data from the National Health Interview Survey (NHIS), which covers both telephone and nontelephone households, to show that wireless substitution among adults increased from 2.9% in 2003 to 18.4% in 2008 while the prevalence of phoneless households remained low and ranged from 1.6-2.1%. Among households with children under 18 years of age, the wireless substitution increased from 2.9% in 2003 to 18.7% in 2008 while the prevalence of phoneless households ranged from 1.5-2.4%. The authors also showed that the prevalence of wireless substitution is higher among certain socio-demographic subgroups: adults aged 25-29 years; men; those living in poverty, renting their home, living alone or living with unrelated roommates; those living in the south, and of Hispanic or non-Hispanic black race/ethnicity. Renting home and living alone or living with unrelated roommates are the strongest predictors of wireless substitution. Rates of landline telephone coverage show substantial variation by socio-demographic status and geography (Blumberg *et al.*, 2009b). In addition, households with mixed telephone service where members primarily use wireless telephones for most calls (wireless-mostly) may not answer their landline telephones resulting in noncontacts. Wireless-mostly households are more likely to be college graduates, living with children, having higher income, and living in metropolitan areas.

Since the characteristics of persons living in landline telephone (LT) households are considerably different from the population living in NLT households, estimates from RDD surveys are subject to potential bias due to noncoverage and adjustments are required to compensate for this noncoverage and to reduce bias. Generally, to reduce bias in survey estimates, sampling weights are adjusted and post-stratified within homogeneous weighting classes to account for interview nonresponse and noncoverage of the target population. Keeter (1995), Brick *et al.* (1996), Frankel *et al.* (2003), and Srinath *et al.* (2002) previously showed that the socioeconomic characteristics of persons who live in households with interruptions of one week or more in landline telephone service within the past 12 months (LTI population; ~4%) are similar to those who live in nontelephone households (~3%); households with interruption of less than one week are assumed to be similar to those with continuous landline service. This is based on the observation that had the survey been conducted at some point in time, when the household had interruptions, the household would have been considered as part of the population of nontelephone households (regardless of access to a wireless telephone). Therefore, persons living in households with an interruption in landline telephone service can be used to represent persons living in nontelephone households in RDD surveys. However, Keeter's interruption method may not be effective when the prevalence of noncoverage is substantially higher and >90% of the noncoverage is due to wireless phone substitution. Also, characteristics of the LTI population (~4%) might not be the same as the WPO population. Khare *et al.* (2009) and Chowdhury *et al.*, (2007) concluded from their analyses that although some of the characteristics of the LTI or NP household members are similar to those of the WPO household members (e.g., renters or under 200% poverty level), the interruption method was not completely effective in reducing noncoverage bias due to the exclusion of the WPO households with young children. Also, the interruption method introduced substantial variation in the final sample weights due to large adjustment factors. (Copeland, *et al*., 2009)

The increasing prevalence of the WPO and wireless-mostly populations may affect the validity of estimates from telephone surveys such as the National Immunization Survey (NIS; Smith *et al.,* 2005). We used data from the NHIS-Child sample for the age groups 1-4 years to assess potential bias in vaccination estimates for age-eligible children in the NIS-Child (19-35 months) survey assuming similar nonresponse and noncoverage characteristics of persons from landline telephone households from the two surveys; we selected children aged 1-4 years to increase the sample size for this research. We used four weighting methods to adjust for noncoverage to identify the method that best reduces the bias.

Data

The target population for the NHIS is the US civilian non-institutionalized resident population (with or without access to telephones) and data are collected through in-person interviews. In 2003, a question about access to wireless telephone was added to the NHIS and in 2007 another question was added on usage pattern of wireless phones (sometime or most-of the time). Data on 2,203 children aged 1-4 years from the 2007 NHIS-Child sample (http://www.cdc.gov/NCHS/nhis/nhis_2007_data_release.htm) are used to model and compare characteristics of children living in phoneless (NP) and wireless-only households (WPO) with children living in landline telephone (LT) households or in households with interruptions (LTI) in landline telephone service. We created six groups based on household telephone status:

1) LTI contains children from households which had only LT service at the time of the survey and had interruptions in LT service (I) for one week or more during the previous 12 months;
2) LTWP-some contains children from mixed households which had LT service, had no interruption in LT service and also report using wireless phones sometime;
3) LTWP-mostly contains children from mixed households which had LT service, had no interruption in LT service, and also report using wireless phones most of the time;
4) LT-only contains children from households which had only LT service, had no interruption in LT service, and had no access to wireless phones in the household;
5) WPO contains children from households without any LT service during the previous year and which had at least one household member with access to a wireless telephone during that time;
6) NP contains children from households with no access to LT or wireless telephone service in the household during the previous year (i.e. phoneless households).

Methods

To assess bias, we assumed that the LT sample from the NHIS is similar to samples from a telephone survey like the NIS where households and children are selected randomly. We used variables common to both the NIS and the NHIS and compared the prevalence of selected health and vaccination related variables such as influenza vaccinations and asthma among children aged 1-4 years. Because NHIS-Child does not collect any information on childhood vaccinations, we created a model-based vaccination variable from the NIS to predict the vaccine series 4:3:1:3:3 status (4 or more doses of DTaP, 3 or more doses of poliovirus vaccine, 1 or more doses of MMR vaccine, 3 or more doses of Hib vaccine, 3 or more doses of hepatitis B vaccine) for the NHIS children. A similar model has been previously used and the model-based estimate of the 4:3:1:3:3 coverage rate was not statistically different from the observed NIS estimates (Khare *et al.*, 2007). We used data from the 2007 NIS and covariates associated with vaccination status (available from both the NIS and the NHIS) and then used the parameter estimates from the NIS model to predict the 4:3:1:3:3 vaccination status for the 2007 NHIS children. We included region, metropolitan statistical area (MSA), age, household size, race/ethnicity, mother's age and education, and poverty status as covariates in the model (Khare *et al.*, 2006, 2007) and used the average of the propensity scores to obtain the coverage rates. The value of 'c' at 61% (area under the curve) from the 2007 NIS model indicates a moderate association between the observed and predicted propensity of being up-to-date for the 4:3:1:3:3 series.

