

Adjustment for Noncoverage of Non-landline Telephone Households in an RDD Survey

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Abstract

The National Immunization Survey (NIS) — a nationwide, list-assisted RDD survey conducted by the NORC for the Centers for Disease Control and Prevention — monitors vaccination rates of children between the ages of 19 and 35 months. As in any RDD survey, households without landline telephone (i.e., phoneless and cell-only households) are not sampled in the NIS. To compensate for this noncoverage, a special poststratification adjustment (Keeter 1995; Frankel *et al.* 2003) is applied, in which households with an interruption in landline service are used to represent non-landline households. With the increasing proportion of cell-only households among the non-landline households, this adjustment may no longer be very effective unless the characteristics of cell-only households are similar to that of households with interruption in landline service. Also, the adjustment introduces a considerable variation in sampling weights. The paper evaluates the impact of this adjustment on bias and variance of the estimates. The characteristics of different types of households in terms of telephone availability are compared to assess the effectiveness of this adjustment and to explore the possibility of improving this adjustment by treating cell-only and phoneless households separately.

Key words: interruption in telephone service, noncoverage adjustment, nontelephone households, poststratification, RDD survey

1. Introduction¹

Random-digit-dial (RDD) telephone surveys are a cost-effective and quick method for conducting household surveys. However, a major weakness of an RDD survey is that it only covers those households with landline telephones, leaving phoneless and an increasing number of cell-only households not covered by the sample. Based on the National Health Interview Survey (NHIS), the proportion of households without a landline phone has increased from 2.8% in 2003 to 11.6% in 2006. Table 6 of this paper shows that, based on the NHIS, 15.9% of children 0-4 years live in households without a landline phone (11.4% in cell-only households, 4.5% in phoneless households). With such an increasing rate of noncoverage, RDD surveys are being subjected to more questions as to the potential for coverage bias.

Currently, a special poststratification adjustment is often applied (Frankel *et al.* 2003; Keeter 1995) during the weighting adjustment of RDD samples to compensate for such noncoverage. In this adjustment, households with an interruption in landline telephone service in the previous year are used to represent non-landline households. When this adjustment was introduced in 1995, non-landline households were mainly the phoneless households. Due to the widespread use of cell phones over the years, many households with landline telephone have switched to using cell phones only, so the households without landline telephones are increasingly dominated by the households with cell phones only. It raises the question whether households with an interruption in telephone service provide a good representation of both cell-only and phoneless households. If this is not the case, then this special adjustment may no longer be an effective method for adjusting for noncoverage of both cell-only and phoneless households. In this paper, we investigate the effectiveness of this adjustment in the case of the National Immunization Survey (NIS), which is an RDD survey that monitors the immunization coverage among young children. We try to assess the impact of this adjustment on estimates and corresponding variances. We also compare the characteristics of the households by telephone status (landline without interruption, landline with interruption, cell-only, and phoneless) to see if there is a possibility of developing an improved adjustment procedure by making separate adjustments for cell-only and phoneless households. For this later comparison, we use the data from the NHIS, since the NIS does not cover non-landline households.

1.1 The National Immunization Survey

The NIS has been conducted quarterly since 1994 by the Centers for Disease Control and Prevention (CDC) to estimate the vaccination rates among children aged 19 to 35 months in the U.S. within geographic areas (called estimation areas) consisting of 50 states, the District of Columbia, and several large metropolitan areas. The NIS

¹ “The findings and conclusions in this paper are those of the author(s) and do not necessarily represent the views of Centers for Disease Control and Prevention.”

collects vaccination data on childhood vaccines such as diphtheria, tetanus toxoids and pertusis vaccine (DTaP), poliovirus vaccine (polio), measles, mumps and rubella vaccine (MMR), *Haemophilus influenzae* type b vaccine (HIB), hepatitis B vaccine (HepB), and varicella. The NIS uses a two-phase survey design where the first phase is an RDD survey that identifies the households with age-eligible children and collects information on vaccinations and vaccination providers of the eligible children. In the second phase, a mail survey of providers called the provider record check (PRC) collects detailed vaccination histories for the children for whom the RDD-phase interview was complete and consent to contact providers was received. The weighting adjustment for the NIS sample includes a series of adjustments for noncoverage and nonresponse (see Smith *et al.* 2005). The NIS 2006-07 analysis file includes 29,116 children with complete household interviews and 20,058 children with adequate provider data.