We selected those children 1-4 years of age living in LT households from the 2007 NHIS-Child sample to approximate a RDD type sample and evaluated alternate adjustment methods using ratio- and propensity-based weighting methods. We used the nonresponse adjusted interim NHIS weights WTIA_SC ($=W_i^B$) for the children in the 2007 NHIS-Child LT sample to adjust for noncoverage. To assess bias in the resulting weighted estimates, mean-squared errors (MSE= $\text{Bias}^2 + \text{SE}^2$) are computed with respect to the estimates from the 2007 NHIS-Child sample and ratios of MSEs are compared to select the method with least bias. The weighting method with the smallest MSEs is expected to perform better in reducing collectively the bias and variance in estimates.

The noncoverage adjustment method M1 is similar to the interruption method currently used in the NIS to compensate for the noncoverage of nontelephone households (Frankel *et al.*, 2003; Smith *et al.*, 2005). In method M1, initial weights W_i^B for children from households with interruptions (LTI) are directly ratio-adjusted to the [(LTI) + (NP+WPO)] population control totals (N_i) within the demographic [race/ethnicity (3)] weighting cells; no noncoverage adjustments were applied to the sampling weights of children from the LTWP-some, LTWP-mostly, and LT-only households. Thus, the new noncoverage adjusted sampling weight M1 for the unit *i* in the LTI group is defined as

$$W_i^{M1,LTI} = W_i^B * \frac{(N_{LTI,ps} + N_{NP,ps} + N_{WPO,ps})}{\sum_{i \in LTI,ps} W_i^B}.$$

Method M2 used a hybrid of method M1 with a slightly different direct ratio-adjustment procedure. Khare *et al.* (2009) showed that the characteristics of children living in LT-only households are somewhat similar to those who live in WPO households. Thus, method M2 could separately adjust sampling weights of children from LT-only households to represent children from WPO households. However, because the proportions and sample sizes of the LTI and NP groups are very small and the children from the two groups had somewhat similar characteristics as the children from the WPO and the LT-only groups, method M2 simultaneously adjusted weights for the children from the combined LTI and LT-only groups for those from the NLT (WPO + NP) group. Hence, weights of the children in the (LT-only + LTI) groups are adjusted to the (LT-only + LTI + WPO + NP) estimated population control totals within weighting cells based on characteristics [house tenure, <200% poverty level, and race/ethnicity] associated with the WPO and the NP households; no noncoverage adjustments were applied to the sampling weights of children from the LTWP-some and LTWP-mostly households. Thus, the new sampling weight M2 for the unit *i* in the (LT-only + LTI) group is defined as

$$W_i^{M2,(LT-only+LTI)} = W_i^B * \frac{N_{(LT-only+LTI),ps} + N_{WPO,ps} + N_{NP,ps}}{\sum_{i\in(LT-only+LTI),ps} W_i^B}.$$

An alternative approach to the direct ratio-adjustment method is to use logistic regression to model response propensities of nontelephone status for the LT sample and use the predicted propensities to create weighting classes and adjust sampling weights for noncoverage (Battaglia *et al.*, 1995; Davis and Khare, 2004; Khare and Chowdhury, 2006) within those classes. Method M3 used two procedures to adjust sampling weights for noncoverage-- method M3a used the inverse of the predicted propensity scores and M3b used quintiles of the predicted propensity scores. We used data from the 2007 NHIS-Child sample to develop a logistic regression model of response propensities for NLT households consisting of (WPO + NP) households and (LT-only + LTI + LTWP-mostly) households. To identify covariates for the model we first used separate stepwise logistic regression models for binary outcome variable NLT, NP, WPO, LTI, LT-only, and LTWP-mostly with all possible covariates (Table 3) and selected a subset of those covariates common to most of these models to develop the final NLT model. The final NLT propensity score model used child's age group(2), housing status(2), region (4), mother's age group (3), mother's marital status(4), and poverty level(4) as covariates. To account for the complex sample design we used normalized sampling weights WTIA_SC in the logistic regression model. Next, in method M3b, WTIA_SC weights for the children from the NHIS telephone sample are adjusted within weighting classes based on the quintiles of the predicted propensity scores and selected socio-demographic characteristics [house tenure(2), and <200% poverty level(2)]; no noncoverage adjustments were applied to the sampling weights of children from the LTWP-some households.

Finally, a poststratification step adjusted the total weighted cell counts for children from the LT sample using methods M1--M3b to the total target US population 1-4 years of age within demographic cells [sex (2), and race/ethnicity(4)]. These final poststratified weights are then used to compute the new noncoverage adjusted estimates which are compared with the overall 2007 NHIS-Child sample estimates.