2. Comparison of Households With and Without Interruption in Service

In this section, we compare the characteristics of children in households with and without interruption in landline telephone service of one week or more during the previous year using the NIS 2006-07 sample (i.e., July 2006 to June 2007 sample). The purpose of this comparison is to assess differences in the characteristics of the NIS target children in households with interruption who are used to represent the children in non-landline households. The impact of the special adjustment for noncoverage of non-landline households depends on the extent of difference in characteristics of the children in households with and without interruption.

Table 1 shows that about 7% of the NIS sample comes from households with interruption in landline service. However, this group represents about 13% of the target population after weighting due to the special adjustment that puts higher weight on households with interruption to account for children in non-landline households. Table 2 presents comparisons of race/ethnicity, income-to-poverty ratio, and mother's education of the NIS sample by landline interruption status of the household. This table shows that the distributions of children by these characteristics are noticeably different in households with interruption than in households without interruption. The children in households with interruption appear to have lower household income and mother's education. Table 3 compares vaccination rates by interruption status; it shows the overall vaccination rates of children in households with interruption are slightly lower than that of the children in households without interruption. This difference appears somewhat more pronounced for vaccination rates at 19 months of age.

3. Impact of Noncoverage Adjustment

3.1 The Adjustment

The basic idea of this adjustment is to use households with an interruption in landline telephone service to represent themselves and also households without a landline telephone. The method is based on dated empirical evidence suggesting that non-landline households and landline households with an interruption in service have similar characteristics (Keeter 1995; Frankel *et al.* 2003). The adjustment is also known as the Keeter adjustment.

Under this method, two post-stratification cells are formed within each estimation stratum, depending on the interruption status of the landline service of a household. The weights for the sample from households with an interruption are benchmarked to the population control total for the target population in non-landline households plus the estimated control total for the population in households with interruption. Similarly, the weights for the sample from households without interruption are benchmarked to the population control total for the target population in households with landline service with no interruption. In the NIS, to derive the control total for the children in non-landline households, the proportion of children in non-landline households is estimated from the Current Population Survey (CPS). Further details of how this adjustment is applied to the NIS can be found in the NIS methodology report (CDC 2007).

3.2 Comparison of Estimates With and Without Adjustment

Table 4 presents a comparison of the NIS vaccination rates with and without Keeter adjustment at the national level and for two estimation areas where proportions of children in non-landline households are high (around 10% based on CPS). The comparison shows that the estimates of vaccination rates are generally lower and the corresponding confidence intervals are generally larger under the adjustment. The adjustment pulls down the estimates of vaccination rates due to the lower vaccination rates in households with interruption as shown in Table 3 and increases the variances of the estimates due to the extra variation in weights generated by the additional adjustment. The differences in estimates and confidence intervals, however, are negligible at the national level and non-significant, though noticeable, at the estimation area level. The non-significant differences in the estimates may be due to the fact that the proportion of children in non-landline households is still less than 10% (based on CPS) in most estimation areas. Therefore, unless the difference in vaccination rates is very large between households with and without interruption, the adjustment will have a small impact at the estimation area level. For example, if the difference in a vaccination rate is 20 percentage points between households with and without interruption and if 10% of children are in non-landline households, then the

expected impact due to the adjustment on the vaccination rate is 2 percentage points, which is small compared to standard errors of the estimates at the estimation area level (generally around 2.5 percentage points). The impact could become significant if the proportion of children in non-landline households continues to increase.

3.3 Impact on Bias and Variance

Table 5 presents coefficients of variation (CV) of weights at different steps with and without the adjustment. Although the Keeter adjustment produces a large difference in CV, the relative difference in the CV of the final weights decreases due to subsequent adjustments that add more variation to both with and without adjusted weights. This has reflected on the smaller differences in 95% confidence intervals (CI) of the estimates with and without the Keeter adjustment in Table 4. At the national level, differences in CIs are almost negligible but at the area level there are some noticeable differences in CIs. An analysis of the tradeoff between variance increase and the bias reduction (assuming bias is the difference between the estimates with and without adjustments) shows that the gross impact is generally negligible. The gain in Mean Squared Error (MSE) is sometimes slightly positive and sometimes slightly negative.