To compare the four adjustment methods, weighted estimates of selected health related and socio-demographic characteristics are compared. We selected household respondent-reported information on child's access to health insurance, receiving influenza vaccinations, ever having asthma, and ever having chickenpox and the model-based predicted 4:3:1:3:3 vaccination coverage to assess bias by taking the difference between the overall 2007 NHIS-Child sample estimates and the estimates from the LT sample using the sampling weights from methods M1--M3b. To account for the complex sample design of the NHIS, SUDAAN (RTI, 2008) was used to compute standard errors. Differences in estimates and ratios of estimated MSEs are used to compare weighting methods and evaluate bias.

Results

Characteristics of children by household telephone status

In 2007, 15.2%, 13.3% and 13.8% of children aged <18 years were living in non-landline (NLT), wireless-only (WPO), and wireless-mostly households, respectively. The prevalence of children living in WPO households decreased with increasing age of children and was 20.6%, 11.7 %, and 8.7% among children aged 0-4 years, 5-12 years, and 13-17 years, respectively. The corresponding prevalence of children from NP households was 3.3%, 1.4%, and 1.3% for the three age groups. Prevalence of wireless-mostly was similar across the three age groups (12.7%, 13.0%, 14.6%, respectively).

To identify characteristics correlated with noncoverage of NLT (WPO+NP) households, Table 1 presents the distribution of household telephone status (LTI, LTWP-some, LTWP-mostly, LT-only, WPO, and NP) by selected characteristics. In 2007, among children 1-4 years of age, only 77% lived in LT household, 20% lived in WPO household, and 3% had no access to telephone. Also, only 4% of children lived in LT households with interruptions of ≥1 week in telephone service in the past 12 months who represent children from the NP households in the current noncoverage adjustment method.

In order to identify one or more landline telephone groups which resemble the children from the WPO households, we compared the characteristics of children by household telephone status. Although none of the four LT groups completely resemble the WPO group, Table 2 shows that the characteristics of children living in WPO households have some similarity with those living in LT-only or LTI households (e.g., living in rented house, race/ethnicity, mother's education, mother's age, or household poverty level) than with those living in LTWP-some or LTWP-mostly households (see bolded numbers in the table for characteristics with high percentages). Table 3 also shows that four of the five significant covariates in the WPO model are also significant in the LT-only model. On the contrary, children living in LTWP-mostly household are more likely to have a mother with higher education, have a single parent, and have high household income (>200% poverty level). The characteristics of children living in LTWP-mostly households appear to have more similarity in characteristics of children from the LTWP-some households than children from WPO or NP households. Hence, as previously shown by Khare *et al.* (2008), the LT-only group could be combined with the LTI group to collectively adjust for the noncoverage of children from the WPO and the NP households in adjusting sampling weights.

Table 3 shows significant variables from logistic regression models predicting each type of household telephone status using a stepwise selection method. LTWP-some households without any interruptions in telephone service were excluded from all of these models because the sample was not expected to have any noncoverage adjustments. However, LTWP-mostly households were included in these models because they were expected to have some noncoverage due to noncontact. As found in previous studies and mentioned in the methods section, house tenure status, region, mother's education, mother's age group and poverty level are found significant for most of the separate telephone status models and hence, used in the final NLT noncoverage model. Interruption in telephone service is not found to be significant for any of these models except for the LTWP-mostly model (similar results were found by Chowdhury *et al*, 2008 and Copeland *et al.*, 2009).

Propensity score model for NLT households

The final propensity score model for predicting NLT (WPO+NP) status among all children except for those living in LTWP-some households, included housing status, race/ethnicity, region, mother's education level, mother's age, household size and poverty status (Table 4) as covariates. These covariates are a subset of the characteristics listed in Tables 1 and 2 and most of these variables except for the house tenure status are also available in the NIS. The predicted propensities of being an NLT household are used to create weight adjustment cells among children from LTI, LT-only and LTWP-mostly households. Method M3b used the quintiles of the predicted propensity score to create homogeneous weighting cells and adjusted for noncoverage among the LTWP-mostly, LT-only, and LTI households. It is expected that including the LTWP-mostly group in the model and using house tenure status, mother's education and poverty level may simultaneously adjust for the residual noncontact with the LTWP-mostly households. The first column of Table 4 lists the set of covariates selected in the final model to predict propensity scores for the NLT status; beta coefficients and estimates of odds ratios for the covariates are shown in columns 2 and 3 of the table. Table 4 also shows some model diagnostics. The concordance (68%) and estimated value of 'c', the area under the ROC curve (68%), indicate a moderate association between the predicted propensities and the observed indicator of the NLT status.

Comparison of adjustment factors

Table 5 shows the distribution of the overall adjustment factors that are applied to the WTIA_SC weights using methods M1--M3b. It shows that methods M2 and M3b performed slightly better than the method M1 (i.e., the Keeter's method) by reducing variation in sampling weights and standard errors. The maximum adjustment factor using method M1 was ~2 times larger than the maximum factor using methods M2 and ~3 times larger than the maximum factor using M3b; The coefficient of variation from method M1 is also ~2 times larger than other two methods. The ratio of methods M3b to M2 (the last column) shows that method M3b performed slightly better than M2 with ratio<1.0 for mean, standard deviation, and inter-quartile range. These statistics for adjustment factors are also smaller using method M3b when compared to method M3a.

The four plots in Figure 1 show the distribution of the NHIS-Child sample weight (WTFA_SC) versus the new weights adjusted using methods M1--M3b. The weight distribution plot of WTFA_SC versus method M1 is highly dispersed and new weights are much deviated from the diagonal axis of the NHIS-Child weight, whereas, the distribution is relatively smooth and more concentrated around the diagonal axis for the plot WTFA_SC versus Method M2. Because of high variability in weights of method M3a, we limited our focus on method M3b based on quintiles of the noncoverage propensities. The plot for method M3b shows a much smoother distribution of adjusted weights than using the other three methods.