4. Comparison of Household Characteristics by Telephone Status

The Keeter adjustment is applied based on the assumption that characteristics of children in households without landline are similar to those of children in households with interruption in telephone service. This assumption is based on studies conducted when the majority of non-landline households were phoneless, but with rapidly increasing use of cell phones, the majority of the non-landline households are cell-phone-only users nowadays (Table 6). To examine whether the households with interruption in landline service are still representative of all non-landline households or which group of non-landline households (cell-only or phoneless) are more similar to households with interruption, a comparison of the characteristics of children 0-4 years is presented in this section by the telephone status of their households using the 2006 NHIS data. The NHIS is based on an area sample design and covers both landline and non-landline households (see NHIS 2005).

Comparisons of the distributions of children within each telephone status group as presented in Table 7 suggest that children in households with interruption in landline service are more similar to children in cell-only households than to children in phoneless households. The race-ethnicity distribution of children in households with interruption is very similar to that of children in cell-only households. The proportion of children with Hispanic origin is considerably higher (39.4%) in phoneless households compared to that in the cell-only households (23.3%) or in interruption households (25.76%). Also, in terms of income-to-poverty ratio and mother's education, children in phoneless households appear to be noticeably disadvantaged compared to children in cell-only or in interruption households. Table 8 presents similar comparison in terms of some other characteristics (such as home ownership, health insurance, welfare income, etc.) that also show children in households with interruption are more similar to children in cell-only households than to children in phoneless households.

Table 9 presents a similar comparison in terms of selected health-related characteristics for children 0-9 years. In this case, however, the relative similarity between children in households with interruption and children in cell-only households compared to children in phoneless households are not that pronounced. This could be due to the higher volatility of these estimates which are based on a smaller sample size than those in previous tables.

5. Conclusion

The analysis presented in this paper shows that the characteristics of the children in the households with interruption in landline service are different than those in households without interruption. However, the impact of the Keeter adjustment for noncoverage on the NIS estimates for children in non-landline households is not significant either at the national level or at the estimation area level. However, although not significant, the differences in estimates at the area level (in the two areas with higher proportion of non-landline households that are compared) are noticeable. This indicates that if the proportion of children in non-landline households continues to increase further the impact of adjustment may become significant.

An analysis of the tradeoff between variance and bias of the estimates does not show any significant gain or loss due to the adjustment. Since the impact of the adjustment on the variance increase is not significant, the adjustment should continue to be applied, providing protection against coverage bias should the proportion of non-landline households be high or increase rapidly in some areas. Of course, a large increase in the proportion of cell-only households and using the small number of households with interruption in the sample for adjustment will have a higher impact on the variance due to larger weights on the small number of cases.

A comparison of the characteristics of children in different types of households in terms of telephone status using NHIS data indicates that children in households with interruption are more similar to those in cell-only households than those in phoneless households. The concern that the adjustment based on households with interruption is becoming less appropriate due to the increasing proportion of cell-only households is not supported. The analysis rather suggests that

the use of households with interruption to adjust for noncoverage will be more appropriate as the proportion of cell-only households increases further. It may be more appropriate to use households with interruption to represent the cell-only households and a separate adjustment for phoneless households. However, since none of the telephone status group seems to represent the phoneless group very well, further investigation will be required to develop a separate adjustment strategy for the phoneless group.

Overall, the analysis indicates that the NIS estimates are not significantly biased for noncoverage of non-landline households, which is consistent with the conclusion in other studies (Khare *et al.* 2007; Molinari *et al.* 2008). The factors that are contributing in keeping the coverage bias low are the proportion of children in non-landline households is still not large enough² and the children in households with interruption provide a reasonable representation of the children in cell-only households, the group that accounts for two-thirds of the noncovered children.

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Table 1. Distribution of Children in the NIS 2006-07 Sample by Interruption in Landline Telephone Service

Landline Service	RDD		PRC		PRC
	Counts	Percent	Counts	Percent	Weighted Percent
No Interruption	27,169	93.31	18,827	93.22	86.72
Interruption	1,947	6.69	1,369	6.78	13.28*
Total	29,116	100.00	20,196	100.00	100.00

*Estimate is larger due to Keeter adjustment accounting for cell-only and phoneless households.