Comparison of weighted estimates and MSEs

Figure 2 shows the magnitude of bias in the prevalence of influenza vaccinations by various characteristics. Almost all of the NHIS estimates of influenza vaccinations are higher than the LT sample estimates adjusted for noncoverage using methods M1--M3b. The average bias in the estimates of influenza vaccination are found to be 2.8%, 2.1%, 2.4% and 1.5% using methods M1, M2, M3a, and M3b and ranged from -4.2% to 7.2%, from -2.9% to 7.3%, from -3.4 to 12.7 and from -1.9% to 6.9%, respectively. The average bias is found to be the smallest using method M3b and the largest using method M1.

Table 6 presents a comparison of the prevalence of influenza vaccinations and 4:3:1:3:3 prediction among children 1-4 age, 95% confidence interval for the NHIS estimates and MSEs ($Bias^2$ + SE^2) using the 2007 NHIS-Child estimates as the true population estimates. The estimates of MSEs are smaller from methods M2 and M3b than from method M1. Also, differences in overall weighted estimates using methods M2 and M3b are very small when compared to the differences in estimates from method M1. MSE ratios associated with the prevalence of influenza vaccinations show that methods M2 and M3b performed 2.5 to 3 times better than the interruption method M1 (with smaller MSE values and ratios<1.0).

Table 6 also shows that differences in the model-based predicted 4:3:1:3:3 coverage estimates are small. This could be because an external model was applied to the NHIS and models tend to smooth estimates.

Conclusion

The prevalence of children from WPO households decreased with increasing age among children less than 18 years of age. Among children aged 1-4 years, socio-demographic characteristics of children living in LT-only, LTI, WPO, or NP households appear to be different from those living in LTWP-some and LTWP-mostly households. Factors that are highly correlated with LT-only, LTI, WPO, or NP household status are house tenure status, household size, race/ethnicity, poverty level, health insurance status, geographic region, and mother's age, education, and marital status. After adjusting for differential noncoverage, the average bias in estimates (i.e., difference) of household-reported influenza vaccinations with respect to the overall 2007 NHIS-Child sample estimates were 2.8%, 2.1%, 2.4%, and 1.5% using four weighting methods M1, M2, M3a, and M3b, respectively (the corresponding maximum differences in estimates were 7.2, 7.3, 12.7, and 6.9%, respectively); some of the large differences could be due to small sample sizes or large variations in adjusted weights. The average bias is found to be the smallest using method M3b and the largest using method M1. A sensitivity analysis indicated that with a prevalence of 25% NLT households, and a 10% difference between the landline and the NLT group estimates, the estimated landline noncoverage bias may be as much as 2.5% [= NLT prevalence* (difference in LT and NLT estimates)].

With increasing trends in the prevalence of wireless only households, using separate adjustments for wireless-only and phoneless household may be desirable and may control for potentially larger bias in population estimates that are correlated to characteristics of wireless-only households. Adjustments based on interruption in landline telephone service reduced some noncoverage bias, especially for those characteristics that are highly correlated with the absence of landline telephone or presence of wireless services, but increased the variance due to small sample sizes and/or large NLT adjustment factors. Methods M2 and M3b appear to perform somewhat better than the Keeter's interruption method M1. The ratios of MSEs in Table 6 suggest slightly greater reduction in bias with method M2 (a hybrid of Keeter's ratio adjustment method) for the model-based predicted 4:3:1:3:3 estimates and with method M3b for the prevalence of influenza vaccinations. Therefore, it is difficult to conclude whether method M2 or M3b would perform better for a specific outcome variable. Because method M3b can use more covariates and categories associated with telephone status of households, it may be desirable for some outcome variables to use the propensity mode-based method to reduce noncoverage bias in RDD estimates; on the other hand, method M2 is easy to implement with the limited information available on telephone status and other associated covariates. To use methods M2 or M3, RDD surveys need to collect information on household tenure (the most significant characteristic of NP, WPO, LT-only, LTWP-mostly households) and on the access to wireless telephones by household members.

Annual evaluation of potential noncoverage bias in the NIS is needed as the prevalence of wireless-only households continues to increase. The NHIS provides a unique source of data for this evaluation and could be used in a similar way for other RDD surveys. Findings from the analysis of the NHIS data by telephone status are reassuring, however, direct assessment of bias in RDD surveys like NIS are needed. In 2009, a provider-record-check study has been added to the NHIS for children aged 19-35 months and teens of age 13-17 years to directly evaluate noncoverage and nonresponse bias in vaccination estimates from the NIS.

Our analyses had a few limitations. First, we assumed that nonresponse and noncoverage patterns were similar for a traditional RDD sample and the NHIS LT sample. Second, the NHIS conducts in-person face-to-face interviews while RDD surveys collect data through computer-assisted telephone interviews which may cause plausible mode effect in responses. Also, NHIS collects limited information related to vaccinations and therefore it is difficult to directly assess noncoverage bias for the NIS estimates. Lastly, we used NHIS estimates as the gold-standard. However, NHIS estimates are also subject to potential nonresponse bias.

To continue further evaluation of reduction in noncoverage bias with increasing substitution of landline telephones with wireless phones, and to adjust for the noncoverage of wireless-only households in telephone surveys, the 2007 NIS added a question on access to wireless telephones during the interruption in landline service. Also, a pilot study was conducted whereby a sample of wireless phone numbers is hand-dialed to interview households with access to wireless phones. In 2008 and 2009, in addition to socio-demographic and geographic information, NIS has added questions to collect information on household tenure status and access to wireless telephones to identify LT-only households. This information can then be used to apply weighting method M2 to adjust the NIS estimates and directly assess potential bias due to noncoverage of wireless-only and non-landline telephone households. Furthermore, for direct assessment, CDC is conducting an NIS experiment using an address-based sampling frame to cover telephone and non-telephone households in 2009. NIS also conducted a national wireless telephone survey in 2009 to compare vaccination coverage estimates from a landline and a wireless telephone survey. NIS is also re-evaluating the household interview weighting procedure to reduce noncoverage bias. Findings from some of these experiments will be available in 2010.

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Appendix

Table 1: Distribution of telephone coverage among US children (age 1-4 years) by selected characteristics, 2007 NHIS-Child sample

Characteristics	Distribution of Household Telephone Status (Children of age 1-4 years)					
	LTI (>1wk)	**LTWP-some**	**LTWP-Mostly**	**LT-only**	**WPO**	**NP**
Total Sample Size (n=2203)	95	927	285	351	472	73
	%	**%**	**%**	**%**	**%**	**%**
All, 1-4 years	4.12	45.52	11.88	15.17	20.03	3.27
House : Owned	2.45	58.97	13.85	12.35	10.48	1.90
Rented	6.38	27.35	9.22	18.98	**32.94**	5.12
Sex: Male	4.55	42.84	11.67	16.15	21.86	2.92
Female	3.67	48.37	12.10	14.13	18.08	3.65
Race/Ethnicity: Hispanic	4.19	32.47	11.35	20.96	**25.32**	5.70
NH White	3.78	53.51	11.86	12.13	16.33	2.39*
NH Black	5.80	32.58	12.06	19.47	**28.39**	1.69*
NH Other	2.76	55.07	13.38	10.25	12.73	5.80
Household size: 2	5.87*	20.70	15.75	13.11	**41.38**	3.19*
3 - 5	4.45	44.23	13.65	13.85	21.05	2.78
5 +	3.48	49.76	8.89	17.32	16.53	4.02
Poverty Level: <100%	8.95	21.43	5.92	17.23	**38.99**	7.47
100 - 199%	5.74	31.20	12.12	19.17	**28.04**	3.74
200 - 399%	1.55*	57.65	12.48	11.12	16.43	0.77*
400% & +	2.41	62.57	20.99	6.52	6.98	0.53*
Region: Northeast	1.61*	52.62	12.67	18.13	13.46	1.51
Midwest	7.04	48.74	8.40	13.03	18.61	4.18
South	4.09	41.47	13.06	11.43	**26.23**	3.72
West	3.11	43.79	12.85	21.02	16.30	2.93
MSA: Yes	4.47	45.76	11.77	15.15	20.33	2.54
No	2.32*	44.27	12.48	15.29	18.48	7.16
Mother's Education: < High School	6.95	25.39	7.19	23.13	**27.54**	9.80
HS Complete	4.78	34.06	10.09	19.72	**28.68**	2.67
> High School	3.01	56.80	14.12	9.85	14.85	1.38
Mother's Age: < 25 years	7.50	24.28	12.10	16.63	**33.12**	6.37
25 - 29 years	3.41	36.16	12.12	14.84	**31.25**	2.22
30 + years	3.36	57.14	11.77	14.76	10.17	2.81
Mother's Marital Status: Married	2.98	51.00	12.06	14.24	16.71	3.00
Sep, Div or Widow	8.76*	30.39	9.90	16.39	**31.71**	2.85*
Never Married	8.31	23.19	11.14	18.23	**34.46**	4.67
Asthma : Yes	7.00*	35.74	8.47	19.12	26.21	3.45*
Influenza vaccination: Yes	3.14	49.39	12.15	12.16	20.11	3.04
Chickenpox: Yes	2.62*	51.94	11.74*	12.81*	19.96	0.92*
Insurance Status: Uninsured	3.17*	23.58	12.68	19.73	**29.85**	10.99
Insured	4.19	47.03	11.83	14.86	19.36	2.74

*****Small sample size; bolded numbers show high percentage of WPO households

Table 2: Distribution and characteristics of US children (age 1-4 years) by household telephone status, 2007 NHIS-Child sample