Table 2. Distribution of NIS Children over Race/Ethnicity Category, Income-to-Poverty Ratio, and Mother's Education by Landline Telephone Interruption Status*

Landline Service	Race/Ethnicity				Total
	Hispanic	NH-Black only	NH-White only	NH-Multiracial/ Other	
No Interruption	20.99	8.21	61.68	9.12	100.00
Interruption	33.78	14.41	41.33	10.78	100.00
	Income-to-Poverty Ratio				Total
	<100	100-199	200-399	400 +	
No Interruption	17.12	35.08	14.25	33.56	100.00
Interruption	45.41	37.87	6.46	10.26	100.00
	Mother's Education				Total
	<12 Years	12 Years	>12 Years, Non-college Grad	College Grad	
No Interruption	11.61	18.73	27.83	41.83	100.00
Interruption	25.99	27.29	29.37	17.35	100.00

*based on children with complete household interview and using the weight before Keeter adjustment and poststratification.

² Less than 10% based on the CPS estimate that is used in the NIS.

Table 3. Vaccination Rates by Landline Telephone Interruption Status*

Landline Service	Overall Vaccination Rates (%)						
	4+ DTaP	3+ Polio	1+ MCV	3+ HIB	3+HEPB	4+ PCV	4:3:1:3:3
No Interruption	85.54	92.78	93.55	93.14	93.02	74.62	80.76
Interruption	81.97	91.81	92.16	92.00	92.35	66.03	78.24
Landline Service	Vaccination Rates (%) at 19 Months						
	4+ DTaP	3+ Polio	1+ MCV	3+ HIB	3+HEPB	4+ PCV	4:3:1:3:3
No Interruption	71.61	87.96	89.19	90.91	90.85	67.90	66.65
Interruption	61.37	85.00	83.72	88.46	88.73	57.41	56.00

*based on children with adequate provider data and using provider-phase weight.

Table 4. Comparison of Vaccination Estimates (\pm 95% CIs) With and Without Keeter Adjustment

Vaccine Series	National Level		Area 19		Area 27	
	Keeter Adjustment		Keeter Adjustment		Keeter Adjustment	
	No	Yes	No	Yes	No	Yes
All 5 Shots*	67.52 (+/- 1.19)	67.51 (+/- 1.23)	70.93 (+/- 6.95)	70.74 (+/- 7.13)	72.3 (+/- 7.14)	69.53 (+/- 8.1)
4+ DT Containing	85.14 (+/- 0.79)	85.06 (+/- 0.8)	87.61 (+/- 3.82)	86.15 (+/- 4.66)	86.39 (+/- 4.3)	84.46 (+/- 5.7)
3+ Polio	92.64 (+/- 0.58)	92.66 (+/- 0.58)	95.09 (+/- 2.53)	94.49 (+/- 3.15)	93.58 (+/- 3.08)	92.12 (+/- 4.72)
1+ MCV	93.38 (+/- 0.55)	93.36 (+/- 0.55)	95.73 (+/- 2.33)	95.45 (+/- 2.52)	91.88 (+/- 3.42)	90.56 (+/- 4.93)
3+ HIB	93.01 (+/- 0.58)	92.99 (+/- 0.59)	96.74 (+/- 2.12)	96.08 (+/- 2.88)	92.45 (+/- 3.47)	90.98 (+/- 4.96)
4:3:1:3:3	80.44 (+/- 0.88)	80.42 (+/- 0.89)	81.96 (+/- 4.47)	81.21 (+/- 5.04)	82.93 (+/- 4.78)	80.28 (+/- 6.19)
3+ Polio at 19 months	87.67 (+/- 0.74)	87.57 (+/- 0.76)	90.58 (+/- 3.47)	90.11 (+/- 3.91)	89.54 (+/- 3.78)	87.68 (+/- 5.35)
1+ MCV at 19 months	88.68 (+/- 0.7)	88.46 (+/- 0.73)	91.75 (+/- 3.2)	90.72 (+/- 3.71)	86.06 (+/- 4.44)	84.18 (+/- 5.86)
4:3:1:3:3 at 19 months	65.71 (+/- 1.05)	65.24 (+/- 1.09)	69.98 (+/- 5.38)	68.58 (+/- 6.00)	67.96 (+/- 5.97)	66.39 (+/- 6.72)

*Produced using RDD-phase weight for children with complete RDD-phase data and including Yes/No responses only. All remaining estimates are produced using provider-phase weights for children with adequate provider data.