Characteristics	Telephone Status (Children of age 1-4 years)						
	All	LTI(≥1wk)	LTWP-some	LTWP-mostly	LT-Only	WPO	NP
House : Owned	57.46	34.15	**74.44**	**66.98**	46.79	30.05	33.42
Rented	42.54	**65.85**	25.56	33.02	**53.21**	**69.95**	**66.58**
Race/ethnicity: Hispanic	22.94	23.32	16.36	21.92	31.68	29.00	39.96
NH White	54.59	**50.09**	**64.17**	**54.50**	**43.63**	**44.51**	**39.82**
NH Black	15.63	21.99	11.18	15.87	20.06	22.14	8.08
NH Other	6.85	4.59	8.28	7.71	4.63	4.35	12.13
Household size: 2	3.64	5.18	1.65	4.82	3.14	7.51	3.54
3 - 5	57.53	**62.02**	**55.89**	**66.11**	**52.51**	**60.45**	**48.79**
5+	38.84	32.80	42.45	29.07	44.34	32.04	47.68
Poverty Level: <100%	22.56	**45.20**	11.75	11.34	**29.18**	**37.55**	**62.81**
100% – 199%	27.34	**31.53**	20.60	25.35	**38.64**	**34.70**	**25.47**
200% – 399%	27.00	9.78	**35.06**	25.84	21.27	20.39	7.81
>400%	23.10	13.49	32.59	**37.47**	10.91	7.37	3.91
Region: Northeast	16.48	6.42	19.06	17.58	19.70	11.08	7.59
Midwest	22.85	**39.02**	24.47	16.16	19.62	21.23	29.19
South	36.99	36.71	**33.70**	**40.66**	27.87	**48.43**	**42.03**
West	23.68	17.84	22.78	25.60	**32.81**	19.27	21.19
Mother's education: <High School	19.34	30.95	11.33	11.65	30.11	25.73	**55.00**
HS complete	22.50	26.78	16.97	18.98	29.44	31.70	18.24
>High School	58.16	**42.26**	**71.70**	**69.37**	**40.45**	**42.57**	26.76
Mother's Age: <25 years	16.99	30.88	9.06	17.31	18.62	28.08	33.04
25 - 29 years	28.77	**24.98**	22.86	28.94	28.62	**44.38**	**20.41**
30+ years	54.24	44.14	**68.08**	**53.75**	**52.76**	27.54	46.54
Mother's Marital Status: Married	78.99	**56.91**	**88.03**	**80.99**	**75.37**	**65.32**	**74.15**
Sep, Div or Widow	8.43	17.85	5.60	7.10	9.26	13.24	7.51
Never married	12.58	25.24	6.37	11.91	15.37	21.45	18.34

Note: bolded numbers show the category with the high percentages.

Table 3: Significant Covariates from Stepwise Logistic Regression Models*: Children Aged 1-4 Years by Household Telephone status, NHIS 2007

Covariates	No Landline (NLT)	Phoneless (NP)	Wireless-Only (WPO)	LT-Interruption (LTI)	LT – Only	LTWP-Mostly
Housing Status	x		x			x
Race/Ethnicity						
Region	x		x	x	x	
Mother's Education		x	x		x	x
Mothers Age Group	x		x		x	
Household Size						x
Poverty Level (Imputed)	x	x	x		x	x
MSA		x		x		
Mother's Marital Status				x		
Landline Phone Interruption	NA	NA	NA	NA		x

*All model exclude LTWP-some households without interruptions; Variables used in the final NLT propensity model (Race/ethnicity was added due to its general correlated with telephone status, vaccinations, and other health measures);
x = variable selected by Stepwise Method;

Table 4: Significant covariates, Beta coefficients, and estimates of Odds Ratios from the final logistic regression model for predicting propensities of NLT (WPO+NP) status among all children (age<1-4 years) except for those from the LTWP-some group, 2007 NHIS-Child sample

Covariates used in the final propensity model (NLT)		Beta coefficient	Odds Ratio (OR)	Odds Ratio 95% CI	
Intercept		-0.493			
Housing Status	**Owned vs Rented**	-0.334	0.513	0.388	0.677
Race/Ethnicity	**Hispanic vs NH Other**	0.100	1.000	0.573	1.747
Race/Ethnicity	**NH-White vs NH Other**	0.024	0.926	0.536	1.600
Race/Ethnicity	**NH Black vs NH Other**	-0.224	0.723	0.402	1.300
REGION	**Northeast vs West**	-0.398	0.937	0.619	1.418
REGION	**Midwest vs West**	0.222	1.742	1.208	2.512
REGION	**South vs West**	0.509	2.319	1.684	3.194
Mother's Education	**<High School vs Less than High School**	-0.005	1.035	0.747	1.433
Mother's Education	**High School Completed vs Less than High School**	0.045	1.088	0.804	1.471
Mother's Age Group	**< 25 Years vs 30 + years**	0.099	1.614	1.161	2.244
Mother's Age Group	**25 -29 vs 30 + years**	0.280	1.935	1.459	2.567
Household Size	**2 vs 5 +**	0.162	1.334	0.760	2.341
Household Size	**3 to 4 vs 5 +**	-0.036	1.093	0.834	1.433
Poverty Status	**<100% vs 400 %**	0.417	2.885	1.787	4.659
Poverty Status	**100-199% vs 400 %**	0.123	2.152	1.365	3.392
Poverty Status	**200-399% vs 400 %**	0.103	2.109	1.333	3.337

Quintiles of propensities and age groups are used to create weighting cells and adjust WTIA_SC weights for children in LTI, LT-only, and LT-mostly groups for non-landline status in the method M3

Association of Predicted Probabilities and Observed Responses

Percent Concordant	67.7	**Somers' D**	0.359
Percent Discordant	31.8	**Gamma**	0.361
Percent Tied	0.4	**Gamma**	0.176
Pairs	398395	**c**	0.680

Table 5: Distribution of adjustment factors to compensate for noncoverage of Children from WPO and NP households using M1--M3b adjustment methods, 2007 NHIS-Child LT sample

Statistics	Adjustment factors by Methods				Ratio of Adjustment factors			
	M1	**M2**	**M3a**	**M3b**	**M2/M1**	**M3a/M1**	**M3b/M1**	**M3b/M2**
Minimum	0.6629	0.6064	0.3846	0.2574	0.9148	0.5801	0.3883	0.4245
Median	1.0183	1.1014	0.8210	0.6170	1.0816	0.8063	0.6059	0.5602
Mean	1.3411	1.3402	1.3631	0.7808	0.9993	1.0164	0.5822	0.5826
Maximum	9.9447	4.7416	8.8528	3.2491	0.4768	0.8902	0.3267	0.6852
Standard Deviation	1.4121	0.6206	1.2625	0.4424	0.4395	0.8940	0.3133	0.7129
Coefficient of Variation	105.2967	46.3068	92.6153	56.6590	0.4398	0.8796	0.5381	1.2236
Inter-Quartile Range	0.2089	0.6461	1.0091	0.4310	3.0928	4.8306	2.0630	0.6670

Note: M1, M2: Direct ratio adjustments; M3a: 1/propensity; M3b: weighting class based on propensity quintile

Figure 1: Plots of new Noncoverage adjusted weights versus WTFA_SC, 2007 NHIS-Child weights for children Aged 1-4 Years by Four Methods M1—M3b (Red line shows WTFA_SC weights without adjustments on the Y axis)

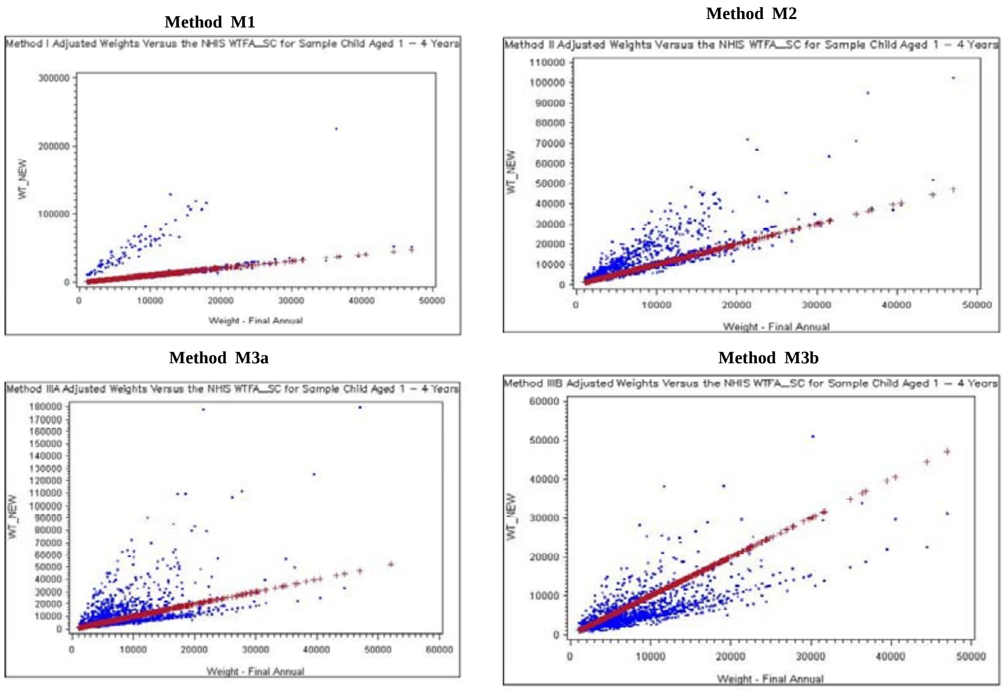

Figure 2: Comparison of Bias in the Prevalence of Influenza vaccinations from the NHIS and Estimates using Four Weighting Methods among Children Aged 1-4 Years, NHIS-LT group, 2007

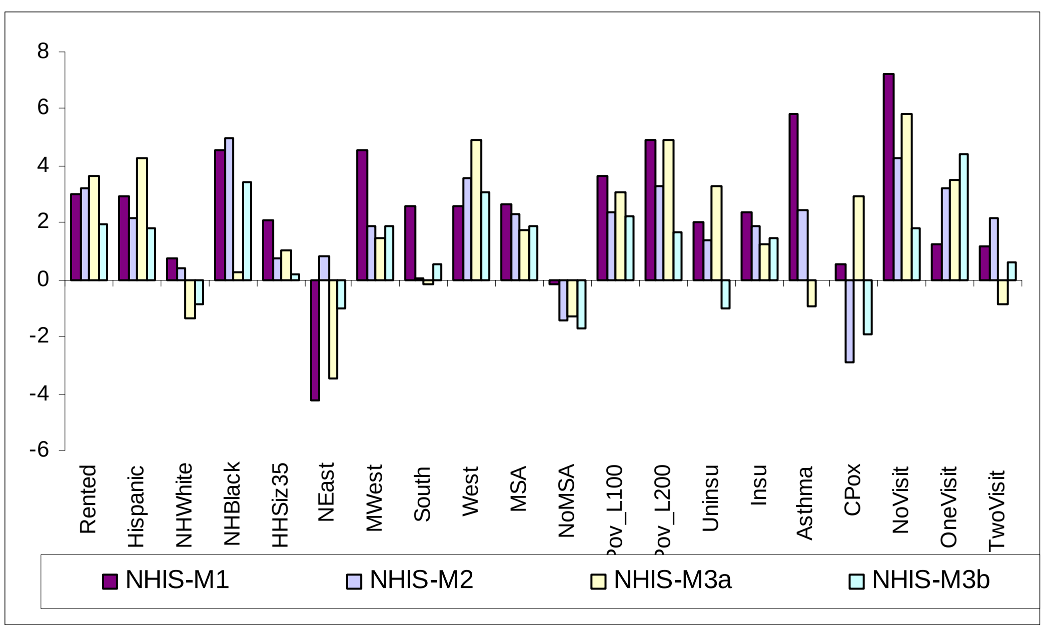

Table 6: Comparison of the percentage of Influenza vaccinations and Predicted 4:3:1:3:3 coverage among children aged 1-4 years using weighting methods M1, M2, and M3b, 2007 NHIS-Child LT Sample (numbers in blue show categories with ratios of MSE<1)