Table 5. Comparison of CV% of Weights With and Without Keeter Adjustment

Weight	National Level		Area 19		Area 27	
	Keeter Adjustment		Keeter Adjustment		Keeter Adjustment	
	No	Yes	No	Yes	No	Yes
Keeter adjusted weight	96.63	102.54	11.49	39.44	10.25	39.63
Poststratified weight	111.17	118.54	36.75	55.85	51.74	69.35
RDD-phase weight	115.02	120.12	38.60	57.44	58.01	75.31
Provider nonresponse adjusted weight	119.13	124.35	40.10	60.64	57.87	72.23
PRC-phase weight	119.23	124.04	38.80	57.53	57.73	74.56

Table 6. Distribution of Children (0-4 Years) by Telephone Status from NHIS 2006

Telephone Status	Number of Children (0-4 Years) in the Sample	Percentage Distribution (unweighted)	Percentage Distribution (weighted)
Landline-No Interruption	4,354	77.97	78.59
Landline-Interruption	303	5.43	5.50
Cell-only	627	11.23	11.41
Phoneless	300	5.37	4.51
Total	5,584	100.00	100.00

Table 7. Distribution of children (0-4 Years) by Race/Ethnicity, Income-to-Poverty Ratio, and Mother's Education Within Each Telephone Status Group from NHIS 2006

Telephone Status	Race/Ethnicity				Total
	Hispanic	NH-Black only	NH-White only	NH-Multiracial/Other	
Landline-No Interruption	21.45	12.91	57.72	7.92	100.00
Landline-Interruption	25.76	19.87	47.84	6.52	100.00
Cell-only	23.30	19.47	49.11	8.12	100.00
Phoneless	39.40	19.93	32.98	7.70	100.00
	Income-to-Poverty Ratio				
	<100	100-199	200-399	400 +	Total
Landline-No Interruption	17.44	22.27	32.00	28.29	100.00
Landline-Interruption	35.35	31.92	23.68	9.05	100.00
Cell-only	33.80	32.97	21.25	11.98	100.00
Phoneless	60.99	29.29	7.91	1.81	100.00
	Mother's Education				
	<12 Years	12 Years	>12 Years, Non-college Grad	College Grad	Total
Landline-No Interruption	14.91	23.90	28.25	32.93	100.00
Landline-Interruption	26.80	26.84	36.24	10.12	100.00
Cell-only	22.66	36.70	31.99	8.65	100.00
Phoneless	51.39	31.22	13.90	3.49	100.00

Table 8. Percentage Distribution of Children (0-4 Years) by Selected Characteristics Within Each Telephone Status Group from NHIS 2006

Telephone Status	Home Owned or Being Bought	Received Income from Welfare/TANF	Child Has Any Health Insurance	Child Has Private Health Insurance
Landline-No Interruption	67.87	4.96	92.65	60.90
Landline-Interruption	40.01	14.92	89.17	31.67
Cell-only	30.87	8.23	86.27	35.40
Phoneless	27.94	21.81	83.17	15.38

Table 9. Percentage of Children (0-9 Years*) with Selected Vaccination and/or Health-Related Status Within Each Telephone Status Group Based on NHIS Sample Child File

Telephone Status	Sample Size	Had well-child checkup, past 12 months	Can't afford prescription medicine, past 12 months	Child had flu shot during last 12 months	Child ever had chicken pox	Child had respiratory allergy, past 12 months	Ever been told child had asthma
Landline-No Interruption	4,213	78.63	3.28	23.82	8.32	12.42	11.43
Landline-Interruption	293	75.05	3.33	24.21	9.75	17.78	16.08
Cell-only	590	77.35	1.69	20.25	7.34	13.49	9.42
Phoneless	196	62.58	6.80	23.99	12.96	10.49	10.60

*Since the sample size is small in the NHIS sample child file, 0-9 years old children instead of 0-4 years is used to increase the sample size.