Characteristics	NHIS-Child sample: All 1-4 Years			Weighting Methods: M1, M2 and M3b							
	Influenza Vaccination Estimate	95% Confidence Limits		LT Sample* estimates			MSE**			Ratio of MSE**	
		LCL	UCL	M1	M2	M3b	M1	M2	M3b	M2/M1	M3b/M1
All children 1-4 years	37.80	35.23	40.36	35.63	36.08	36.55	8.13	5.30	3.84	0.652	0.473
Asthma: Yes	44.55	36.14	52.96	38.74	42.14	44.59	88.25	38.11	27.63	0.432	0.313
Chickenpox: Yes	31.96	17.42	46.50	31.44	34.85	33.85	69.85	74.09	72.43	1.061	1.037
Uninsured: Yes	24.77	14.72	34.82	22.78	23.40	25.79	36.88	28.85	34.17	0.782	0.927
House tenure: Rented	35.28	31.49	39.06	32.25	32.08	33.35	19.60	15.88	9.32	0.810	0.475
Race/ethnicity: Hispanic	33.98	29.95	38.02	31.08	31.80	32.18	20.54	10.92	9.84	0.532	0.479
NH-White	37.50	33.84	41.17	36.73	37.12	38.33	6.90	4.96	5.81	0.719	0.842
NH- Black	41.32	35.10	47.54	36.78	36.37	37.92	46.22	38.43	24.99	0.831	0.541
Poverty level: < 100%	34.91	29.41	40.42	32.57	33.83	33.98	26.73	11.92	11.10	0.446	0.415
100 - 199%	33.99	30.20	40.55	33.37	34.99	36.60	15.21	11.76	17.12	0.773	1.126
200 - 399%	38.87	31.94	41.80	34.03	33.80	34.20	16.95	17.38	14.53	1.025	0.857
400% +	44.56	39.49	49.62	42.86	42.09	42.29	11.71	13.50	12.34	1.153	1.053
Region: Northeast	43.64	39.91	50.37	47.88	42.84	44.63	36.34	15.26	14.92	0.420	0.411
Midwest	37.37	32.14	42.61	32.82	35.49	35.50	34.57	13.93	13.05	0.403	0.378
South	40.15	35.69	44.62	37.59	40.09	39.63	16.90	6.74	7.36	0.399	0.435
West	30.45	26.11	34.78	27.84	26.85	27.40	16.95	20.31	15.99	1.199	0.944

Characteristics	Model-based Predicted 4:3:1:3:3 coverage	95% Confidence Limits		LT Sample*: Model-based Predicted 4:3:1:3:3 coverage			MSE*			Ratio of MSE**	
		LCL	UCL	M1	M2	M3b	M1	M2	M3b	M2/M1	M3b/M1
All children 1-4 years	78.66	78.29	79.04	78.77	78.64	78.85	0.085	0.058	0.089	0.682	1.047
Influenza vaccination: Yes	78.88	78.3	79.46	78.87	78.93	78.99	0.130	0.132	0.172	1.019	1.327
Asthma: Yes	80.66	79.62	81.70	81.15	80.57	81.20	1.015	0.664	0.768	0.655	0.757
Chickenpox: Yes	79.21	77.48	80.94	78.98	79.25	80.06	1.033	1.256	1.763	1.216	1.707
Uninsured: Yes	78.34	77.77	78.91	78.62	78.43	78.69	0.231	0.153	0.275	0.662	1.191
House tenure: Rented	77.96	77.45	78.47	78.14	77.88	77.66	0.177	0.090	0.192	0.512	1.088
Race/ethnicity: Hispanic	77.63	77.11	78.15	77.83	77.59	77.51	0.200	0.117	0.137	0.586	0.684
NH-White	84.18	83.52	84.85	83.62	84.21	84.35	0.847	0.212	0.197	0.251	0.233
NH- Black	76.66	74.87	78.45	77.23	76.83	77.08	0.801	0.857	0.709	1.070	0.886
Poverty level: < 100%	77.07	76.26	77.88	77.83	77.84	78.02	1.111	0.863	1.183	0.777	1.066
100 - 199%	77.82	77.08	78.56	77.48	77.12	77.41	0.346	0.730	0.408	2.110	1.180
200 - 399%	78.84	78.27	79.41	78.99	78.72	79.24	0.125	0.137	0.276	1.096	2.207
400% +	81.01	80.49	81.53	80.91	81.12	81.25	0.133	0.096	0.142	0.726	1.069
Region: Northeast	81.25	80.50	82.00	81.57	81.35	81.56	0.279	0.162	0.248	0.581	0.890
Midwest	77.08	76.15	78.02	76.99	77.06	77.36	0.556	0.410	0.427	0.738	0.768
South	79.92	79.38	80.46	80.24	80.15	80.17	0.239	0.155	0.223	0.649	0.930
West	76.42	75.70	77.14	76.73	76.24	76.38	0.192	0.201	0.131	1.043	0.683

* excludes LTWP-some households without interruptions; ** Smaller MSE means higher reduction in bias, **MSE Ratio <1 means that M2 or M3b method performed better than the method M1